

Oct. 26, 1954

K. S. LION

2,692,948

RADIATION REponsive CIRCUITS

Filed Dec. 29, 1948

4 Sheets-Sheet 1

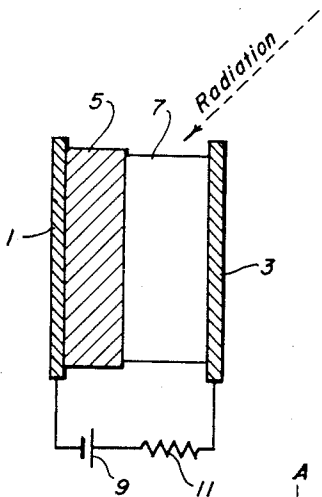


Fig. 1.

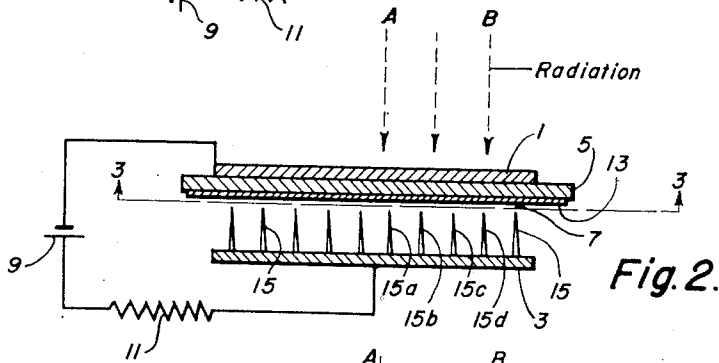


Fig. 2.

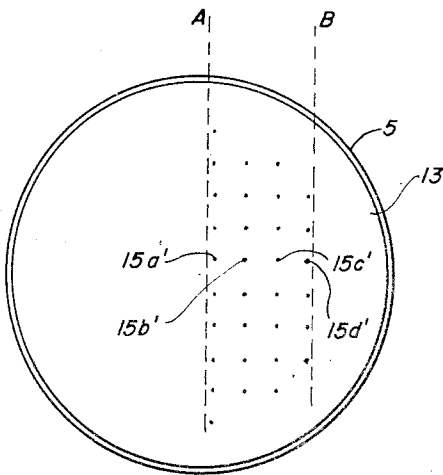


Fig. 3.

Inventor
Kurt S. Lion
by *Rines and Rines*
Attorneys

Oct. 26, 1954

K. S. LION

2,692,948

RADIATION REponsive CIRCUITS

Filed Dec. 29, 1948

4 Sheets-Sheet 2

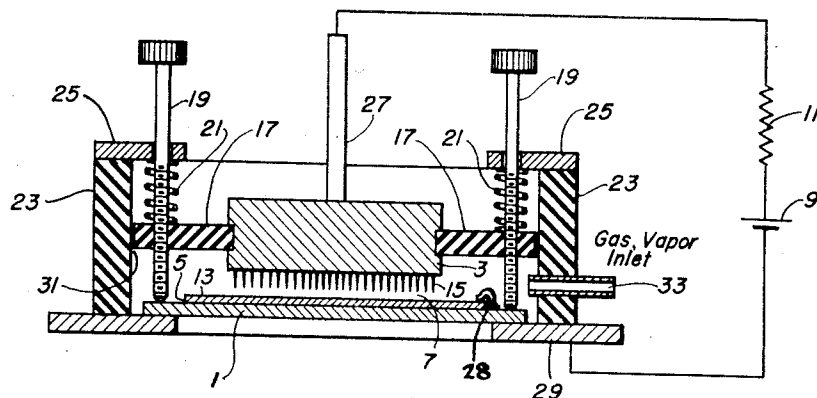
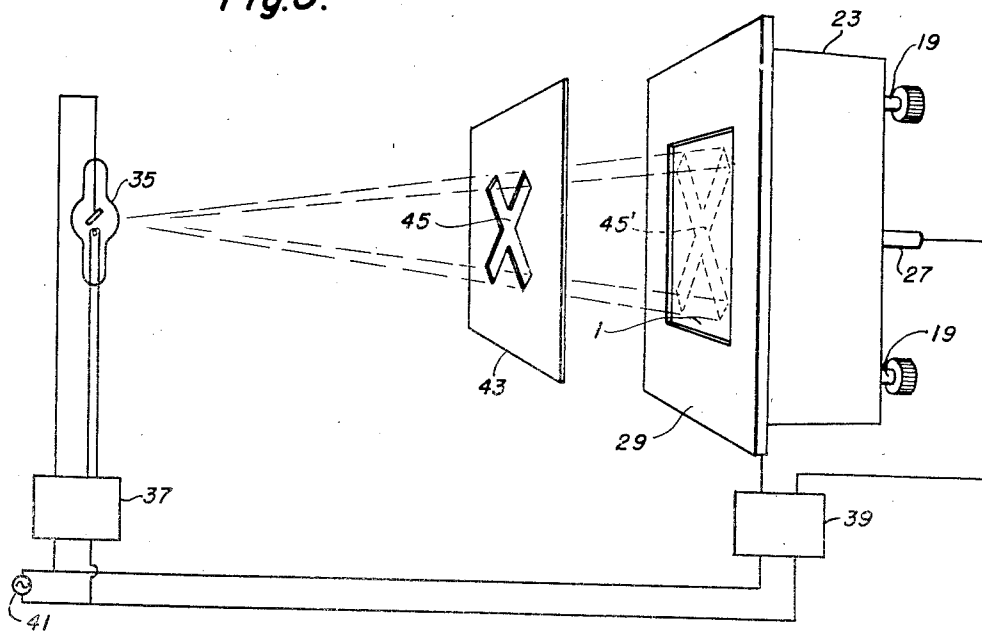


Fig. 4.

Fig. 5.



Inventor
Kurt S. Lion
by *Pines and Pines*
Attorneys

Oct. 26, 1954

K. S. LION

2,692,948

RADIATION REponsive CIRCUITS

Filed Dec. 29, 1948

4 Sheets-Sheet 3

Fig. 6.

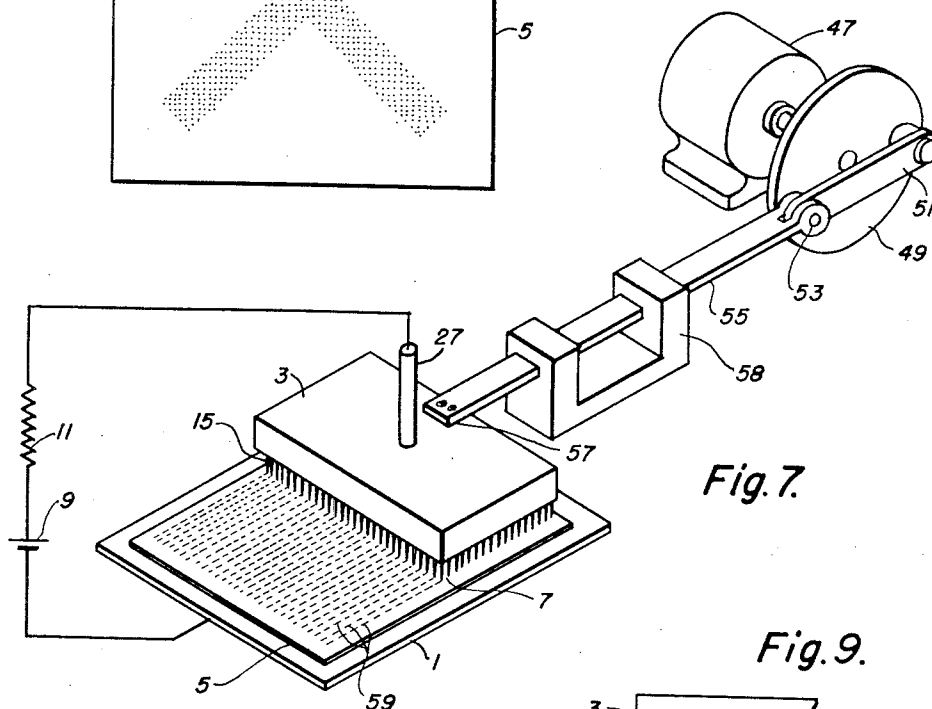
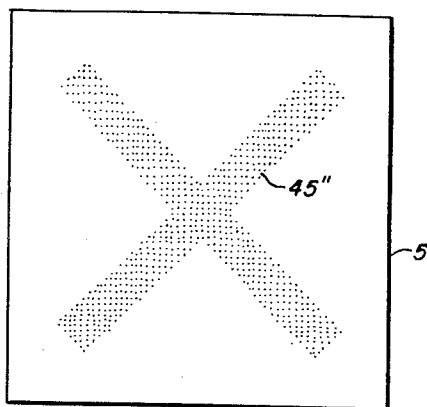


Fig. 7.

