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Brunnett et al.

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[54] **SCINTILLATION RECORDING DEVICE FOR PRODUCING BOTH BLACK AND WHITE AND MULTI-COLOR PHOTOGRAPHIC RECORDS**

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[52] **U.S. Cl.**.....**250/71.5 S,** 178/6.7 R, 178/7.86, 250/65 R, 250/227

[51] **Int. Cl.**.....**G01t 1/20**

[58] **Field of Search**.....250/71.5, 71.5 S, 71, 80, 227, 250/65 R; 178/6.7 R, 6.7 A, 7.86

[56] **References Cited**

UNITED STATES PATENTS

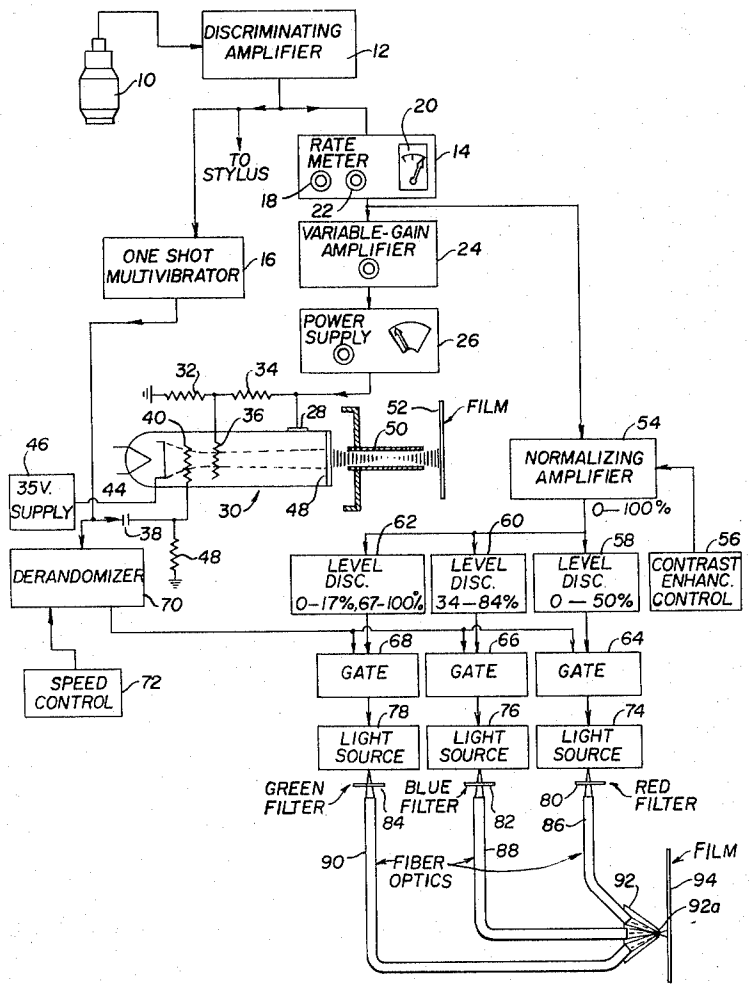
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[57] **ABSTRACT**

The output of a scintillation probe is connected to energize one or more level discriminators, which respond to different levels of radioactivity detected. Each level discriminator is connected to permit energization of a different colored light source, the light from which exposes a color-sensitive photographic film.

9 Claims, 5 Drawing Figures



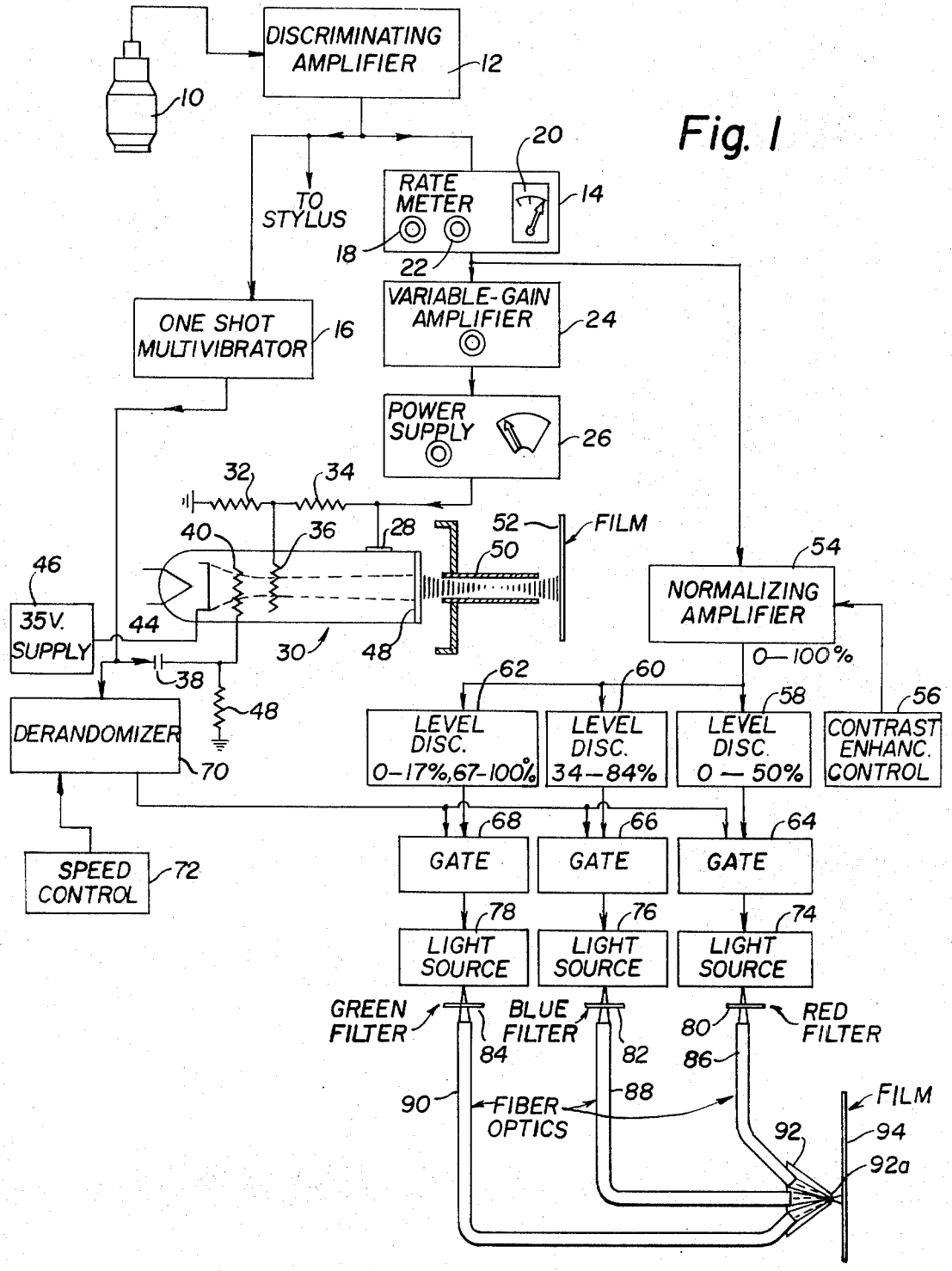


Fig. 1

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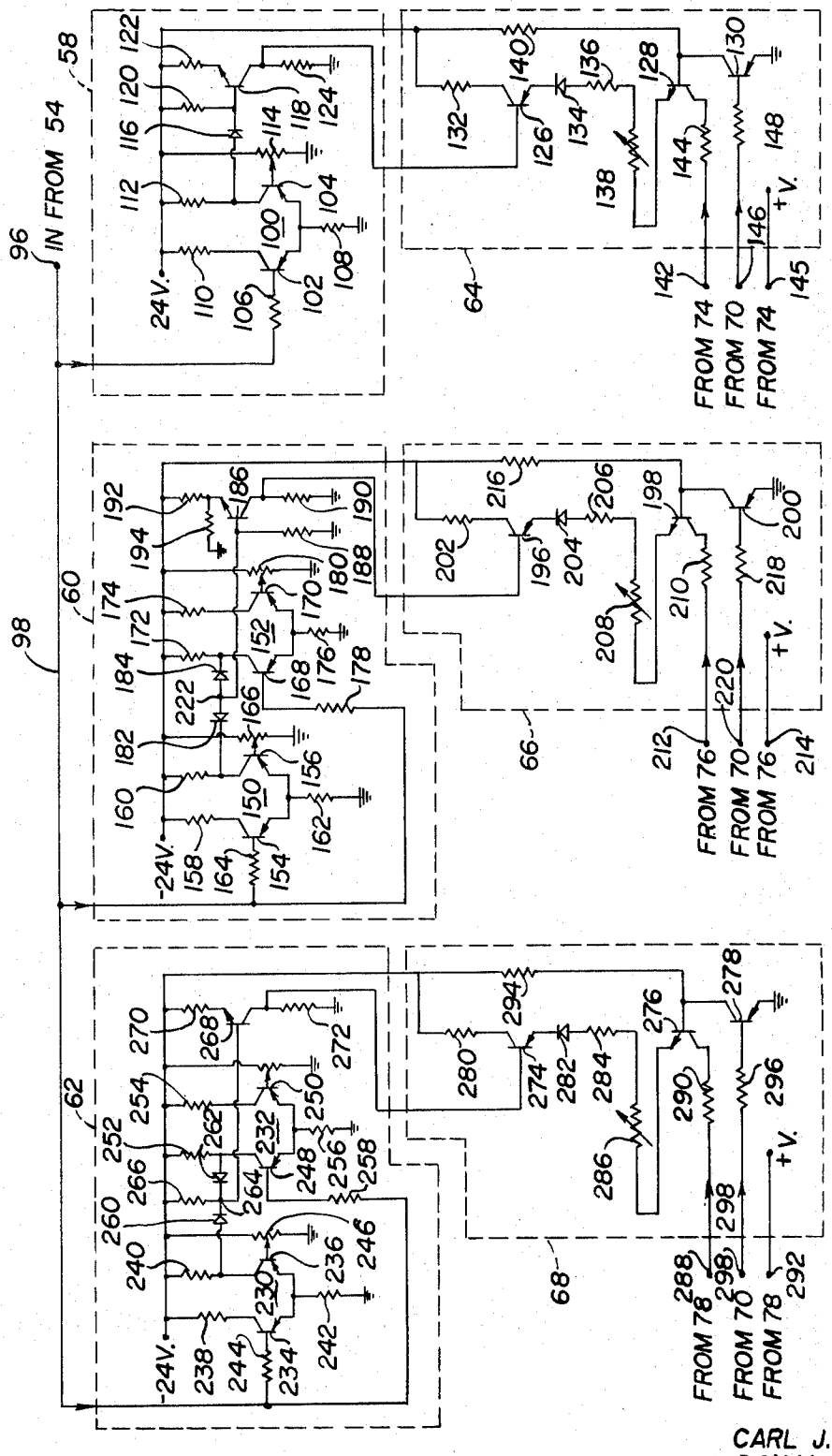


Fig.2

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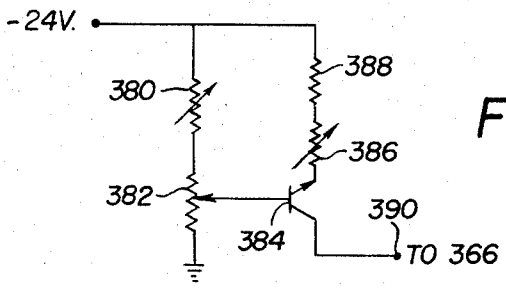


Fig. 3

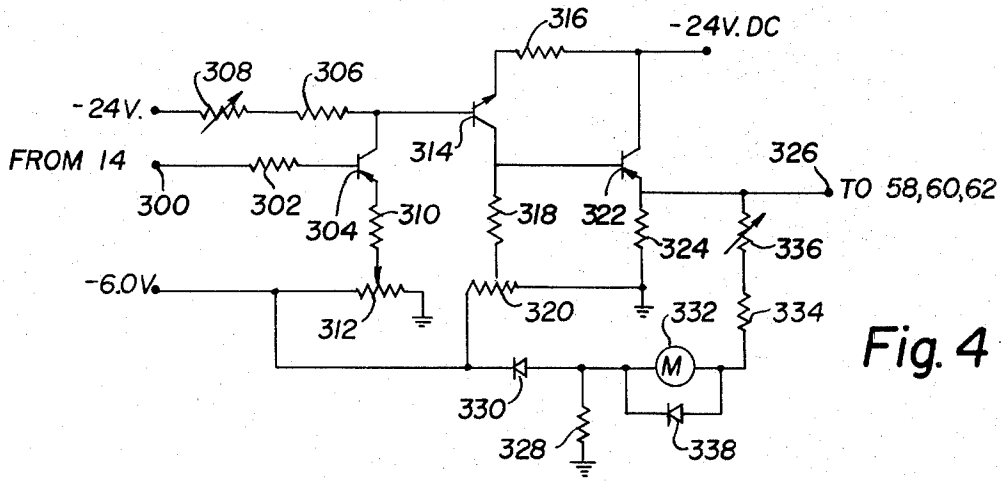


Fig. 4

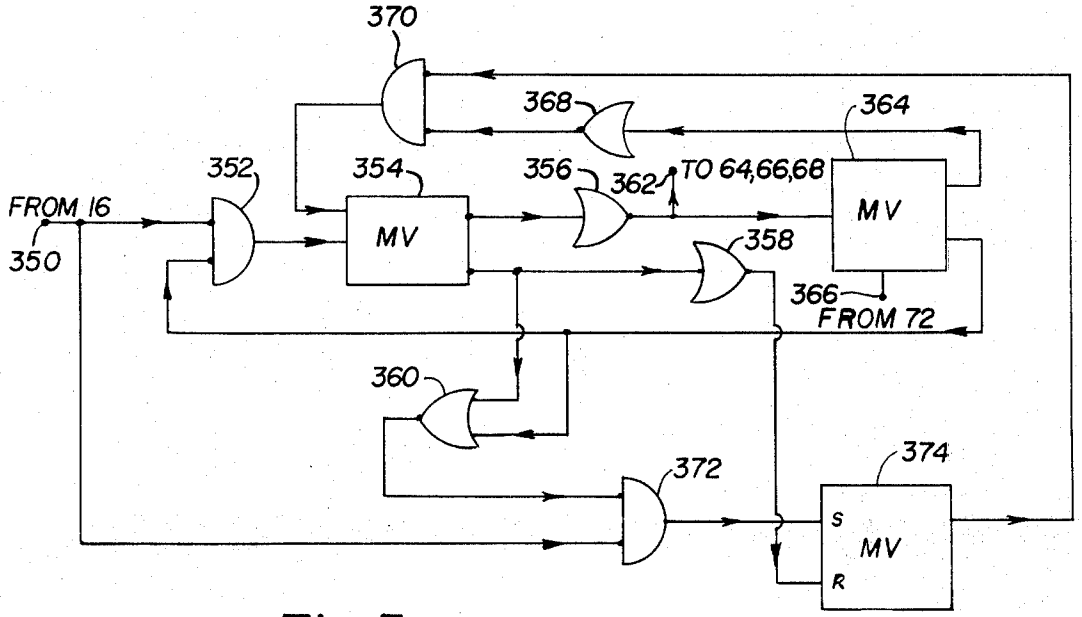


Fig. 5

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SCINTILLATION RECORDING DEVICE FOR PRODUCING BOTH BLACK AND WHITE AND MULTI-COLOR PHOTOGRAPHIC RECORDS

BACKGROUND OF THE INVENTION

1. Field of the Invention.

This invention relates to scintillation scanning of radioactive isotope concentration and distribution, and, more particularly, to a scintillation recording device for producing a multi-colored photographic record.

Scintillation scanning is used in modern medical techniques for the diagnosis of certain types of ailments, such as the presence of malignant or benign tumors. In using a scintillation scanning technique, a quantity of radioactive isotope is administered to a patient. The administered isotope collects in certain organs of the patient's body, such as his liver or spleen. The quantity and distribution of the radioactive energy in the organ under study is then measured and recorded, so that a radiologist or physician may determine the location and extent of the malformation within the organ.

2. Description of the Prior Art.

Various devices have been proposed for accomplishing scintillation scanning and recording. One successful scintillation scanner is described in U.S. Pat. No. Re 26,014, issued May 3, 1966 to J. B. Stickney et al., and assigned to the assignee of the present invention. When utilizing that device, a scintillation probe is positioned over the area of a patient's body to be investigated. The probe is then caused to move back and forth over the patient in a series of spaced rectilinear paths until a graphic representation of the distribution of isotope in the investigative area has been produced.

In the device of the Stickney et al. patent, the scintillation probe is mechanically and electrically connected to a suitable dot recording mechanism for producing one type of permanent graphic image. The probe is also electrically and mechanically connected to a light source, such as a cathode ray tube. The latter electrical connection is described in detail in U.S. Pat. No. 3,159,744, issued Dec. 1, 1964 to J. B. Stickney et al., and assigned to the assignee of the present invention. In the device described in the latter patent, the light source produces light pulses which vary both in frequency and in intensity in accordance with the amount of radioactivity detected to provide what has become known as "enhancement" or "contrast enhancement." The light pulses expose photographic film to produce a graphic display of the distribution of the isotope in the area under investigation, with areas having the greater radioactivity producing lighter images on the negative film than areas of lesser radioactivity.

More recently, various proposals have been made to produce multi-colored graphic displays of the distribution of radioactivity, wherein the variations of color of the image correspond to variations in intensity of the scintillation received by the probe. One such proposal utilizes a plurality of different inks of various colors, so that the finished graphic image is produced in a series of colors. A given color of ink corresponds to a given range of intensity of radioactivity, so that the distribution concentration of radioactivity is reflected not only in the number of dots making up the image, but also in the color in which the dots are printed.