Fig. 9.

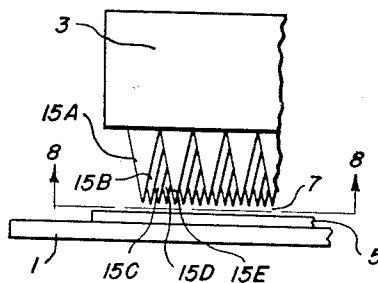
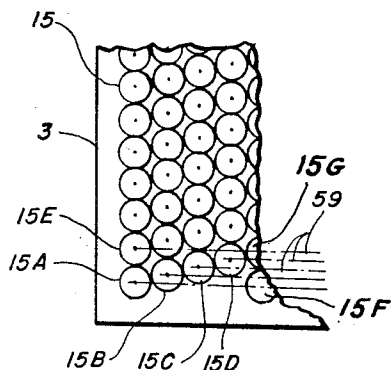


Fig. 8.



Inventor
Kurt S. Lion
by *Hines and Hines*
Attorneys

Oct. 26, 1954

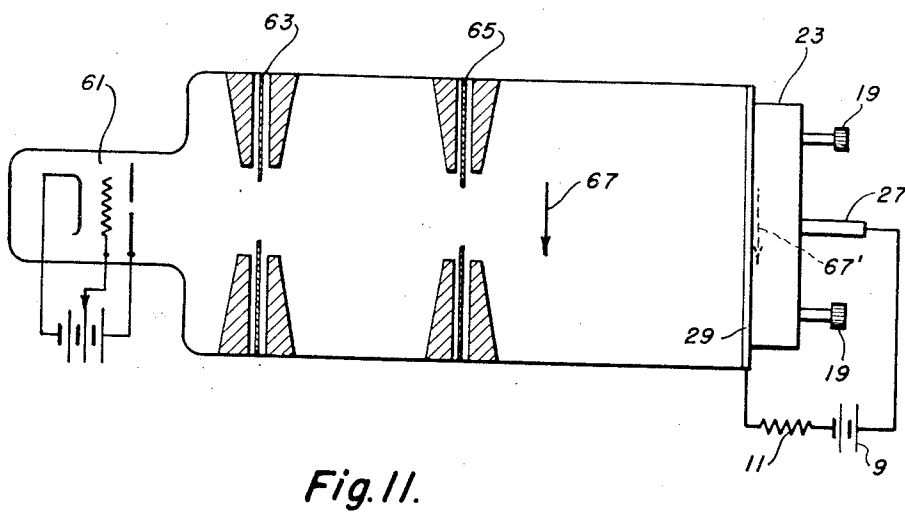
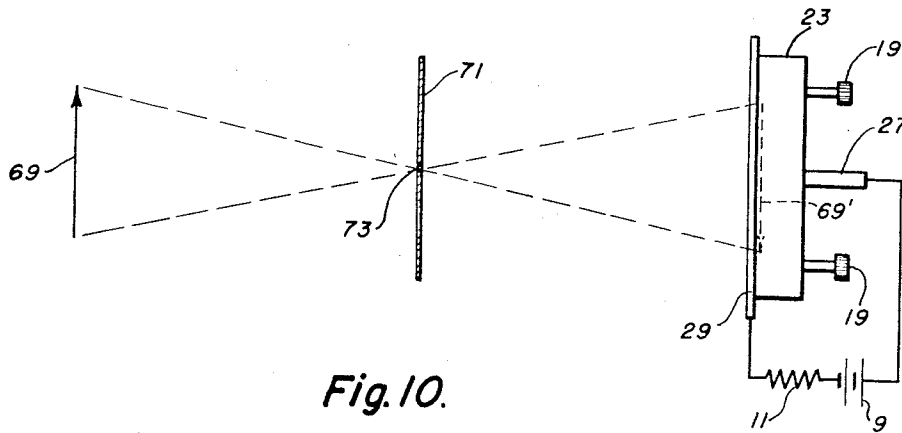
K. S. LION

2,692,948

RADIATION REponsive CIRCUITS

Filed Dec. 29, 1948

4 Sheets-Sheet 4



Inventor
Kurt S. Lion
by *Thies and Rines*
Attorneys

UNITED STATES PATENT OFFICE

2,692,948

RADIATION RESPONSIVE CIRCUITS

Kurt S. Lion, Watertown, Mass.

Application December 29, 1948, Serial No. 67,815

18 Claims. (Cl. 250—65)

1

The present invention relates to electric discharge systems and more particularly to radiation-responsive circuits.

An object of the invention is to provide a new and improved radiation counter.

A further object is to provide a novel apparatus for receiving radiations and automatically producing a response to the presence of the radiations.

Another object is to provide an apparatus for increasing the sensitivity to radiations of films, luminescent screens and similar devices.

The term "radiations" is herein employed in its conventional, broad sense to connote any visible or invisible electromagnetic-wave radiations, such as visible light waves, heat waves, infra-red rays, ultra-violet rays, X-rays or gamma rays or microwaves; atomic and radioactive radiations such as alpha rays; nuclear radiations such as neutron radiation; cosmic radiations; electron or beta radiations; and sound or ultrasonic radiations. Many of these radiations are presently indicated with the aid of radiation counters embodying at least two electrodes between which an ionizable medium is disposed and between which a voltage is established of value not quite sufficient to ionize the ionizable medium. The advent of the radiations in the ionizable medium produces ionization of the medium and a discharge results between the two electrodes. The number of discharges so produced may be used to count the number of radiation bursts or to determine other properties, such as the intensity of the radiations. These radiation counters are frequently connected to an external indicating circuit such as a meter, a tape recorder or a cathode-ray-tube oscilloscope to indicate the counts, or the luminous discharges produced in the counter are received in an external photocell circuit or are photographed from a point outside the counter.

Another object of the present invention is to provide a new and improved combined radiation counter and indicator that does not require external indicating equipment.

High-voltage impulses are also presently detected by instruments, such as clydonographs, comprising a plane electrode provided with a discharge-responsive photographic plate mounted upon the electrode with its emulsion side up. A further electrode makes contact with the emulsion of the photographic plate, and a high potential of the order of two thousand to twenty thousand volts is applied between the plane electrode and the further electrode of value sufficient

2

to produce a discharge therebetween. Luminous radial discharge lines, known as Lichtenberg figures, are produced and the photographic plate responds to the discharge. The length and form of these lines may be used to determine the polarity and amplitude of the voltage pulses.

In accordance with the present invention, on the other hand, extremely high discharge potentials are not essential and lower biasing potentials may be employed in conjunction with the triggering action of radiations to increase the sensitivity of a discharge-responsive medium.

A circuit similar to the clydonograph is presently employed for purposes of electrophotography. A plane electrode is generally provided with a photographic film upon which rests an insulator, the breakdown properties of which are to be measured. By applying a potential between an electrode adjacent the insulator and the plane electrode of value sufficient to break down the insulator, photographic indications of the weak spots of the insulator may be obtained.

A further object of the present invention is to provide a new and improved apparatus for electrophotography.

Other and further objects will be explained hereinafter and will be more fully pointed out in the appended claims.