The production of an image on color-sensitive photographic film has also been proposed. According to the latter proposal, a group of color filters is coupled to a servo-mechanism and positioned between a light source (cathode ray tube) and a color-sensitive film. The servo-mechanism shifts the filters in response to the amount of radioactivity detected. The latter device, although quite successful, does involve moving parts to mechanically position the various filters in front of the spot on the cathode ray tube face. This may be somewhat disadvantageous from the point of view of exact positioning of the filters and obtaining a clear line of demarcation when shifting from one filter to another. The present invention obviates this disadvantage by providing apparatus wherein the change from one color of light to another impinging on the color-sensitive film is controlled electronically, and wherein the only mechanical movement required is that necessary to coordinate movement of the scanning head and movement of the colored light spot with respect to the color-sensitive film. Thus the speed of response is greatly increased.

The use of colored images in scintillation studies has several advantages. One advantage is that a color image facilitates diagnosis of a patient's aliment by a radiologist or other specialist performing the study, and is especially useful to surgeons and other physicians who are not as skilled as the specialist in analyzing the information obtained from such a study. While various shades of gray in a black and white image may be difficult to separate from each other, the use of a multi-colored image accentuates changes in radiation intensity shown by different colors in various parts of the image.

SUMMARY OF THE INVENTION

A device embodying the present invention provides both a conventional black and white photographic image of radiation distribution of an area under study, as well as a multi-colored image of the area. The black and white image is provided by means of the circuitry described in the aforementioned U.S. Pat. No. 3,159,744, whereas the multi-colored image is obtained by utilizing three primary colors of light singly or in various combinations to produce six different colors to expose a color-sensitive photographic film. A signal whose amplitude is proportional to the intensity of radiation detected by the scintillation probe as it scans across an area under investigation, is provided as input to a plurality of level discriminators. The level discriminators are preset to be actuated when the input signal thereto reaches certain percentages of its maximum range of possible amplitudes, and to be unactuated when the input signal is within other amplitude ranges. Each level discriminator controls the energization of a different one of a plurality of light sources, three sources of white light being provided in the present instance. Each of the sources of white light has positioned adjacent thereto a filter for transmitting light of a different color, the transmitted light being one or a combination of the three primary colors red, green, and blue. The light passing through the three filters is fed through a fiber optic system and caused to impinge at one spot on a color-sensitive film.

As in the prior art, signals are produced in the device whenever the radiation detected by the scintillation

probe exceeds a given predetermined value, and the repetition rate of the signals is dependent upon the intensity of the radiation detected. In the black and white image produced, this feature is necessary in order to increase the density of the image in those areas where the radiation intensity is greatest. In the present case where a colored image is also produced, the change in density is no longer required in the colored image.

One of the features of the present invention is the provision of circuitry to prevent the dots making up the colored image from overlapping, which could produce annoying dark spots on the color-sensitive film.

Another feature of the invention lies in the provision of a contrast enhancement control, whereby the range of radiation may be compressed so that the six available colors recorded on the film cover a range of as little as 50 percent of the normal radiation intensity range that may be recorded. For example, it may be that an area of a patient's body under study may emit radiation of considerable intensity but varies from its maximum to minimum values over only 50 percent of the maximum utilizable range. The contrast enhancement control may then be adjusted so that all six available colors are utilized within that 50 percent range rather than only one or two colors being available.

Further features and advantages of the invention will become apparent from the following description of one embodiment thereof, taken in conjunction with the accompanying drawings, in which:

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of a device embodying the invention;

FIG. **2** is a circuit diagram of the level discriminators embodied in the device shown in FIG. **1**;

FIGS. **3** and **4** are circuit diagrams of the speed control and the normalizing amplifier, respectively, embodied in the device of the invention; and,

FIG. **5** is a logic diagram of the derandomizer utilized in the device shown in FIG. **1** to prevent the overlapping of colored light pulses on the color-sensitive film.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Inasmuch as the preferred embodiment of the invention utilizes the circuitry described in the aforementioned U.S. Pat. No. 3,159,744, that portion of the device of the present invention will be described only briefly herein. Reference may be made to that patent for a more complete description of the various elements.

FIG. **1** illustrates in block diagram form a device embodying the present invention. As shown, scintillation responsive means such as a conventional scintillation probe **10** provides output signal pulses in response to radiation detected by the probe. The signal pulses from the probe **10** are provided to a discriminating amplifier **12**. The discriminating amplifier **12** is of conventional type, and amplifies each pulse received from the probe **10** to provide one amplified pulse for each radioactive impulse detected by the probe **10** and falling within a preselected pulse height range. The output of the discriminating amplifier **12** is connected to a stylus (not shown) to produce a graphic image on a sheet of paper in a conventional well-known manner. The output of the amplifier **12** is also connected to the input of a rate meter **14** and the input of a one-shot multivibrator **16**.

The rate meter **14** is of conventional type which detects and indicates the rate of signal pulses. A range control switch **18** is provided for selecting an appropriate scale on a meter dial **20**. A time constant selector switch **22** is also provided for selecting the length of time over which the signal pulse rate is measured to determine the rate. The longer the time constant, the more stable will be the reading on the dial **20**. Any change in the pulse rate will be reflected by the output of the rate meter, but that output will lag the actual change by a length of time proportional to the time constant selected.

The output of the rate meter **14** is connected to the input of a variable-gain, direct-coupled amplifier **24**, whose output signal level lies within a certain predetermined range at all times.

The output of the variable-gain amplifier **24** is connected to the input of the power supply **26**. The varying output signal of the variable-gain amplifier **24** controls the power supply **26**, and causes its output voltage to vary proportionally with the variable-gain amplifier output and therefore with the probe signal pulse count rate.

The power supply **26** is conventional in design, and its output is connected to an accelerating ring or electrode **28** of a cathode ray tube, shown generally at **30**. The output of the power supply **26** is also connected to ground through series-connected resistors **32**, **34**. The cathode ray tube **30** has a focusing electrode **36**, which is connected to the juncture of the resistors **32** and **34**.

The one-shot multivibrator **16**, whose input is connected to the output of the discriminating amplifier **12**, is of a type which will emit one impulse of a predetermined time duration and power for each signal pulse transmitted to it by the discriminating amplifier **12**. The one-shot multivibrator **16**, which is of conventional design, preferably includes an adjustment to vary the time duration of its output pulses.

The output of the one-shot multivibrator **16** is connected through a coupling capacitor **38** to a control grid **40** of the cathode ray tube **30**. The control grid **40** is grounded through a resistor **42**. The cathode ray tube **30** is also provided with a cathode **44**, which is connected to the output of a 35-volt direct-current power supply **46**. The connections of the control grid **40** and the cathode **44** of the cathode ray tube differ slightly from those set forth in the referenced U.S. Pat. No. 3,159,744. In the patent, the control grid is shown at ground potential and the output of the one-shot multivibrator is connected to the cathode. However, the operation of the cathode ray tube **30** is essentially the same as that described in the referenced patent. The cathode ray tube **30** also includes the usual phosphorescent or fluorescent screen **48**, the light from which is focused to an appropriately sized dot by a collimater **50** for impingement on a black-and-white photographic film **52**.

As is more fully described in the referenced patent, once the discriminated level of radiation activity is obtained, one light impulse will be emitted by the cathode ray tube **30** for each count detected by the probe **10** and passed by the discriminating amplifier **12**. The in-

tensity of the emitted light pulse will vary with the signal pulse count rate, because the voltages on the accelerating electrode **28** and on the focusing electrode **36** of the cathode ray tube vary with the count rate. Thus, the intensity of the light incident on the film **52**, and hence the density of the image created thereon, in any given spot will reflect the signal pulse count rate in a corresponding spot in the area being studied. Since the probe **10** and the cathode ray tube **30** are mechanically connected together and move together as a scan is conducted, the resultant film exposure is a graphic reproduction which outlines the distribution pattern of the radiation and the concentration of radioactivity in the area under study.

The variable output signal of the rate meter **14** is connected to the input of a normalizing amplifier **54**. The function of the normalizing amplifier **54** is to provide an output signal whose amplitude level varies over a predetermined amplitude range in response to an input signal from the rate meter **14** that may vary over a different amplitude range. In the present case, for example, the input signal from the rate meter **14** may vary from −5 volts to a more negative voltage not exceeding −10 volts. The normalizing amplifier **54** is so adjusted that its output signal varies from −5 volts to −10 volts over the entire amplitude range of the input signal.

The normalizing amplifier **54** is also provided with a contrast enhancement control **56**, whose function is to raise the transition points at which the level discriminators (to be later described) operate. This merely compresses the range of radiation intensity being studied. Were the contrast enhancement control not provided, it is possible that in certain studies there would be so little difference in the various amounts of radiation received that only one or two of the six available colors would be present in the colored image. By setting the contrast enhancement control, the range may be compressed so that all six colors are available to indicate radiation variations over a smaller range.

The output signal from the normalizing amplifier **54** is provided as an input signal to a plurality of level discriminators **58, 60, 62**. The level discriminators **58, 60, 62** are preset to be actuated when the input signal to the discriminators reaches predetermined amplitude levels and to be unactuated when the input signal amplitude levels are less than or greater than predetermined values. In the present case, wherein three level discriminators are utilized, the discriminator **58** is actuated when the input signal thereto lies between 0 percent and 50 percent of its maximum amplitude range. In other words, if the input signal from the normalizing amplifier **54** ranges from −5 volts to −10 volts, the discriminator **58** is actuated by a signal whose amplitude is between −5 volts and −7.5 volts. The level discriminator **60** responds to an input signal which lies within an amplitude range of 34 to 84 percent of the maximum range of −5 volts to −10 volts, and the level discriminator **62** responds to a signal lying within an amplitude range of 0–17 percent and 67–100 percent of the maximum amplitude range. Thus, if the input signal to the level discriminators falls within the 0–17 percent amplitude range, the discriminators **58** and **62** are actuated; if the signal falls within the range of 17–34 percent, the discriminator **58** is actuated; if the signal falls within the range of 34–50 percent, the discriminators **58** and **60** are actuated; if the signal is within the 50–67 percent range, only the discriminator **60** is actuated; if the signal is within the 67–84 percent range, the discriminators **60** and **62** are actuated; and if the signal falls within the range of 84–100 percent, only the discriminator **62** is actuated. The particular signal level transition points may be varied as desired, and the levels referred to herein are used only by way of example.

The output signals from the level discriminators **58, 60, 62** are respectively provided as inputs to AND-gates **64, 66, 68**. Input signals are also provided to the gates **64, 66, 68** from a derandomizer **70**. The input to the derandomizer **70** is connected to the output of the one-shot multivibrator **16** to receive a pulse of uniform height and width each time a signal pulse is provided from the discriminating amplifier **12** to the multivibrator.

The derandomizer **70** comprises logic means to prevent the overlapping of dots in the colored image, which might result in producing dark spots on the color-sensitive film. To this end, it is necessary that a gating pulse from the derandomizer **70** be present at the inputs of the gates **64, 66, 68** before a signal from the level discriminators **58, 60, 62** can be passed by the gates. The maximum rate of the pulses from the derandomizer to the gates is controlled by a speed control **72**, which is manually set to correspond to the speed of scan of the probe **10**. If desired, the derandomizer and speed control may be omitted and the output of the multivibrator **16** connected directly to the gates **64, 66, 68**. In that case, overlapping of dots may be prevented by scaling down the pulse input rate or by limiting the width of the dots.

If signals are simultaneously received by the gate **64** from the derandomizer **70** and from the level discriminator **58**, the gate **64** is enabled and a light source **74** is energized. Similarly, the gate **66** is enabled when signals are simultaneously received from the derandomizer **70** and from the level discriminator **60**, and the gate **68** is enabled when signals are simultaneously received from the derandomizer **70** and from the level discriminator **62**. When the gates **66** and **68** are enabled, they permit energization of light sources **76** and **78**, respectively. The light sources **74, 76, 78** are identical to each other, and provide essentially white light output. Suitable light sources are available from Sylvania Electric Products, Inc. and are marketed by them as Model R1131C known as a "Glow Modulator." This particular light source, while not the only one that may be utilized in the device embodying the invention, has an advantage in that it can be pulsed on and off at a high rate of speed.

The light sources **74, 76, 78** are respectively provided with filters **80, 82, 84**. In the present application, the filter **80** is red, the filter **82** is blue, and the filter **84** is green. The filters **80, 82, 84** are of conventional Wratten type and may be obtained from the Eastman Kodak Company, of Rochester, New York. Light transmitted through the filters **80, 82, 84** passed through light pipes **86, 88, 90** respectively, each of which consists of a series of parallel light-transmitting fibers. The light pipes **86, 88. 90** constitute a fiber optic structure, which conducts light and is also flexible. The light transmitted through the light pipes **86, 88, 90** passes

through a suitable aperture **92***a* in a collimating device **92** and impinges on a sheet **94** of color-sensitive photographic film. The collimating device **92** is preferably connected mechanically to the probe **10**, so that as the probe scans an area under study the collimating device scans across the film sheet **94**. Alternatively, the device **92** may be fixed in position and the film moved.

The fiber optics system is shown as a preferred form of light transmitting means between the filters **80**, **82**, **84**, but not as the only light transmission means usable. Alternatively, the light transmission means might consist of a mirror system, a lens system, or any other such system that will cause the light from the various filters to coincide over substantially the same area in a plane defined by the aperture **92***a* in the collimating device **92**. Of course, the aperture **92***a* is variable in dimensions to determine the size of the spot or dot of light incident on the film sheet **94**.

In the form of the invention shown and described, the color-sensitive film **94** is of negative type, which produces a color that is complementary to the color of the light exposing the film. Such a film is available commercially from Eastman Kodak Company under the name "Ektacolor" film. It is apparent that the invention is not limited to the use of a negative type film, and a positive type film may be used if desired. Of course, when a negative type color-sensitive film is employed, to produce the desired color in the film, it must be exposed with light of a complementary color. For example, in order to produce cyan in the film, it must be exposed with red light; to produce magenta in the film, it must be exposed with green light; and to produce yellow in the film, it must be exposed with blue light. If a positive type color-sensitive film is employed, it is exposed with the color of light that it is desired to have in the colored image.

The following table shows the various colors produced in a negative color-sensitive film in response to various combinations of colored light incident thereon in response to various input signal levels to the level discriminators:

COLOR OF NEGATIVE FILM

Light Sources	Blue	Cyan	Green	Yellow	Red	Magenta
	Red (74) Green (78)	Red (74)	Red (74) Blue (76)	Blue (76)	Blue (76) Green (78)	Green (78)

0% 17% 34% 50% 67% 84% 100%

INPUT SIGNAL LEVEL

Attention is particularly drawn to the fact that the order in which the various light sources and their combinations there are utilized is designed to aid as much as possible a color blind person in distinguishing between the various colors representing radiation of different intensities. It is well known that a person suffering from dichromatism has his color perception reduced essentially to distinguishing between only yellows and blues. Most such persons confuse reds, greens and yellows of certain shades with one another, but never confuse the yellows and blues. Therefore, the order in which the various light sources are energized causes blue and yellow to be well separated, so that the usual color blind person can easily distinguish increases in radiation intensity as the film color progresses from blue through cyan and green to yellow and thence to red and magenta. Thus the red and green areas of confusion are separated by yellow, which is clearly distinguishable from blue by the ordinary color blind person. Of course, if the viewer's color blindness is of the monochromatic type, he will see all colors as various shades of gray and the colored photographic image will be of little assistance to him over the black and white image.

If a positive color-sensitive film is being used, and the same arrangement of colors is desired on the film as in the case of a negative color-sensitive film, the light sources will have to be energized in a different order. In order to provide cyan, the blue and green sources must be energized; in order to provide yellow, the green and red sources must be energized; and in order to provide magenta, the red and blue sources must be energized. Such an adaptation is well within the skill of one versed in the art.

FIG. **2** is a circuit diagram of the level discriminators **58**, **60**, **62** and the gates **64**, **66**, **68**. The input signal from the normalizing amplifier **54** (−5 volts to −10 volts) is connected by means of a terminal **96** to an input line **98** that feeds all three of the level discriminators.

As previously mentioned, in the example shown, the level discriminator **58** is actuated when the input signal from the normalizing amplifier **54** is between 0 and 50 percent of its total range. Thus, if the total range of the input signal is from −5 volts to −10 volts, the level discriminator **58** is actuated when the signal is between −5 volts and −7.5 volts. As shown, the discriminator **58** comprises a differential amplifier, shown generally by the numeral **100**, which includes two PNP transistors **102**, **104**. The base of the transistor **102** is connected to the input line **98** through a resistor **106**, and the emitters of the transistors **102**, **104** are connected together and to ground through a resistor **108**. The collectors of the transistors **102**, **104** are respectively connected through load resistors **110**, **112** to a −24 volt direct-current supply (not shown). The base of the transistor is connected between the −24 volt supply and ground. The collector of the transistor **104** is also connected directly to the anode of a diode **116**, whose cathode is connected to the base of an NPN-transistor **118**. The base of the transistor **118** also is connected to the −24 volt supply through a resistor **120** having a relatively high resistance value. The transistor's emitter is connected to the −24 volt supply through a load resistor **122**, and its collector is grounded through a resistor **124**. The collector of the transistor **118** is also connected directly to the base of a PNP-transistor **126** in the gate **64**.

The gate **64** comprises the transistor **126**, an NPN-transistor **128**, and a PNP-transistor **130**. The collector of the transistor **126** is connected through a load resistor **132** to the −24 volt supply, and the emitter of the transistor is connected to the cathode of a diode **134**.

The anode of the diode **134** is connected to one end of a fixed resistor **136**, whose other end is connected through a variable resistor **138** to the emitter of the transistor **128**. The base of the transistor **128** is connected to the −24 volt supply through a resistor **140**, and is also connected directly to the collector of the transistor **130**. The collector of the transistor **128** is connected to a terminal **142** through a resistor **144**. The terminal **142** is connected to one side of the light source **74** located behind the red filter **80** (FIG. **1**), the other side of the light source being connected to a positive voltage source (not shown) through a terminal **145**. When the transistors **128**, **126** are conducting, current flows through the light source and through the transistors to the −24 volt supply. The variable resistor **138** serves as a brightness control for the light source **74**. The base of the transistor **130** is connected to a terminal **146** through a resistor **148**, and the emitter of the transistor **130** is connected directly to ground. The terminal **146** is connected to receive negative gating pulses from the derandomizer **70** (FIG. **1**) to cause the transistor **130** to conduct.