The invention will now be described in connection with the accompanying drawings Fig. 1 of which is a schematic sectional diagram of a radiation counter and associated circuit embodying the principles of the present invention; Fig. 2 is a sectional view of a radiation counter constructed in accordance with the present invention and embodying a mosaic comprising a plurality of pint-point electrodes; Fig. 3 is a plan view taken along the line 3—3 of Fig. 2, looking in the direction of the arrows, and illustrating a reproduction of a photograph obtained with the apparatus of Fig. 2; Fig. 4 is a sectional view of a preferred instrument embodying the principles of the present invention; Fig. 5 is a perspective view illustrating the use of the instrument of Fig. 4 in an X-ray receiving system, illustrating also a synchronizing feature; Fig. 6 is a reproduction of a photograph obtained with the aid of the apparatus of Figs. 4 and 5; Fig. 7 is a perspective view of a modification in which a modified pin-point electrode mosaic is oscillated to produce greater detail; Fig. 8 is a fragmentary underside view of the modified pin-point electrode structure of Fig. 7, taken along the line 8—8 of Fig. 9, looking in the direction of the arrows; Fig. 9 is a fragmentary right-

hand elevation of the pin-point electrode mosaic of Fig. 7; Fig. 10 is a side elevation of a modified radiation image-reproducing system embodying the apparatus of Fig. 4; and Fig. 11 is a similar schematic view of an electron microscope embodying the apparatus of Fig. 4.

In the schematic diagram of Fig. 1, two spaced parallel plane electrodes 1 and 3 are shown connected in parallel with a source of energy 9, such as a battery, and a limiting resistor 11. A medium 5 is disposed in the region between the electrodes 1 and 3, spaced from the electrode 3, and preferably, though not essentially, immediately adjacent to and mounted upon the electrode 1, as by cement. This medium 5 is responsive to discharges occurring in the space between the electrodes 1 and 3. It may comprise a photographic film, a luminescent screen, such as a fluorescent phosphor screen, a combination of a photographic film layer and a luminescent screen layer, a discharge sensitive paper such as teledepos paper, an indicator that changes color in response to discharges such as a potassium dichromate layer, discharge-sensitive plates as of thin aluminum or silver, or any similar discharge-responsive device.

In the space between the medium 5 and the electrode 3, an ionizable medium 7 is disposed. The ionizable medium 7 may be an air gap or it may comprise a hermetically sealed gas chamber employing a gas or vapor under low as well as high pressure, including atmospheric pressure, as hereinafter described. A rare gas or mercury vapor may be employed. Polyatomic gases with and without other gas impurities have been found admirably suited to the purposes of the present invention. The medium 7 may, as hereinafter explained, comprise, also, a vessel containing an ionizable liquid, or it may comprise a crystal or other ionizable solid substance.

The voltage produced by the source 9 is adjusted to a magnitude insufficient to produce a discharge in and of itself between the electrodes 1 and 3. This voltage adjustment will, of course, depend upon the properties and thickness of the ionizable medium 7, the concentration of the medium 7 and the other properties of the discharge path between the electrodes 1 and 3. In all cases, however, the source of energy 9 is adjusted to produce a voltage gradient insufficient to ionize or break down the medium 7 as positioned between the electrodes 1 and 3. If, however, radiations are caused to impinge upon the medium 7, though the battery 9 can not of itself produce ionization in the medium 7, its potential is adjusted to a value sufficient, when the added energy of the radiations is absorbed by the medium 7, to render the medium conductive by ionization and to produce a discharge from the source 9 through the medium 7 between the electrodes 1 and 3.

The discharge-responsive medium 5, such as the photographic film before mentioned, which, of course, is somewhat electrically resistive, is positioned in the path of the discharge current from the electrode 1 through the medium 7 to the electrode 3, so that the film will respond to the discharge. Though the film may not itself be responsive to the radiations, or the radiations may be too weak to produce an effect on the film, the film will, however, respond to the discharge from the source 9 thus triggered by the radiations, thereby indicating the presence of the radiations. In this manner a self-contained, highly sensitive radiation indicator or recorder is provided.

If visible or invisible light radiations are to be employed, the ionizable medium 7 may comprise a photoemissive or photoconductive crystal such as an alkali-halide crystal. The voltage from the source 9 is not enough in and of itself to ionize the crystal and produce a discharge, but when the light radiations impinge on the crystal, either from the side as shown in Fig. 1 or through a light-wave transparent electrode 1 or 3, as of half-silvered glass, photon energy is absorbed by the crystal to provide sufficient energy in combination with the biasing voltage from the source 9 to ionize the crystal and produce a discharge between the electrodes 1 and 3. Similarly, a gaseous medium 7 which, when ionized, emits a particular wavelength of light, may be triggered into ionization by incident light radiations of that same wavelength.

Gaseous media, such as neon and mercury vapor, may be employed in the region 7 if microwave or other radio-wave radiations are used as the triggering agent. If such gases are provided with a biasing voltage from a source 9, the advent of even very weak radio signals will cause the gases to ionize in response thereto.

If X-rays, atomic, nuclear, electron or cosmic radiations and the like are employed, polyatomic gases as of ether, ethyl alcohol and xylol are suitable ionizable media, as are the rare gases and other well-known media. A liquid medium 7, such as paraffin oil, may also be employed. Though the voltage source 9 is adjusted so that it can not itself break down the liquid medium 7, the advent of X-rays or other radiations markedly varies the conductivity of the liquid to produce a discharge through the medium 7 between the electrodes 1 and 3. Solid media, such as paraffin, hard rubber or resinous materials, may also be used, as well as crystal media which will be later discussed.

Sound or ultrasound radiations, as before mentioned, may also be employed as triggering radiations since, as is well known, they act markedly to alter the concentration and dielectric constant of both gaseous and solid media 7 as the radiations are propagated therethrough.

Though for purpose of illustration, reference may be made hereinafter to a particular type of radiation in the discussion of the various embodiments of the present invention, it is to be understood that all types of radiation may be employed by the use of suitable media 7, as above shown. Though, furthermore, one type of discharge-responsive medium may be specifically referred to hereinafter in connection with a particular embodiment, it is also to be understood that any of the other types of discharge-responsive media before mentioned, or any similar indicators may equally well be employed.

In the embodiment of Fig. 2, a circular film 5 having an emulsion 13 is shown mounted emulsion side down upon a plane electrode 1. A second plane electrode 3, preferably disposed parallel to the plane of the electrode 1, is shown provided with a plurality of conducting elements 15 projecting upward from the plane of the electrode 3 toward the emulsion 13, but spaced therefrom. It is desirable that the conducting elements 15 extend from the electrode 3 in a direction substantially perpendicular to the planes of the electrodes 1 and 3 and that they be provided with sharp pin-points or needle-like tips, as shown, to produce sharp discharges, as hereinafter described. The biasing voltage 9 and the limiting resistor 11, discussed in connection with

Fig. 1, are shown connected between the electrodes 1 and 3. The medium 7 between the tips of the pin-point conducting elements 15 and the discharge-responsive emulsion 13, may, for example, be an ionizable air gap, or preferably an ionizable gap containing a polyatomic gas, such as ether, maintained at atmospheric pressure, as later discussed in connection with the system of Fig. 4. Radiation such as, for example, X-rays, may impinge, as illustrated by the dotted arrows, upon the electrode 1 from some source, not shown. If the electrode 1 is transparent to these radiations, as when it is constituted of a thin sheet of aluminum, for example, the radiations will penetrate the electrode 1, the responsive medium 5—13, such as the film, and pass into the ionizable gaseous medium 7 between the electrodes 15 and the film.

The voltage of the battery 9, as before explained, is adjusted to a magnitude insufficient to produce a discharge between the pin-point electrodes 15 and the corresponding oppositely disposed regions of the plane electrode 1 in the absence of the X-ray radiations, but of sufficient magnitude to permit such discharges to take place when X-ray radiations penetrate to the ionizable medium between the electrodes 1 and 15.

It is well known that radiation counters may be operated over certain voltage ranges, such as a voltage range of the order of 1200 to 1500 volts, in which a discharge occurs when radiation is present, and ceases when the radiation is no longer present. In such a voltage range, however, no continuous discharge within the counter will occur. This range of voltage is often referred to as the "plateau" of the radiation counter characteristic operating curve. In the plateau region, the advent of radiations impinging upon the counter will trigger or ionize the biased counter medium to produce a discharge. To sharpen the discharge phenomenon by very rapidly quenching a discharge triggered by radiations, a limiting resistor such as the resistor 11 of Figs. 1 and 2, may be employed to lower the voltage produced between the electrodes 1 and 3—15 after the discharge has commenced, thereby rapidly to stop the discharge. The resistor 11 may be replaced by a reactance such as an inductance, or a combined resistance and reactance. The use of a self-quenching polyatomic gaseous ionizable medium 7, of course, further aids the sharp quenching process since gases of high molecular weight absorb the energy in the ions produced during the discharge. A sinusoidal, square-wave or other pulsing voltage of peak amplitude insufficient to ionize the ionizable medium 7 may also be employed, as hereinafter discussed, in order that the medium 7 may be conditioned for ionization by radiations only during the application of the peaks of such a pulsing voltage, and a discharge can not continue once the pulsing voltage has been removed.

I have found that not only the voltage applied to a system such as that diagrammatically illustrated in Fig. 2, but also the separation between the pin-point electrodes 15 and the film emulsion 13 must be carefully regulated to produce a plateau counting characteristic. The proper voltage value of the source 9 for any given ionizable medium 7 depends chiefly upon the separation of the projecting pin-point electrodes 15 from the emulsion 13 of the film 5—13, upon the radius of curvature of the pin-point electrodes

15, and upon the conductive properties of the film 5—13.

If the spacing between the emulsion 13 and the pin-point electrodes 15 is too small, this system will not act as a radiation counter at all, but will behave as a clydonograph, previously described. Continuous discharges are produced once the voltage from the battery 9 has exceeded the breakdown voltage between the pin-point electrode 15 and the electrode 1. If the battery 9 is kept at a potential under this breakdown potential, moreover, no discharge is ever produced irrespective of whether or not radiations are impinged on the medium 7 between the electrodes 1 and 3—15. If the spacing between the emulsion 13 and the pin-point electrodes 15 is too large, on the other hand, relatively large biasing sources 9 are necessary, and variations in the properties of the relatively large medium 7 may produce non-uniform results. Within a proper range of spacings between the pin-point electrodes 15 and the emulsion 13, however, and with the battery 9 adjusted to a voltage less than the breakdown voltage between the electrodes 1 and 3—15, counting action may occur, as before mentioned, when radiation strikes any part of the ionizable medium 7 between one of the pin-point electrodes 15 and the emulsion 13. With an ether medium 7 and an array of commercial phonograph needles 15, for example, spacings of the needles 15 from a silver-bromide emulsion 13 of the order of several hundredths of a millimeter have been found to produce a good plateau characteristic for voltages from the source 9 of the order of 500 volts. Radiations from, for example, extremely weak radium bromide and similar sources, have been found to trigger such a system. Voltages up to about 1400 volts have been employed for greater needle-to-emulsion separations, and higher voltages may also be used. For each needle-to-emulsion separation, of course, the voltage source 9 must be adjusted to another value not quite sufficient to ionize the medium 7 in and of itself, but sufficient to operate the counter on a plateau-like characteristic when radiations enter the medium 7 and trigger off the counter by adding to the medium sufficient additional energy to ionize the medium and permit the source 9 to produce a discharge current between the electrodes 1 and 3.

I have discovered that with the system of Fig. 2, discharges take place only between those pin-point electrodes in the neighborhood of portions of the ionizable medium 7 in which the radiations have entered and the corresponding oppositely disposed regions of the electrode 1. With the pin-point electrode structure, moreover, I have found that the discharges remain very sharply defined and do not interfere or overlap either in the medium 7 or on the film or other indicator 5—13. Discharges will not be produced, however, between a pin-point electrode of the mosaic of pin-point electrodes 15 and its corresponding oppositely disposed region of the electrode 1 in the absence of radiations in the portion of the medium 7 in the immediate neighborhood of the pin-point electrode and its corresponding oppositely disposed region of the electrode 1.

I have found, further, that a counter of this nature may be rapidly quenched after a discharge without a separate limiting resistor for each pin-point electrode 15, by employing the combination of a common limiting resistor 11 and a polyatomic gaseous medium 7. I have also found that successful quenching may be accomplished

with the aid of short square-wave impulses applied between the electrodes 1 and 3 from any well-known pulse generator, as later discussed in connection with the embodiment of Fig. 5, the pulses being of peak voltage corresponding to the voltage of the source 9 so that only during the application of the peak of a pulse can a discharge occur in response to the triggering action of radiation in the ionizable medium 7.

In Fig. 2, radiations are shown, for purposes of illustration, penetrating only a portion of the electrode 1 and of the medium 7 on the right-hand side of the figure between arrows A and B. If the plane electrodes 1 and 3 are of circular shape and the pin-point electrodes 15 are disposed over the circular surface of the electrode 3, the photographic film 5-13 will produce a photograph as shown in Fig. 3. Each dot on this photograph represents a response by the film to a sharp and discreet discharge from one of the right-hand pin-point electrodes of the electrode mosaic 3-15 lying within the radiation region A-B to the corresponding oppositely disposed region of the electrode 1 through the portion of the medium 7 in the neighborhood of the said one pin-point electrode. The discharges triggered by the radiations in the medium 7 in the neighborhood of electrodes 15a, 15b, 15c and 15d of Fig. 2, for example, are shown recorded upon the film 5-13 of Fig. 3 at 15a', 15b', 15c' and 15d', respectively. To the right of and to the left of the lines A and B, however, no discharges are produced since no triggering radiations are present. The greater the radiation signal intensity, the greater the number of discharges, and the heavier the dot produced on the photograph.

Successive photographs of the radiation field may be produced by advancing a continuous film 5-13, such as a motion-picture film, across the face of the electrode 1, by techniques well known in the art. Alternately, the electrode structure 3-15 may be moved across the face of the film as discussed in connection with Fig. 7. It is to be understood, as before mentioned, that the film 5-13 may be replaced by a discharge-sensitive recording paper system, or any other discharge-responsive member including a fluorescent screen, to indicate the discharges produced by the triggering action of the radiations. If a fluorescent screen or a combination of a layer of fluorescent screen material and a photographic permanent recording layer is employed, the electrode 1 may be transparent to light waves in order that the luminescent discharge indications on the screen may be observed. The fluorescent screen 5-13 may, as an illustration, have a low persistency willemite phosphor, or it may be provided with a cascade high persistency phosphor screen such as those employed in many cathode-ray tubes. The electrode 1, in order to serve both as an electrode and as a light-transparent medium through which the luminescence of the screen may be observed, may comprise a half-silvered glass sheet.

Fig. 4 illustrates an experimental apparatus, embodying the principles discussed in connection with the schematic diagram of Fig. 2, that I have constructed and successfully operated. A conductive base plate 29 is shown supporting, and in electrical contact with an electrode 1 upon which is mounted, for example, a film 5 with, its emulsion surface 13 facing upward. The electrode 1 or the electrode 3 may be transparent to the radiations to be detected, as before explained. The emulsion surface 13, furthermore, may be disposed adjacent

the electrode 1, or emulsion surfaces may be employed on both faces of the film 5, or the emulsion may be formed upon the electrode 1 itself. In the case of X-ray radiation, the electrode 1 may be an aluminum sheet. The film 5-13 may be mounted upon the electrode 1 by cement, or it may be held mounted upon the electrode 1 and spaced from the electrode 3-15 by a clip 28 or by any other similar device. A preferably cylindrical electrode 3 is shown provided with a mosaic comprising a plurality of pin-point electrodes or needles 15, projecting toward the electrode 1. The electrode structure 3-15 is carried by a top chamber wall 17.