In the operation of the level discriminator **58**, the transistor **104** is normally conducting, and the transistor **102** is normally non-conducting. This is accomplished by setting the movable arm of the potentiometer **114** so that a potential of approximately −7.5 volts is placed on the base of the transistor **104**. Conduction of the transistor **104** causes a voltage drop across the resistor **108** of substantially 7.2 volts. Thus the emitter of the transistor **102** is negative with respect to the base of the transistor **102** until the input signal on the line **98** reaches approximately −7.5 volts going in a negative direction. When this occurs, the transistor **102** will start to conduct, which will increase the voltage drop across the resistor **108** and cause the transistor **104** to be cut off.

When the transistor **104** is conducting, the potential transferred from its collector through the diode **116** to the base of the transistor **118** is positive with respect to the potential of the emitter of the transistor **118**. Therefore, the transistor **118** conducts. When the transistor **118** conducts, the potential on its collector is approximately −12 volts, which is transferred to the base of the transistor **126** in the gate **64**. Thus, the base of the transistor **126** is negative with respect to the emitter and the transistor **126** will conduct if the transistor **128** is conducting. The transistor **128** will conduct when its base is positive with respect to its emitter. This condition occurs when the transistor **130** is conducting. The transistor **130** will conduct when a negative gating pulse is received from the derandomizer **70** and applied to its base. When the transistor **130** conducts, the base of the transistor **128** rises virtually to ground potential, which causes that transistor to conduct. Therefore, a current path is established from the terminal **74** through the transistors **128**, **126**, to the −24 volt supply to energize the lamp **74**. An input signal to the level discriminator **58** of −5 volts to −7.5 volts must be received simultaneously with a negative pulse from the derandomizer **70** to the gate **64** in order to energize the light source **74**.

When the input signal on the line **98** reaches or exceeds −7.5 volts in a negative direction, the transistor **102** conducts, which cuts off the transistor **104**. The collector potential of the transistor **104** drops to −24 volts, which potential is transferred to the base of the transistor **118**. The base and emitter of the transistor **118** are now both at the same potential, and that transistor is cut off. When the transistor **118** is cut off, the potential of its collector rises to ground, which in turn cuts off the transistor **126** and breaks the current path from the terminal **142** to the −24 volt supply.

The level discriminator **60** and the gate **66**, which permit energization of the light source **76** located adjacent the blue filter **82** (FIG. **1**), are generally similar to the discriminator **58** and the gate **64** previously described. The level discriminator **60** differs from the level discriminator **58**, however, in that it employs two differential amplifiers, indicated generally by the numerals **150**, **152**. The operation of the level discriminator **60** is different from that of the level discriminator **58**, because the discriminator **60** actuates or opens the gate **66** when the input signal to the discriminator **60** is between 34 percent and 84 percent of the maximum input signal amplitude range.

The differential amplifier **150** employs two PNP-transistors, **154**, **156**. The collectors of the transistors **154**, **156** are respectively connected through load resistors **158**, **160** to the −24 volt supply. The emitters of the transistors **154**, **156** are connected together and to ground through a resistor **162**. The base of the transistor **154** is connected through a resistor **164** to the input line **98** to receive the signal from the normalizing amplifier **54**. The base of the transistor **156** is connected to the movable arm of a potentiometer **166**, one end of which is connected to the −24 volt supply and the other end of which is grounded.

The second differential amplifier **152** is very similar to the amplifier **150** and comprises two PNP-transistors **168**, **170**. The collectors of the transistors **168**, **170** are respectively connected through load resistors **172**, **174** to the −24 volt supply, and the emitters are connected together and to ground through a resistor **176**. The base of the transistor **168** is connected through a resistor **178** to receive the input signal from the line **98**. The base of the transistor **170** is connected to the movable arm of a potentiometer **180**, which serves as a voltage divider connected between the −24 volt supply and ground.

A pair of diodes **182**, **184**, have their cathodes respectively connected to the collectors of the transistors **156**, **168**. The anodes of the diodes are connected together and to the base of an NPN-transistor **186**. The base of the transistor **186** is connected to ground through a resistor **188** having a relatively high resistance value, and the collector of the transistor **186** is connected to ground through a resistor **190**. The emitter of the transistor **186** is connected to the juncture of resistors **192**, **194** which form a voltage divider connected between the −24 volt supply and ground. The collector of the transistor **186** is also connected directly to the base of a PNP-transistor **196** in the gate **66**.

The gate **66** comprises the transistor **196**, an NPN-transistor **198**, and a PNP-transistor **200**. The collector of the transistor **196** is connected to the −24 volt supply through a load resistor **202**, and the emitter is connected to the cathode of a diode **204**. The anode of the diode **204** is connected to one end of a resistor **206**,

the other end of which is connected to the emitter of the transistor **198** through a variable resistor **208**, which serves as a light source brightness control. The collector of the transistor **198** is connected through a resistor **210** to a terminal **212**. The light source **76** located behind the blue filter **82** (FIG. **1**) is connected between the terminal **212** and a terminal **214** (positive voltage) to be energized when the transistors **196** and **198** are both conducting. The emitter of the PNP-transistor **200** is grounded, the collector is connected through a load resistor **216** to the source of −24 volts, and the base is connected through a resistor **218** to a terminal **220**. Negative gating pulses are supplied to the terminal **220** from the derandomizer **70** to turn on and off the transistor **200**.

In operation, the transistors **156** and **170** are conducting when the input signal received on the line **98** is at the zero end of the signal amplitude. range, that is, at −5.0 volts. The movable arms of the potentiometers **166, 180** are set to provide appropriate negative voltages to the bases of the transistors **156, 170** to maintain them conducting until the input signals to the transistors **154, 168** reach predetermined percentage values of the maximum signal amplitude range. In the present example, it is desired to have the transistor **170** stop conducting when the input signal on the line **98** reaches −6.7 volts going in a negative direction, and the transistor **156** to stop conducting when the input signal reaches −9.2 volts. This is accomplished by appropriately setting the movable arms on the potentiometers **166, 180** to provide negative voltages on the bases of the transistors **156, 170** of approximately −9.2 volts and −6.7 volts, respectively.

Until the input signal on the line **98** reaches −6.7 volts increasing in a negative direction, the transistor **156** is fully conducting because its base is negative with respect to its emitter. The transistor **154** is non-conducting because of the negative potential on its emitter. Similarly, the transistor **170** is fully conducting, and the transistor **168** is cut off. When the transistor **156** is conducting, its collector voltage is approximately −14 volts. When the transistor **168** is non-conducting, its collector potential is at approximately −24 volts. A juncture point **222** between the anodes of the diodes **182, 184** assumes the most negative voltage present on the collectors of the transistors **156, 168**. This voltage (−24 volts) is connected to the base of the transistor **186** and maintains that transistor in a cutoff condition because its base is negative with respect to its emitter.

When the transistor **186** is cut off, its collector potential is at ground level to maintain the gate **66** closed and the light source **76** de-energized. This occurs because, when the base of the transistor **196** is at ground potential, that transistor is non-conducting. Even though a negative pulse is received from the derandomizer on the terminal **220**, and the transistor **200** becomes conductive, the light source **76** will remain un-energized because there is no path from the terminal **212** to the −24 volt source.

When the input signal applied to the base of the transistor **168** from the input line **98** reaches the predetermined level of −6.7 volts (34 percent of the signal amplitude range), the base of the transistor **168** becomes negative with respect to its emitter and the transistor is turned on. When the transistor **168** is turned on, the transistor **170** turns off. The voltage at the juncture point **222** rises to approximately −14 volts, which makes the base of the transistor **186** positive with respect to the transistor emitter. The transistor **186** is thus turned on, and the potential of its collector and the base of the transistor **196** falls below ground level to approximately −14 volts. Because the emitter of the transistor **196** is positive with respect to its base, the transistor **196** will conduct if the transistor **198** is conducting, which in turn will occur when the transistor **200** is conducting. The transistor **200** will conduct when a negative pulse is received at the terminal **220** from derandomizer **70**, and will make the base of the transistor **198** positive with respect to the transistor emitter. A circuit is then completed through the light source **76** connected between the terminals **212, 214** and through the transistors **198, 196** to the −24 volt supply to energize the light source.

The current path for the light source **76** will be broken if current flow through the transistor **200** is interrupted by the absence of a negative gating pulse from the derandomizer **70** or if current flow through the transistor **196** is interrupted due to non-conduction of the transistor **186** in the level discriminator **60**. The latter will occur when the input signal on the line **98** reaches the predetermined amplitude level of −9.2 volts (84 percent of the signal amplitude range). When the input signal reaches that predetermined level going in a negative direction, the base of the transistor **154** becomes negative with respect to the transistor emitter. The transistor **154** then conducts, which cuts off current flow through the transistor **156**. The collector of the transistor **156** then drops to −24 volts, which is transferred through the diode **182** to the base of the transistor **186**. The base of the transistor **186** is then negative with respect to the potential of the transistor emitter, and current flow through the transistor **186** is cut off. This condition exists until the input signal to the discriminator is reduced below the 84 percent level, at which time the transistor **156** will again conduct and cause the transistor **186** to conduct. During the time that the input signal exceeds 84 percent of the signal amplitude range, the transistor **168** remains in a conductive state and the transistor **170** is cut off.