Side chamber walls 23 having upper flanges 25 extend upward from the base mounting 29 and enclose the space between the electrodes 1 and 3-15. Adjusting screws 19 pass through the upper flanges 25 of the side walls 23 and through the margin of the top chamber wall 17 to the outer edges of the electrode 1 in order to raise or lower the mosaic electrode structure 3-15 with respect to the electrode 1. Springs 21 inserted between the upper flanges 25 and the top chamber wall 17 provide for a tight adjustment. A gas or vapor inlet or outlet opening 33 is provided in one of the side walls 23.

For many applications it may be desired to employ a gas-tight medium between the multiple electrode 3-15 and the electrode 1. In such cases, the ends 31 of the top chamber wall 17 may be hermetically sealed, as is well-known in the art, to the side walls 23 of the chamber, as may be the edges of the electrode 1 to the base mounting 29. The space enclosed therebetween, includes the pin-point electrodes 15, the photographic plate or other discharge-responsive medium 5-13, the ionizable medium 7 and the electrode 1. By means of the opening 33 in the side wall 23, this space may be evacuated by a pump connected to the opening 33, or filled with any desired gas at any desired pressure, and the gas inlet or outlet opening 33 may be sealed off so that the counter formed by the elements 1, 5-13, 7 and 3-15 is enclosed in a gas-tight vessel or envelope. I have found, however, that such a gas-tight chamber is not essential for many applications, as where polyatomic gases such as ether, butane, ethyl alcohol, xylol, amyl acetate, and the like are employed as the ionizable medium 7. I have successfully operated this apparatus, for example, by continually feeding such gases at atmospheric pressure from a container through the gas inlet 33, and by leaving the ends of the upper chamber wall 17 spaced slightly from the side walls 23 of the chamber, as shown at 31 in Fig. 4, in order to permit the gas to escape therefrom. By continually supplying fresh gas in this manner, uniform gas concentrations and effective photographs have been obtained.

The biasing source 9 and limiting resistor 11 may be connected, as shown, between terminal electrodes 27 and 29 which are respectively connected to the electrodes 3-15 and the electrode 1.

In one test, the cylindrical electrode 3 was about two inches in diameter and supported about twelve-hundred phonograph needles placed with their bases in contact and their points projecting toward the emulsion 13 of a conventional silver bromide or silver chloride film. The limiting resistor 11 had a value of about ten megohms. For a needle-to-emulsion separation of about sixty microns, a bias voltage from the source 9 of about 800 volts, and employing a continuous stream of ether as the medium 7, I found that X-ray radiations of intensity of the order of frac-

tions of a Roentgen unit would trigger the counter

Fig. 5 illustrates a typical system which I have successfully operated employing X-rays as the source of triggering radiation for the counter of Fig. 4. An X-ray camera 35 is shown directed towards an X-ray opaque screen 43 as of lead, from which, for purposes of illustration, a cross 45 may be cut away. It is to be understood, of course, that this X-ray machine 35 may be X-raying any part of the human body or any metal or dielectric structure instead of the cross 45, or may be used for diffraction photographs or in any other way that X-rays are employed. The X-rays may, indeed, be emanating from a radioactive source. The system of Fig. 5 is merely for purposes of illustration.

The X-rays that penetrate through the cross 45 impinge upon the electrode 1 of the multiple radiation counter system of Fig. 4. Since, as before discussed, the electrode 1 may be transparent to the radiations, the X-rays will pass through the electrode 1 and the film 5-13 and into the ionizable medium 7 of the counter. Assume that the X-ray radiations are too weak to expose the film 5-13 or even that the film 5-13 is not sensitive to the radiations. The dotted cross 45' illustrates the portions of the medium 7 into which the radiations have penetrated. Discharges are produced between those pin-point electrodes 15 and the corresponding oppositely disposed regions of the electrode 1 lying within the latent radiation cross image 45'. The film 5-13 will thus respond only to these discharges, and a photograph, Fig. 6, will be obtained upon development of the film 5-13, illustrating a visual cross 45''.

With the previous assumption that the X-ray radiation is of too small a magnitude to produce an X-ray exposure on the film 5-13 in and of itself, it is clear that the counter of the present invention has effectively increased the sensitivity of the film by employing these weak radiations to trigger off discharges in the ionizable medium 7 in order to expose the photographic film. It is thus possible to obtain photographs of radiations too weak otherwise to record. Even if the film 5-13 does respond to the radiations, moreover, the substantially simultaneous ionizing discharges in the medium 7 produce an enhanced exposure of the film.

If the film 5-13 be replaced by an other type of discharge-responsive medium such as a paper that is not of itself sensitive to radiations, the present invention permits a record of the radiations to be made on the paper by employing the discharges triggered by the radiations to produce indications on the paper.

With the aid of the present invention, radiation sources, such as the X-ray machine 35, may be operated with much less intensity than present-day sources in order to obtain the same degree of photographic exposure. An amplification of photon sensitivity of the photographic film of many orders of magnitude may thus be obtained. This increased sensitivity of the film may be increased even more by reducing the radiation signal-to-noise ratio of the recording process in the following manner.

In the periods that the radiations to be detected are not present, the ionizable medium 7 may still be ionized by stray cosmic or other radiations, producing a background fog, often termed "noise," on the photographic film 5-13. This fog or noise limits the magnitude of detectable radiation signal. If the fogging of the film

can be prevented, radiation signals of the order of magnitude of the stray fogging radiations may be detected. This result may, to a large extent, be accomplished by causing the radiation counter to be sensitive to operation by the triggering action of received radiations only at the instants that the radiations that it is desired to detect are produced.

In a controlled system, such as the X-ray system of Fig. 5, this may be quite easily effected. The X-ray tube 35 is a normally ineffective source of radiations. If, for example, an alternating current power supply source 41 energizes a pulse transformer or other X-ray power-supply mechanism 37 to render the X-ray tube 35 effective and thereby to produce pulses of X-ray radiation, or to produce continuous radiation for a desired period of time, this same power supply source 41 may be fed, also, to a pulse generator 39 to supply to the radiation counter of the present invention biasing pulses of voltage, or a continuous biasing voltage of peak value just below the ionizing potential of the ionizable medium 7. In the absence of the biasing voltage, corresponding to the voltage produced by the source 9, the counter is normally ineffective even when radiations are present. When the biasing voltage is applied, the counter is effective to produce a count when radiations occur. The pulsing or other operating of the X-ray tube 35 and the biasing of the radiation counter are thus effected in synchronism. Only at the time that the X-ray machine is operating, therefore, is the medium 7 of the radiation counter biased to produce ionization upon the receipt of the radiations. By this synchronizing expedient, spurious radiations can not trigger off the medium 7 in the intervals that the X-ray machine is not operating, since the medium 7 is not biased near ionization to make effective such spurious radiations in between the operations of the X-ray tube 35.

With the aid of the present invention, therefore, unwanted random discharges may be prevented and extremely high sensitivity for recording radiation effects may be provided. If the present invention is used for X-ray radiology or radiography, it is possible to obtain adequate exposures with extremely small X-ray equipment. Large metal and other plates may be investigated in a short period of time and with a minimum of equipment. In medical radiography, since extremely weak radiations may be employed to produce an adequate exposure, it is possible to obtain pictures of a patient without subjecting the patient to the danger of prolonged exposure to X-rays and without subjecting the person taking the pictures to the same danger. X-ray diffraction patterns may also be obtained in this manner in a matter of minutes, because weak radiations are detectable by their triggering action and not by their intensity-exposure action upon a film. This feature also permits a study of contracting or expanding muscle structure and other structures by means of X-rays which has not heretofore been possible.

While the embodiments of Figs. 4 and 5 have been described in connection with X-rays, it is to be understood that this is only for purposes of illustration and this is only one application of the present invention.

The top and side walls 17 and 23 of the radiation detector of the present invention may be impervious to the radiations so that only radiations entering the transparent electrode 1 produce their effect. This is not necessary, of course, if just an

indication of the presence of radiations and not a picture of a radiation image or distribution is to be produced. If radiation counting alone is desired, the radiations may enter the medium 7 from any direction including through the walls 17 and 23, merely to produce a discharge that may be recorded on the film or other discharge-responsive medium 5—13. If it is desired, for example, merely to detect atomic or nuclear radiations, such as, for example, alpha rays, beta rays, gamma rays or cosmic rays, or similar radiations resulting from nuclear processes, the walls 17, 23 of the counter may be transparent to such radiations in order that some part of the medium 7 will be triggered to produce a discharge in the counter. Where it is desired to know the distribution of radiations and over what area radiations are present, on the other hand, the walls may be opaque to such radiations, and the radiations may be caused to penetrate into the ionizable medium 7 through the electrode 1 in order to produce discharges only at the regions where radiations enter the counter.

If a radiation-opaque screen 71, Fig. 10, having a small pin hole 73 is employed adjacent the electrode 1, radiations from a complete area or source 69 will become converged into an image 69' in the counter medium 7. The counter of the present invention will then take a photograph in the same manner as pin-hole light cameras, producing an actual visual likeness or image 69' of the radioactive source 69. The electrode 1 itself may be opaque to the radiations except for a small pin hole which will form an image of the radiation source in the ionizable medium 7.

In this manner, radiation pictures of a nuclear process, such as an explosion, or of objects in which radioactive substances are embedded, such as a thyroid gland, may be obtained, or a picture of any other radio-active area may be thus produced.

Radiation images may also be produced by employing focusing lenses and similar devices instead of the pin-hole device 71—73. In the case of electron radiations, for example, as employed in electron microscopes and electron diffraction cameras, the apparatus of Fig. 4, employing a fluorescent screen 5—13, as before discussed, may be substituted for the fluorescent screen of present-day electron microscopes and cameras. A conventional electron microscope or camera is illustrated in Fig. 11. Electron radiations are produced in an electron gun 61 in the form of a stream of electrons. The stream of electrons is focused by magnetic lenses 63 and 65, schematically shown with magnet pole pieces, to produce either an electron shadow or diffraction image 67' of an object or specimen 67 in the medium of the counter of the present invention. The counter is shown enclosed in the same evacuated envelope as the rest of the elements of the electron microscope or camera, having been substituted for the conventional fluorescent screen. If a film 5—13 is employed in the counter, a photographic image of the effective radiation source 67 will be produced. If a combination film and fluorescent screen is employed, in the counter, as before discussed, both temporary visual and permanent images of the object 67 will be produced. The electron gun supply voltage and the counter biasing voltage may be synchronously operated, as explained in connection with Fig. 5, to produce increased sensitivity.

The image definition obtainable with a pin-point electrode structure 15 such as that shown

in Figs. 2, 4 and 5, has limitations. As before explained, the film or other discharge-responsive medium 5—13 responds to discharges produced only in the immediate vicinities of the pin-point electrodes 15, and the remaining portions of the film or other medium will not record any phenomenon. Only those portions of the film opposite the pin-point electrodes 15 are thus sensitized in accordance with the present invention. Unless, therefore, a large number of needles can be employed, a satisfactory complete picture from a radiation source will not be obtained, but the picture, rather, will consist of spaced spots, as shown in Figs. 3 and 6.

It is well known, however, that a picture composed of spots may be quite satisfactory when the spots are close enough together. This technique is employed, indeed, in such processes as electro-engraving. If, therefore, the pin-point electrodes 15 are closely spaced to correspond to the individual pin-point regions of an electro-engraved picture, for example, good photographic or other visual definition of the radiation source may be obtained.

In the embodiment of Fig. 7, a modified system for producing good definition is illustrated. The pin-point electrodes 15, carried by the electrode 3, are arranged as shown in the end elevation of Fig. 9 and in the underside view of Fig. 8. If these electrodes 15 were merely spaced in horizontal and vertical rows and columns, the closest spacing between the points of the electrodes would be limited by the diameter of the base of the pin-point electrodes themselves. By staggering the electrodes, however, so that each adjacent electrode does not lie in a horizontal line with respect to the other electrodes but lies in a line inclined to the horizontal, the pin-point electrodes comprising successive columns will produce discharges that are closer together, horizontally, than would be the corresponding discharges produced by electrodes arranged along horizontal rows. Needle electrodes 15A, 15B, 15C and 15G are shown disposed in staggered relationship along a line at an angle to the horizontal. Electrodes 15A and 15F lie in a horizontal column, as do electrodes 15E and 15G, and so on, for the complete array or mosaic of electrodes 15. A large number of needles may thus be employed in this staggered arrangement to produce staggered discharges of horizontal separation as close as may be desired.

If, moreover, such a staggered electrode structure 15 is caused to oscillate back and forth preferably in a plane parallel to the plane of the electrodes 1 and 3, successive portions of the film along very closely spaced lines 59 will be exposed by discharges, thereby effectively sensitizing substantially the complete area of the film to produce a fine definition radiation picture of a radiation source.

The relative oscillating motion between the electrode structure 3—15 and the electrode 1 may occur extremely rapidly since the discharges produced by radiation are extremely short. If desired, the oscillating process may be repeated several times to produce a complete exposure. An apparatus for oscillating the electrode structure 3—15 of Fig. 7 is shown comprising a motor 47 driving a plate 49 upon which an eccentrically disposed crank arm 51 is mounted. The crank arm 51 is connected through a link 53 to a driving rod 55 which is oscillated back and forth through a yoke 58. The driving rod is shown connected at 57 to the electrode structure 3—15

to move the structure relative to the electrode 1 and the discharge-responsive medium 5.

Fine definition may also be obtained with the aid of solid materials including photo-conductive crystals, serving as a mosaic of pin-point electrodes. In the embodiment of Fig. 2, for example, the mosaic of needles 15 may be replaced by a photo-conductive crystal having surface irregularities of atomic or macroscopic dimensions which will serve as pin-point electrodes; by television transmitter mosaics, such as the iconoscope screens; by a mosaic comprising a sheet of emery paper, mica, or Masonite; or by similar elements. I have successfully used such mosaic structures to produce a very large number of extremely fine discharges.

Diamonds, alkali halide crystals such as silver bromide, and the like may also be employed. In the embodiment of Fig. 1, for example, the medium 7 may comprise such a crystal, as before mentioned. Not only may the crystal surface adjacent the discharge-responsive medium, such as the film 5, comprise irregularities which may serve as pin-point electrodes, but the crystal may serve also as the ionizable medium. If radiations such as alpha particles, for example, impinge upon the electrode 1 and penetrate through the film 5 to the biased crystal 7, the crystal will absorb the radiation energy and ionize, as before described, producing discharges through the film 5 at those portions of the crystal where radiation has impinged. The radiation may enter through the electrode 1 or through the electrode 3, as before described. The photo-conductive properties of the crystal apparently cause the voltage at each surface portion of the crystal adjacent the film 5, upon which radiations have fallen, to increase in potential, thereby triggering a discharge from the source 9 through the electrode 3, through the portion of the crystal 7 in the vicinity of the potential increase produced by the radiations, through the film 5, and to the corresponding oppositely disposed region of the electrode 1. Since the crystal surfaces are not perfectly flat, some irregular portions of the surface may not make complete contact with the film 5. An ionizable medium, such as air, may therefore assist in the recording or indicating process of the present invention by ionizing, also, upon the advent of radiations, to produce a discharge from the spaced irregular portions of the crystal 7 to the electrode 1 through the discharge-responsive indicator 5.