To recapitulate briefly, when the input signal level to the level discriminator **60** ranges from −5 volts to −6.7 volts (0–34 percent of the signal amplitude range), the transistors **154** and **168** are cut off, the voltage on the base of the transistor **186** is approximately −24 volts and the transistor **186** is non-conductive. When the voltage level of the input signal lies between −6.7 volts and −9.2 volts (34–84 percent of the input signal range), the transistors **154** and **170** are non-conductive, and the transistors **156** and **168** are conductive. The voltage at the base of the transistor **186** is approximately −14 volts, and the transistor **186** is conductive. When the input voltage from the line **98** exceeds −9.2 volts in a negative direction (84–100 percent of the signal amplitude level), the transistors **154** and **168** are conductive, and the transistors **156** and **170** are non-conductive. This causes the potential at the base of the transistor **186** to again fall to −24 volts to cut off that transistor. It is now apparent that the light source **76** connected between the terminals **212** and **214** can be energized only when the input signal level on the con-

ductor **98** lies between −6.7 volts and −9.2 volts, that is, between 34 percent and 84 percent of the input signal amplitude range.

The level discriminator **62** is very similar to the level discriminator **60** just described, except that the discriminator **62** is actuated to open the gate **68** when the input signal level lies between 0 and 17 percent of the signal amplitude level range and again when it lies between 67 percent and 100 percent of the signal level range. Again, the discriminator **62** includes two differential amplifiers, indicated generally by the numerals **230** and **232**.

The differential amplifier **230** comprises a pair of PNP transistors **234**, **236**. The collectors of the transistors **234**, **236** are respectively connected through load resistors **238**, **240** to the −24 volt supply. The emitters of the two transistors are connected together and to ground through a resistor **242**. The input signal from the normalizing amplifier is supplied from the line **98** to the base of the transistor **234** through an input resistor **244**. A potentiometer **246** is connected between the −24 volt supply and ground and its movable arm is connected directly to the base of the transistor **236** to provide a predetermined negative potential on the transistor base.

The differential amplifier **232** comprises a pair of PNP transistors **248**, **250**. The collectors of the transistors **248**, **250** are respectively connected through load resistors **252**, **254** to the −24 volt source, and the emitters of the transistors are connected together and to ground through a resistor **256**. The base of the transistor **248** is connected to the input line **98** through an input resistor **258**. The base of the transistor **250** is connected to the movable arm of a potentiometer **260**, which is connected as a voltage divider between the −24 volt supply and ground to provide a predetermined negative potential on the transistor base.

The collectors of the transistors **236**, **248** are respectively connected to the anodes of diodes **260**, **262**. The cathodes of the diodes **260**, **262** are connected to a juncture point **264**, which is connected to the −24 volt supply through a resistor **266** and is connected directly to the base of an NPN-transistor **268**.

The emitter of the transistor **268** is connected to the −24 volt supply through a resistor **270**. The collector of the transistor **268** is connected to ground through a resistor **272**, and is also connected directly to the base of a PNP-transistor **274** in the gate **68**. The state of the transistor **268** in the level discriminator **262** controls the opening and closing of the gate **68**, disregarding for the moment the presence or absence of a negative pulse from the derandomizer **70** applied to the gate **68**.

The gate **68** comprises the transistor **274**, an NPN-transistor **276** and a PNP-transistor **278**. The collector of the transistor **274** is connected to the −24 volt supply through a resistor **280**. The emitter of that transistor is connected to the cathode of a diode **282**, whose anode is connected to one end of a fixed resistor **284**. The other end of the resistor **284** is connected through a variable resistor **286** to the emitter of the transistor **276**. The collector of the transistor **276** is connected to a terminal **288** through a resistor **290**. The light source **78** located adjacent the green filter **84** (FIG. **1**) is connected between the terminal **288** and a positive terminal **292**. The variable resistor **286** serves as a brightness control for the light source **78** when the transistor **274** is conducting. The base of the transistor **276** is connected to the −24 volt supply through a resistor **294** and is connected directly to the collector of the transistor **278**. The emitter of the transistor **278** is grounded, and its base is connected through a resistor **296** to a terminal **298** to receive negative gating pulses from the derandomizer **70**.

The gate **68** operates in the same fashion as the gates **64** and **66** previously described, and its operation will not be described in detail. It is sufficient to note that a conductive path will be established from the terminal **288** to the −24 volt supply if the transistors **274**, **276** are both conducting. The transistor **274** will be conductive if the transistor **268** in the level discriminator **62** is conducting. If the transistor **268** is cut off the potential on the base of the transistor **274** will rise to ground level and cause that transistor to be cut off. Also, if the transistor **278** is cut off due to the absence of a negative input pulse at the terminal **298**, the potential on the base of the transistor **276** will drop to-**24** volts and cause that transistor to be cut off. Thus, it is seen that the transistors **268**, **274**, **276**, **278** must all be conducting in order for the light source **78** to be energized.

In order for the level discriminator **62** to operate in the desired manner, the transistor **268** must be conducting when the input signal level on the line **98** lies between −5 volts and −5.8 volts (between 0–17 percent of the signal amplitude range). The transistor **268** must be non-conductive when the input signal level lies between −5.8 volts and −8.4 volts, and must be conductive again when the input signal level lies between −8.4 volts and −10 volts (between 67–100 percent of the input voltage signal range). In the example being described, the movable arm of the potentiometer **246** is set to provide a potential of −5.8 volts on the base of the transistor **236**, and the movable arm of the potentiometer **260** is set to provide potential of −8.4 volts on the base of the transistor **250**. Until the input signal applied to the base of the transistor **234** in the first differential amplifier **230** exceeds −5.8 volts in a negative direction, the transistor **234** is non-conducting and the transistor **236** is conducting. During that time, the transistor **248** is non-conducting and the transistor **250** is conducting. The collector of the transistor **236** is at approximately −14 volts when that transistor is conducting, and the collector of the transistor **248** is at −24 volts when that transistor is non-conducting. The juncture point **264** is at the more positive of the potentials of the collectors of the transistors **236**, **248**. A potential of −14 volts is therefore applied to the base of the transistor **268**, which causes the transistor **268** to conduct. The collector of the transistor **268** is at approximately −14 volts, which causes the transistor **274** to become conductive.

When the input signal level on the base of the transistor **234** reaches −5.8 volts going in a negative direction, the transistor **234** becomes conductive and the transistor **236** is cut off. The transistor **248** remains cut off and the transistor **250** remains in a conductive state. This causes the voltage at the juncture point **264** and at the base of the transistor **268** to drop to −24 volts, which cuts off the transistor **268**. The collector voltage of the transistor **268** rises to ground level and

cuts off the transistor **274** in the gate **68**. The circuits remain in this condition until the input signal level applied to the base of the transistor **248** reaches −8.4 volts going in a negative direction. When that level is reached, the transistor **248** becomes conductive, and cuts off the transistor **250**. The transistor **234** remains in a conductive state and the transistor **236** remains in a non-conductive state. The juncture point **264** and the base of the transistor **268** assume the voltage at the collector of transistor **248**(−14 volts) and the transistor **268** again becomes conductive. The potential of the collector of the transistor **268** drops from ground level to approximately −**14** volts, which causes the transistor **274** in the gate **68** to turn on. The circuits remain in this condition throughout the remainder of the 67–100 percent input signal amplitude range.

Briefly, when the input signal level to the level discriminator **62** ranges from −5 volts to −5.8 volts (0–17 percent of the signal amplitude range), the transistor **236** is conducting, the voltage applied to the base of the transistor **268** is approximately −14 volts, and the transistor **268** is conducting. When the voltage level of the input signal lies between −5.8 volts and −8.4 volts, the transistor **236** is cut off. The voltage applied to the base of the transistor **268** drops to −24 volts, and that transistor is cut off. When the input voltage from the line **98** exceeds −8.4 volts in a negative direction (67–100 percent of the signal amplitude range), the transistor **248** becomes conductive, which causes a potential of approximately −14 volts to again be applied to the base of the transistor **268**. This causes the transistor **268** to again become conductive and applies approximately −14 volts to the base of the transistor **274** to cause it to become conductive. The light source **78** will be energized only when a negative gating pulse is received at the terminal **298** from derandomizer **70** and an input signal is simultaneously received from the normalizing amplifier **54** which lies within the ranges of 0–17 percent and 67–100 percent of the input signal amplitude range.

It is pointed out that more than six output colors may be obtained by utilizing more than one level discriminator in conjunction with each light source. If more than one discriminator is utilized with one light source, each discriminator would control a separate switching transistor to provide more than one level of current flow through the corresponding source of monochromatic light. For example, if the green and blue sources provide equal intensity light, the combination will produce cyan light. If then, the intensity of the green light is increased, the light output of the two sources will tend toward green rather than be true cyan. Of course, such additional level discriminators could be provided almost indefinitely to produce virtually a continuous spectrum of output light. However, it has been found that one or two intensity levels of the three primary light sources provide sufficient output colors for normal analyzing purposes.