The crystal medium 7, moreover, may deliberately be spaced from the film 5 with an air or other ionizable gap in between, in order that the ionizing properties of the gap between the crystal and the film may be employed, either in combination with the ionizing properties of the crystal or in combination with the photo-conductive properties of the crystal alone. In the latter instance, the voltage from the source 9 may not be of sufficient magnitude to produce a discharge across the gap from the crystal to the electrode 1, but may be sufficiently high to produce such a discharge when the potential of regions of the crystal upon which radiations have impinged has increased in response to photo-conductive phenomena. Radiations may, for example, penetrate the electrode 3 and fall upon regions of the crystal, thereby photo-conductively increasing the potential between the said regions and the corresponding oppositely disposed regions of the electrode 1 to produce discharges therebetween.

An apparatus, such as disclosed in Fig. 1, employing a crystal medium 7, thus constitutes a

compact, new and improved film or other radiation indicator or recorder. If desired, furthermore, a combination of the media 5 and 7 may be effected in order that the combination may provide both an ionizable medium and a discharge-responsive medium. An array or region of silver bromide crystals, for example, may serve as such a combination, preferably when employed under heat. Some of the crystal molecules of the region will become ionized in response to the triggering action of the incident radiations, thereby serving as an ionizable medium. Other of the crystal molecules of the region will respond to the resulting discharge, forming silver sub-bromide, as in exposed photographic plates, thereby providing a discharge-responsive medium. Fluorescent particles may, if desired, be mixed with such crystal or other ionizable substances to provide a medium responsive to the discharges produced by the radiation-triggered ionization.

Further modifications will occur to those skilled in the art, and all such are considered to fall within the spirit and scope of the present invention as defined in the present claims.

What is claimed is:

1. Apparatus of the character described comprising spaced electrodes between which a discharge may pass through a normally non-conductive medium that may be rendered conductive in response to radiation in the space between the electrodes, means for connecting the electrodes to a source of energy to impress between the electrodes from the source a voltage of magnitude insufficient to produce the said discharge from the source through the medium between the electrodes when the medium is non-conductive but sufficient to produce the said discharge from the source through the medium between the electrodes when the medium is rendered conductive in response to radiation in the space between the electrodes, and means for spacing from at least one of the electrodes in the path of the said discharge a medium responsive to the said discharge.

2. Apparatus of the character described comprising a normally non-conductive medium that may be rendered conductive in response to radiation in the medium, spaced electrodes between which a discharge may pass through the medium when the medium is rendered conductive, means for connecting the electrodes to a source of energy to impress between the electrodes from the source a voltage of magnitude insufficient to produce the said discharge from the source through the medium between the electrodes when the medium is non-conductive but sufficient to produce the said discharge from the source through the medium between the electrodes when the medium is rendered conductive in response to radiation in the medium, and means for mounting a photographic film responsive to the said discharge on one of the electrodes in the path of the said discharge.

3. Apparatus of the character described comprising a normally non-conductive medium that may be rendered conductive in response to radiation in the medium, two spaced electrodes between which a discharge may pass through the medium when the medium is rendered conductive, means connected between the electrodes comprising a source of energy for impressing between the electrodes a voltage of magnitude insufficient to produce the said discharge from the source through the medium between the electrodes when the medium is non-conductive but

sufficient to produce the said discharge from the source through the medium between the electrodes when the medium is rendered conductive in response to radiation in the medium, and means for mounting a medium responsive to the said discharge on one of the electrodes in the path of the said discharge.

4. Apparatus of the character described comprising a normally non-conductive medium that may be rendered conductive in response to radiation in the medium, two spaced electrodes between which a discharge may pass through the medium when the medium is rendered conductive, means connected between the electrodes comprising a source of energy for impressing between the electrodes a voltage of magnitude insufficient to produce the said discharge from the source through the medium between the electrodes when the medium is non-conductive but sufficient to produce the said discharge from the source through the medium between the electrodes when the medium is rendered conductive in response to radiation in the medium, means for promptly quenching the said discharge, and means for mounting a medium responsive to the said discharge on one of the electrodes in the path of the said discharge.

5. Apparatus of the character described comprising a normally non-conductive gaseous medium that may be rendered conductive in response to radiation in the gaseous medium, two spaced electrodes between which a discharge may pass through the gaseous medium when the gaseous medium is rendered conductive, means connected between the electrodes comprising a source of energy for impressing between the electrodes a voltage of magnitude insufficient to produce the said discharge from the source through the gaseous medium between the electrodes when the gaseous medium is non-conductive but sufficient to produce the said discharge from the source through the gaseous medium between the electrodes when the gaseous medium is rendered conductive in response to radiation in the gaseous medium, and means for mounting a medium responsive to the said discharge on one of the electrodes in the path of the said discharge.

6. Apparatus of the character described comprising a normally non-conductive ionizable solid medium that may be rendered conductive in response to radiation in the ionizable solid medium, two spaced electrodes between which a discharge may pass through the ionizable solid medium when the ionizable solid medium is rendered conductive, means connected between the electrodes comprising a source of energy for impressing between the electrodes a voltage of magnitude insufficient to produce the said discharge from the source through the ionizable solid medium between the electrodes when the ionizable solid medium is non-conductive but sufficient to produce the said discharge from the source through the ionizable solid medium between the electrodes when the ionizable solid medium is rendered conductive in response to radiation in the ionizable solid medium, and means for mounting a medium responsive to the said discharge on one of the electrodes in the path of the said discharge.

7. Apparatus of the character described comprising a normally non-conductive medium that may be rendered conductive in response to radiation in the medium, two spaced electrodes between which a discharge may pass through the medium when the medium is rendered conductive, means connected between the electrodes

comprising a source of energy for impressing between the electrodes a voltage of magnitude insufficient to produce the said discharge from the source through the medium between the electrodes when the medium is non-conductive but sufficient to produce the said discharge from the source through the medium between the electrodes when the medium is rendered conductive in response to radiation in the medium, and a luminescent screen responsive to the said discharge mounted on one of the electrodes in the path of the said discharge.

8. Apparatus of the character described comprising two spaced electrodes one of which comprises a conducting element projecting toward the other electrode and from which a discharge may pass to the other electrode through a normally non-conductive medium that may be rendered conductive in response to radiation in the space between the electrodes, means for connecting the electrodes to a source of energy to impress between the electrodes from the source a voltage of magnitude insufficient to produce the said discharge from the source through the medium between the electrodes when the medium is non-conductive but sufficient to produce the said discharge from the source through the medium between the electrodes when the medium is rendered conductive in response to radiation in the space between the electrodes, and means for mounting a medium responsive to the said discharge on one of the electrodes in the path of the said discharge.

9. A system for producing a likeness of radiations received from an object that comprises a radiation receiver having, in combination, a normally non-conductive medium that may be rendered conductive in response to radiation in the medium, spaced electrodes between which discharges may pass through the medium when the medium is rendered conductive, means for connecting the electrodes to a source of energy to impress between the electrodes from the source a voltage of magnitude insufficient to produce the said discharges from the source through the medium between the electrodes when the medium is non-conductive but sufficient to produce the said discharges from the source through the medium between the electrodes when the medium is rendered conductive in response to radiation in the medium, means for mounting a medium responsive to the said discharges in the path of the said discharges, and means for forming a radiation image of the object upon the receiver to produce the said discharges from the source through the medium between the electrodes whereby a likeness of the radiation image is produced upon the discharge-responsive medium.

10. Apparatus of the character described comprising a normally non-conductive medium that may be rendered conductive in response to electromagnetic radiation in the medium, spaced electrodes between which a discharge may pass through the medium when the medium is rendered conductive, means for connecting the electrodes to a source of energy to impress between the electrodes from the source a voltage of magnitude insufficient to produce the said discharge from the source through the medium between the electrodes when the medium is non-conductive but sufficient to produce the said discharge from the source through the medium between the electrodes when the medium is rendered conductive in response to electromagnetic radiation in the medium, means for passing electromagnetic radi-

ation into the normally non-conductive medium, and means for mounting a medium responsive to the resulting discharge in the path of the said discharge.

11. Apparatus of the character described comprising a normally non-conductive medium that may be rendered conductive in response to atomic radiation in the medium, spaced electrodes between which a discharge may pass through the medium when the medium is rendered conductive, means for connecting the electrodes to a source of energy to impress between the electrodes from the source a voltage of magnitude insufficient to produce the said discharge from the source through the medium between the electrodes when the medium is non-conductive but sufficient to produce the said discharge from the source through the medium between the electrodes when the medium is rendered conductive in response to atomic radiation in the medium, means for passing atomic radiation into the normally non-conductive medium, and means for mounting a medium responsive to the resulting discharge in the path of the said discharge.

12. Apparatus of the character described comprising a normally non-conductive medium that may be rendered conductive in response to electron radiation in the medium, spaced electrodes between which a discharge may pass through the medium when the medium is rendered conductive, means for connecting the electrodes to a source of energy to impress between the electrodes from the source a voltage of magnitude insufficient to produce the said discharge from the source through the medium between the electrodes when the medium is non-conductive but sufficient to produce the said discharge from the source through the medium between the electrodes when the medium is rendered conductive in response to electron radiation in the medium, means for passing electron radiation into the normally non-conductive medium, and means for mounting a medium responsive to the resulting discharge in the path of said discharge.

13. Apparatus of the character described comprising a normally non-conductive medium that may be rendered conductive in response to radiation in the medium, a pair of spaced electrode means between which a discharge may pass through the medium when the medium is rendered conductive, one of the electrode means comprising a two-dimensional array of electrodes, means for connecting the electrode means to a source of energy to impress between the electrode means from the source a voltage of magnitude insufficient to produce the said discharge from the source through the medium between the electrode means when the medium is non-conductive but sufficient to produce the said discharge from the source through the medium between the electrode means when the medium is rendered conductive in response to radiation in the medium, means for passing radiation into the normally non-conductive medium, and means for mounting a medium responsive to the resulting discharge in the path of the said discharge.

14. Apparatus of the character described comprising a normally non-conductive medium that may be rendered conductive in response to radiation in the medium, two spaced electrodes between which a discharge may pass through the medium when the medium is rendered conductive, means connected between the electrodes comprising a source of energy for impressing between the electrodes a voltage of magnitude insufficient to pro-

duce the said discharge from the source through the medium between the electrodes when the medium is non-conductive but sufficient to produce the said discharge from the source through the medium between the electrodes when the medium is rendered conductive in response to radiation in the medium, and a luminescent screen responsive to the said discharge mounted on one of the electrodes in the path of the said discharge, one of the electrodes being transparent to the luminescence of the luminescent screen.

15. Apparatus of the character described comprising a pair of spaced substantially plane parallel electrodes between which discharges may pass through a normally non-conductive medium that may be rendered conductive in response to radiation in the space between the electrodes; means for connecting the electrodes to a source of energy to impress between the electrodes, from the source, an electric field the lines of force of which between the electrodes are substantially parallel to one another and substantially perpendicular to the planes of the electrodes, and the magnitude of which is insufficient to produce the said discharges from the source through the medium between the electrodes when the medium is non-conductive, but sufficient to produce the said discharges from the source through the medium between the electrodes when the medium is rendered conductive in response to radiation in the space between the electrodes; a resistive discharge-responsive medium disposed in substantial electrical contact with one of the electrodes in the path of the said discharges; means whereby radiation may enter the said space between the electrodes at a plurality of points corresponding to a plurality of the said lines of force, the radiation at each point of the plurality of points producing at the said point charged particles that thereupon become accelerated along the corresponding line of force to produce a well-defined individual discharge through the medium along the said line of force; and means for promptly quenching the plurality of individual discharges produced along the said plurality of lines of force, each of the said individual discharges producing an individual response at a corresponding point of the discharge-responsive medium.

16. Apparatus of the character described comprising a pair of spaced substantially plane parallel electrodes between which discharges may pass through a normally non-ionized gaseous medium that may be rendered ionized in response to radiation in the space between the electrodes; means for connecting the electrodes to a source of energy to impress between the electrodes, from the source, an electric field the lines of force of which between the electrodes are substantially parallel to one another and substantially perpendicular to the planes of the electrodes, and the magnitude of which is insufficient to produce the said discharges from the source through the medium between the electrodes when the medium is non-ionized, but sufficient to produce the said discharges from the source through the medium between the electrodes when the medium is rendered ionized in response to radiation in the space between the electrodes; a photographic film disposed in substantial electrical contact with one of the electrodes in the path of the said discharges; means whereby radiation may enter the said space between the electrodes at a plurality of points corresponding to a plurality of the said lines of force, the radiation at each point of the plurality of points producing at the said point charged

particles that thereupon become accelerated along the corresponding line of force colliding with molecules of the gaseous medium to produce a well-defined individual ionization discharge through the medium along the said line of force, and means for promptly quenching the plurality of individual ionization discharges produced along the plurality of lines of force, each of the said individual discharges producing an individual response at a corresponding point of the photographic film.

17. Apparatus of the character described comprising a pair of spaced substantially plane parallel electrodes between which discharges may pass through a normally non-ionized gaseous medium that may be rendered ionized in response to radiation in the space between the electrodes; means for connecting the electrodes to a source of energy to impress between the electrodes, from the source, an electric field the lines of force of which between the electrodes are substantially parallel to one another and substantially perpendicular to the planes of the electrodes, and the magnitude of which is insufficient to produce the said discharges from the source through the medium between the electrodes when the medium is non-ionized, but sufficient to produce the said discharges from the source through the medium between the electrodes when the medium is rendered ionized in response to radiation in the space between the electrodes; means whereby radiation may enter the said space between the electrodes at a plurality of points corresponding to a plurality of the said lines of force, the radiation at each point of the plurality of points producing at the said point charged particles that thereupon become accelerated along the corresponding line of force colliding with molecules of the gaseous medium to produce a well-defined individual ionization discharge through the medium along the said line of force, and means for promptly quenching the plurality of individual ionization discharges produced along the plurality of lines of force.

18. Apparatus of the character described comprising a pair of spaced substantially plane parallel electrodes between which discharges may pass through a normally non-ionized gaseous medium that may be rendered ionized in response to radiation in the space between the electrodes; means for connecting the electrodes to a source of energy to impress between the electrodes, from the source, an electric field the lines of force of which between the electrodes are substantially parallel to one another and substantially per-

pendicular to the planes of the electrodes, and the magnitude of which is insufficient to produce the said discharges from the source through the medium between the electrodes when the medium is non-ionized, but sufficient to produce the said discharges from the source through the medium between the electrodes when the medium is rendered ionized in response to radiation in the space between the electrodes; a resistive discharge-responsive medium disposed in substantial electrical contact with one of the electrodes in the path of the said discharges; means whereby radiation may enter the said space between the electrodes at a plurality of points corresponding to a plurality of the said lines of force, the radiation at each point of the plurality of points producing at the said point charged particles that thereupon become accelerated along the corresponding line of force colliding with molecules of the gaseous medium to produce a well-defined individual ionization discharge through the medium along the said line of force; and means comprising resistance in the said means for connecting the electrodes to the said source of energy for promptly quenching the plurality of individual ionization discharges produced along the plurality of lines of force, each of the said individual discharges producing an individual response at a corresponding point of the discharge-responsive medium.

References Cited in the file of this patent UNITED STATES PATENTS

Number	Name	Date
1,702,595	Cooley	Feb. 19, 1929
2,225,940	Grossman	Dec. 24, 1940
2,351,028	Fearon	June 13, 1944
2,436,084	Weller	Feb. 17, 1948
2,445,305	Hochgesang	July 13, 1948
2,457,555	Haworth	Dec. 28, 1948
2,458,099	Roop	Jan. 4, 1949

FOREIGN PATENTS

Number	Country	Date
464,112	Great Britain	Apr. 12, 1937

OTHER REFERENCES

The Geiger Point Counter, Morgan et al., Franklin Institute Journal, 1944, pp. 371-384.

Electron and Nuclear Counters, Korff, publ. by Van Nostrand Co. Inc., New York, N. Y., 1946, pp. 89-117.

Greinacher: Helvetica Physica Acta, 1936, vol. 9, pp. 590-594.