It is also pointed out that all three sources may be illuminated simultaneously at equal intensity levels to provide white light. This may be done manually or automatically.

The normalizing amplifier **54** shown in FIG. **1** is essentially a direct-current amplifier, whose function is to provide output signals whose amplitudes vary over predetermined range in response to input signals from the rate meter **14** that may vary over a different range of amplitudes. As shown in the schematic diagram of FIG. **4**, input signals from the rate meter **14** are supplied to a terminal **300**, which is connected through an input resistor **302** to the base of a PNP transistor **304**. In the present case, the arrangement is such that input signals from the rate meter **14** may vary in amplitude from −5 volts to a more negative voltage not exceeding −10 volts. The collector of the transistor **304** is connected in series through a fixed resistor **306** and a variable resistor **308** to the −24 volt supply. The variable resistor **308** serves as a gain control for the amplifier. The emitter of the transistor **304** is connected through a resistor **310** to the movable arm of a potentiometer **312**. The ends of the potentiometer **312** are respectively connected to ground and to a direct-current supply of −6 volts. The potentiometer **312** serves as a zero adjustment control for adjusting the amplifier to provide an output signal of −5 volts, when the input signal from the rate meter **14** is −5 volts.

The collector of the transistor **304** is also directly connected to the base of an NPN-transistor **314**. The emitter of the transistor **314** is connected through a resistor **316** to the −24 volt supply. The collector of the transistor **314** is connected through a fixed resistor **318** to the movable arm of a potentiometer **320**. One end of the potentiometer **320** is connected to ground and the other end is connected to the −6 volt supply. The potentiometer **320** serves as the contrast enhancement control, previously referred to in connection with FIG. **1** and designated **56** in that figure.

The collector of the transistor **314** is also connected directly to the base of a PNP-transistor **322**, whose collector is connected directly to the −24 volt supply. The emitter of the transistor **322** is connected to ground through a fixed resistor **324**, and is also connected directly to an output terminal **326** to supply a signal to the level discriminators **58**, **60**, **62** previously described.

The −5 volt starting point of the output signal amplitude range is provided by the voltage drop across a resistor **328**, one end of which is grounded and the second end of which is connected to the anode of a diode **330**. The cathode of the diode **330** is connected directly to the −6 volt supply. The second end of the resistor **328** is also connected in series through a meter **332**, a fixed resistor **334** and a variable resistor **336** to the output terminal **326**. The variable resistor **336** serves as a meter calibration adjustment to adjust the meter at its full scale reading. The dial of the meter **332** may be calibrated in terms of percent of output signal amplitude range or in terms of color of energized light sources. The purpose of the diode **330** is to compensate for the base-to emitter drop of the transistor **322**. A diode **338** is connected across the meter **332** with its anode connected to the resistor **334** and its cathode connected to the anode of the diode **330**. The purpose of the diode **338** is to prevent excess reverse current from flowing through the meter **332** when the transistor **332** is in a non-conducting state.

In operation, the potentiometer **312** is first adjusted to provide a −5 volt output signal at the terminal **326** when the input signal received at the terminal **300** is −5 volts and the arm of the potentiometer **320** is set at −6

volts. In other words, the potentiometer **312** is adjusted so that the transistor **304** is just non-conductive when the input signal to its base is −5 volts, which maintains the transistor **314** in a non-conductive condition. The emitter of the transistor **322** and the output terminal **326** are at a potential of approximately −5 volts. If it is desired to have the amplitude range of the input signal from the rate meter **14** provide a corresponding proportionate amplitude range of the output signal from the amplifier, the arm of contrast enhancement potentiometer **320** is set to provide −6 volts on the base of the transistor **322**. The emitter of the transistor **322** is at −5 volts and hence the terminal **326** is at −5 volts. The output terminal **326** becomes more negative in response to input signals exceeding −5 volts in a negative direction. The gain control resistor **308** is then set to provide a −10 volt output signal at the terminal **326** in response to the most negative input signal from the rate meter **14**. On the other hand, if it is desired to have the output signal at the terminal **326** vary from −5 volts to −10 volts in response to an input signal variation of, for example, from −6 volts to its most negative level, the contrast enhancement potentiometer **320** is adjusted to provide a less negative voltage on the base of the PNP-transistor **322**. This requires an input signal that is more negative than −5 volts to produce a −5 volt output signal at the terminal **326**. In this manner, input signals, having amplitudes lying within a predetermined portion of the input signal amplitude range are effectively suppressed. In other words, input signals having amplitudes less negative than a predetermined level, produce no output color change. The upper portion of the normal output range of the amplifier is expanded so that the six colors of light which expose the color sensitive film represent less than the entire range of input signal amplitudes.

It is pointed out that the end of the winding of the contrast enhancement potentiometer **320** shown as connected to ground may alternatively be connected to a positive source of voltage (not shown), which will serve to increase the available contrast range.

The derandomizer **70** (FIG. 1) comprises logic circuitry which is shown in FIG. **5**. It serves to prevent the overlapping of dots in the colored image produced on the color-sensitive film **94**, which might result in producing dark spots on the film. Inasmuch as the derandomizer comprises a plurality of logical elements, each of which is well-known in the art, its particular circuitry will not be described. Reference may be made to any one of a number of various technical publications for descriptions of the circuitry of the various elements, including Department of the Army Technical Manual TM11–690, published in 1959.

It is pointed out that all pulses received by, produced within and provided by the derandomizer are below ground potential. In other words, when a positive pulse or a positive-going pulse is mentioned, it means a pulse that starts from a negative potential and rises to ground potential and then returns to its negative potential. Similarly, a negative pulse or a negative-going pulse means a pulse that starts at ground potential, drops to a negative potential and then rises to ground potential again.

As shown in FIG. **5**, positive-going input pulses are received from the one-shot multivibrator **16** at an input terminal **350**, which is connected as one input to a NAND-gate **352**. The output of the NAND gate **352** is connected as one input to a one-shot multivibrator **354**. The multivibrator **354** provides a positive-going pulse to an inverter **356** and a negative-going pulse to an inverter **358** and to one input of a NOR-gate **360**.

The negative-going output pulse of the inverter **356** is provided to an output terminal **362**, from which it is connected to the gates **64**, **66**, **68** previously described. The negative-going output pulse of the inverter **356** is also connected to the input of a one-shot multivibrator **364**. The one-shot multivibrator **364** is a conventional type in which the width of its output pulse is determined by the discharge time of a capacitor in the multivibrator. In order to discharge the capacitor at various rates, depending on the rate of scan of the probe **10** (FIG. 1), a connection is provided to the multivibrator on a terminal **366** from the speed control circuit **72**. The speed control circuit will be later described in detail.

The multivibrator **364** provides two output signals. A positive-going output pulse is coupled through an inverter **368** to one input of a NAND-gate **370**. The output pulse from the NAND gate **370** is connected as a second input to the one-shot multivibrator **354**.

The negative-going pulse output of the multivibrator **364** is connected as an input to the NAND-gate **352** and as an input to the NOR-gate **360**. The output signal from the NOR-gate **360** is connected as one input to a NAND-gate **372**, a second input to which is from the input terminal **350**.

A negative-going output signal from the NAND-gate **372** is connected to a "set" input terminal of a bistable multivibrator **374**. A reset input terminal of the multivibrator **374** is connected to receive the positive-going signal from the inverter **358**. A positive-going output signal from the bistable multivibrator **374** is connected as a second input to the NAND-gate **370**.

To aid in understanding the operation of the derandomizer, assume first that no input pulses have been received for a time. This means that the output from the NAND-gate **352** to the multivibrator **354** is at ground level, the output of that multivibrator to the inverter **356** is at a negative level, and the output of that multivibrator to the inverter **358** and the NOR-gate **360** is at ground level. It follows that the input to the one-shot multivibrator **364** from the inverter **356** will be at ground level, and the input to the reset terminal of the multivibrator **374** will be at a negative level. The output of the one-shot multivibrator **364** to the inverter **368** will be at a negative level, and the output of the inverter **368** to the NAND-gate **370** will be at ground level. The output of the multivibrator **364** to the NOR-gate **360** and to the NAND-gate **352** will be at ground level. If now a positive-going pulse is received at the input terminal **350**, a negative pulse is supplied from the NAND-gate **352** to the one-shot multivibrator **354**. The multivibrator **354** provides a positive pulse to the inverter **356**, which inverts the pulse to provide a negative pulse to the output terminal **362** and to the input of the one-shot multivibrator **364**. A negative output pulse from the multivibrator **354** is inverted by the inverter **358** to provide a positive pulse to the reset terminal of the bistable flip-flop **374**. A negative pulse is also supplied to an input of the NOR-gate **360** from the

multivibrator 354. The one-shot multivibrator 364 does not respond to a negative pulse and so continues to provide a negative voltage to the inverter 368, and ground potential to the NOR-gate 360 and to the NAND-gate 352. The negative pulse applied to the input of the NOR-gate 360 from the multivibrator 354 provides a positive output pulse to the NAND-gate 372. If while the input pulse to the NAND-gate 372 from the NOR-gate 360 is positive, another positive pulse is supplied to the NAND-gate 372 from the input terminal 350, the output of the NAND-gate 372 will be a negative pulse which will set the multivibrator 374 to provide a positive voltage to the gate 370. The bistable multivibrator 374 will then remain in its set condition, regardless of how many pulses are received from the input terminal 350 through the NAND-gate 372, until it has been reset by a positive pulse from the inverter 358.

When the output from the first one-shot multivibrator 354 again goes negative and a positive pulse is transmitted to the second one-shot multivibrator 364, the multivibrator 364 provides a positive pulse to the inverter 368 which in turn provides a negative pulse to one input of the gate 370. A negative output pulse is also provided from the one-shot multivibrator 364 to the NOR-gate 360 and to the second input of the NAND-gate 352. Thus the NAND-gate 352 is closed, and no further input pulses can be supplied to the one-shot multivibrator 354 from the input terminal 350 until the input to the NAND-gate 352 from the one-shot multivibrator 364 again returns to ground potential. It is again pointed out that the output pulses supplied from the second one-shot multivibrator 364 are of variable width, the width of the pulses being determined by adjustment of the speed control circuit connected to the terminal 366 of the multivibrator. The circuit connection to the terminal 366 provides a path to discharge a capacitor in the multivibrator 364 when the charge on the capacitor has built up to a predetermined value, and thus to end the output pulse from the multivibrator.

When the output pulse from the one-shot multivibrator 364 to the inverter 368 again goes negative, a positive pulse will be applied to one input of the NAND-gate 370. If at this time the multivibrator 374 is in its set condition, a positive potential will also be applied to the other input of the NAND-gate 370, which will cause a negative output from the NAND-gate 370 to be supplied to the first one-shot multivibrator 354. Thus another output pulse will be produced by the one-shot multivibrator 354. If, during the time that either of the multivibrators 354 or 364 was set, no additional pulse is received on the input terminal 350, the pulse supplied to the NAND-gate 370 from the inverter 368 will not go through the gate 370 because the multivibrator 374 will not have been set and its output supplied to the gate 370 will be negative. Therefore, another output pulse will not be obtained from the derandomizer at its output terminal 362 until another input pulse comes in on the terminal 350.

It is apparent that the bistable multivibrator 374 serves in effect as a memory unit to store one input pulse if the pulse is received on the input terminal 350 before the first one-shot multivibrator 354 is in a condition to be again set, that is, before the end of the negative pulse supplied from the multivibrator 364 to the NAND-gate 352. The inverter 358 supplies a pulse to the multivibrator 374 to reset it at the leading edge of the output pulse from the one-shot multivibrator 354, so that the multivibrator 374 may be again set during the next cycle of operation.

The speed control circuit which is connected to the terminal 366 of the second one-shot multivibrator 364 in the derandomizer is shown in FIG. 3. It comprises a variable resistor 380 and a potentiometer 382 connected in series between the −24 volt supply and ground. A movable arm of the potentiometer 382 is connected to the base of an NPN-transistor 384. The emitter of the transistor 384 is connected through a variable resistor 386 and a fixed resistor 388 to the −24 volt supply. The collector of the transistor 384 is connected to an output terminal 390, which is connected to the terminal 366 of the multivibrator 364 shown in FIG. 5. The variable resistors 380 and 386 serve only as calibration adjustments.

The setting of the movable arm of the potentiometer 382 determines the potential applied to the base of the transistor 384, and therefore controls the collector current of the transistor. This current controls the widths of the output pulses of the multivibrator 364 in the derandomizer. The arm of the potentiometer 382 may be manually set in accordance with various available scanning speeds of the probe 10, or it may be mechanically linked to the speed control mechanism of the probe. In either case, the potentiometer is so set that when the probe is scanning at a slow rate of speed, the widths of the output pulses from the second one-shot multivibrator 364 are relatively wide. Conversely, if the probe is scanning at a relatively high rate of speed, the widths of the output pulses from the multivibrator 364 may be considerably narrower. In other words, if the probe scanning speed is slow, the potentiometer 382 is adjusted to decrease the collector current of the transistor 384, whereas if the probe scanning speed is relatively fast, the potentiometer is adjusted to provide increased collector current through the transistor. Thus, the capacitor in the one-shot multivibrator 364 is discharged in varying time periods of time depending upon the probe scanning speed.

Although an embodiment of the invention has been shown and described in detail, it is apparent that many changes and modifications may be made by one skilled in the art without departing from the true scope and spirit of the invention.

What is claimed is:

1. In a scintillation recording device including a scintillation responsive means for providing signal pulses at a rate proportional to radioactivity detected, rate detection means connected to the scintillation responsive means for providing a first output signal whose value varies over a first range with the rate of said signal pulses, and amplifier means connected to receive said first output signal and to provide a second output signal whose value varies over a second range with the rate of said signal pulses, the improvement comprising:

a. first, second and third discriminators connected to receive said second output signal, said discriminators being selectively actuated in response to various values of said second output signal to provide first, second and third energizing signals;

b. first, second and third light sources corresponding to said first, second and third discriminators, each of said light sources being connected for energization to its corresponding discriminator;

c. said first, second and third light sources including first, second and third means for generating light and first, second and third optical means being adapted to direct light from its corresponding source toward a common point; and,

d. each of said light sources being adapted to produce a light which is different in color from that produced by the others of said light sources;

e. whereby one or a combination of said light sources may be energized and the light therefrom transmitted by said optical means to said common point where such light is combined to produce a color indicative of the radioactivity detected.

2. The scintillation recording device of claim 1 additionally including first, second and third gates interposed between said discriminators and said light sources, each of said gates being connected to receive the energizing signal from its corresponding discriminator, and being connected to receive said signal pulses and being operative to energize its corresponding light source upon receipt of an energizing signal.

3. In a scintillation recording device including a scintillation responsive means for providing signal pulses at a rate proportional to radioactivity detected, rate detection means connected to the scintillation responsive means for providing a first output signal whose value varies over a first range with the rate of said signal pulses, and amplifier means connected to receive said first output signal and to provide a second output signal whose value varies over a second range with the rate of said signal pulses, the improvement comprising:

a. first, second and third discriminators connected to receive said second output signal, said discriminators being selectively actuated in response to various values of said second output signal to provide first, second and third energizing signals;

b. first, second and third gates corresponding to said first, second and third discriminators, each of said gates being connected to receive the energizing signal from its corresponding discriminator, and being connected to receive said signal pulses;

c. first, second and third light sources corresponding to said first, second and third gates, each of said light sources being connected for energization to its corresponding gate;

d. each of said gates being operative to energize its corresponding light source upon receipt of an energizing signal;

e. each of said light sources being adapted to produce a light which is different in color from that produced by the others of said light sources; and,

f. first, second and third optical means corresponding to said first, second, and third light sources, each of said optical means being adapted to direct light from its corresponding source toward a common point;

g. whereby one or a combination of said light sources may be energized and the light therefrom transmitted by said optical means to said common point where such light is combined to produce a color indicative of the radioactivity detected.

4. The scintillation recording device of claim 3 wherein said optical means comprise fiber optic means for delivering light from said light sources to said common point.

5. The scintillation recording device of claim 3 wherein said light sources individually provide light of three different primary colors.

6. The scintillation recording device of claim 3 additionally including aperture means, and said optical means is adapted to transmit light from said sources to a common point within a plane defined by said aperture means.

7. The scintillation recording device of claim 6 wherein said optical means comprise fiber optic means for causing light from said sources to be coincident in said plane defined by said aperture means.

8. The scintillation recording device of claim 7 wherein said light sources are energizable one at a time and in combination to provide a combined light as viewed through said aperture means ranging progressively in color from yellow to red to magenta to blue to cyan to green as the amplitude of said output signals vary progressively from end to end of said first and second ranges, respectively.

9. In a scintillation recording device including a scintillation responsive means for providing signal pulses at a rate proportional to radioactivity detected, rate detection means connected to the scintillation responsive means for providing a first output signal whose value varies over a first range with the rate of said signal pulses, and amplifier means connected to receive said first output signal and to provide a second output signal whose value varies over a second range with the rate of said signal pulses, the improvement comprising:

a. first, second and third discriminators connected to receive said second output signal, said discriminators being selectively actuated in response to various values of said second output signal to provide first, second and third energizing signals;

b. first, second and third gates corresponding to said first, second and third discriminators, each of said gates being connected to receive the energizing signal from its corresponding discriminator, and being connected to receive said signal pulses;

c. first, second and third light sources corresponding to said first, second and third gates, each of said light sources being connected for energization to its corresponding gate;

d. each of said gates being operative to energize its corresponding light source upon simultaneous receipt of an energizing signal;

e. said light sources being adapted to produce light of three different primary colors;

f. first, second and third fiber optical means corresponding to said first, second, and third light sources, each of said optical means being adapted to direct light from its corresponding source toward a common point; and,

g. aperture means positioned within a plane including said common point;

h. whereby one or a combination of said light sources may be energized and the light therefrom transmitted by said optical means to said common point where such light is combined to produce a color indicative of the radioactivity detected, and said combined light is transmitted through said aperture means.

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