Aug. 28, 1945. S. ROSENBLUM 2,383,820

APPARATUS AND METHOD FOR UTILIZING IONIZING RADIATIONS

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Fig. 1

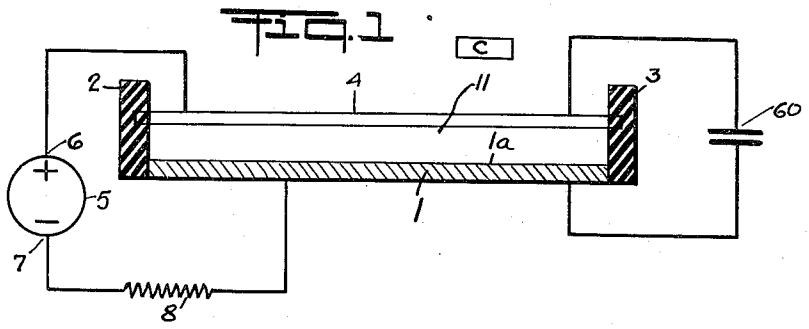


Fig. 2

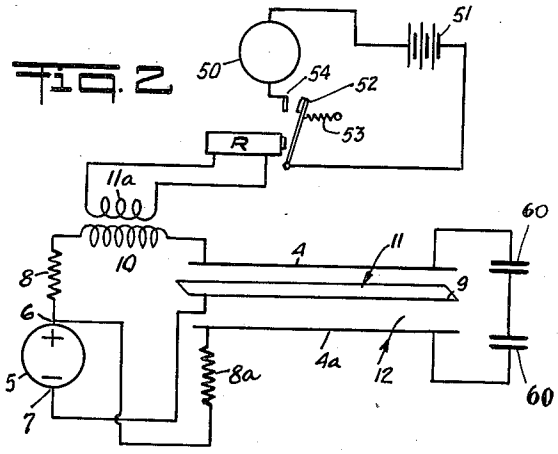


Fig. 3

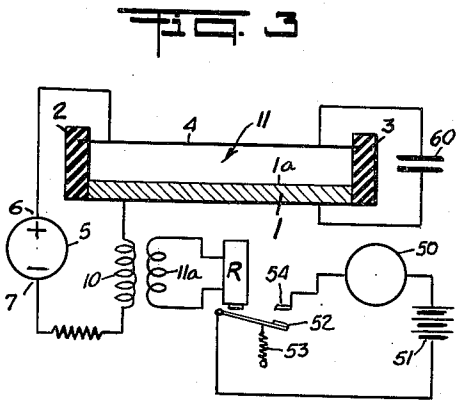


Fig. 4

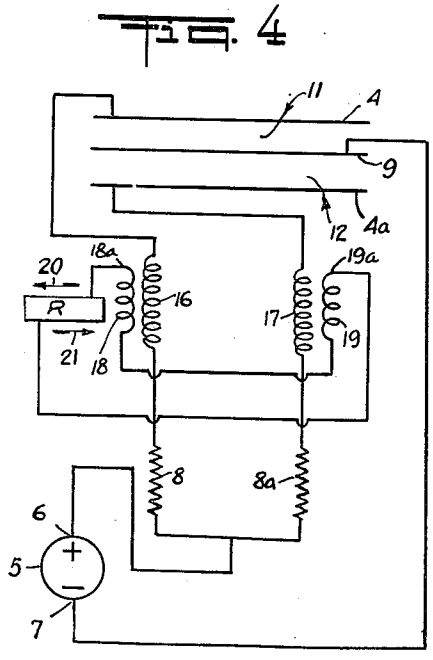
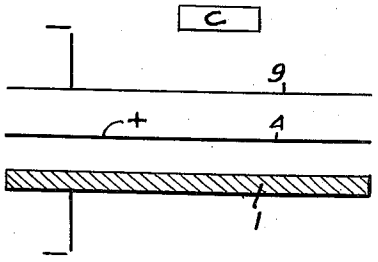


Fig. 5



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APPARATUS AND METHOD FOR UTILIZING IONIZING RADIATIONS

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5 Claims. (Cl. 250—83.6)

My invention relates to a new and improved apparatus and method for demonstrating the presence of, and utilizing the ionizing radiations of radio-active material, and more particularly, the alpha radiations, or other radiations of high ionizing power.

One of the objects of my invention is to provide an apparatus which can be used for demonstration purposes or for various industrial purposes, in the open air, or in an enclosure, so that the apparatus can be operated in air of normal humidity, at normal temperature of about 15° C., and under normal pressure of 760 millimeters of mercury.

Another object of my invention is to provide an apparatus which can be used as a ray counter, as a substitute for the Geiger-Muller counter. The improved apparatus is superior to said Geiger-Muller ray counter, because said improved apparatus can count the passage of the alpha radiations or particles, without the use of thermionic amplifiers and thyration tubes.

Another important advantage of my invention is that the ionic discharge which is produced can be observed without the use of an electrometer, which is expensive and which requires delicate manipulation.

Another object of my invention is to provide a simple and convenient apparatus which can be used or detecting small quantities of various gases, such as methane, chlorine and the like. The apparatus is therefore useful in detecting the presence of methane and chlorine or other explosive or dangerous gases in mines, submarines and the like.

Numerous additional objects of my invention will be stated in the annexed description and drawing, which illustrate a preferred embodiment thereof.

The drawing is wholly diagrammatic.

Fig. 1 illustrates one embodiment of my invention, in which one of the electrodes consists of a single wire or a plurality of wires, associated with a companion electrode.

Fig. 2 illustrates a second embodiment in which I use a pair of wire electrodes, combined with an intermediate electrode which is made of thin conductive material which is permeable to the alpha rays.

Fig. 3 illustrates another embodiment of my invention, in which the apparatus includes a counter.

Fig. 4 illustrates another modification, in which the embodiment of Fig. 2 is combined with auxiliary parts which operate a counter.

Fig. 5 illustrates another embodiment which operates on the same general principle of Fig. 4, and which is more easy to make.

The standard ray counter, which is known as the Geiger-Muller counter, consists of a cylindrical chamber which is provided with a fine axial wire. The cylindrical chamber forms one electrode, and said fine wire forms another electrode. The space between said electrodes is suitably evacuated and said electrodes are maintained at a suitable difference of potential so that the gap between the electrodes is substantially at the discharge potential. When an alpha particle or proton or high-speed electron enters said evacuated gap or space, it produces a number of ions so that an ionization current then passes between said electrodes. This ionization current can be observed with an electrometer. However, said electrometer is an expensive and delicate piece of apparatus and it renders the ionization current visible only to one person. This ionization current does not produce visible flashes of light. Hence, this type of apparatus is not suitable for classroom demonstration. In order to count the passage of the particles with the use of the Geiger-Muller ray counter, it is necessary to use thermionic amplifiers and thyration tubes, which operate the counter mechanically.

These demonstration difficulties are eliminated by the very simple apparatus which I have devised, so that the passage of radio-active radiations can be readily observed by a number of students in a classroom. The radiations of the radio-active material cause the current to pass intermittently through the gap, and each intermittent current pulse produces a visible flash of light. Likewise, since I need not use an evacuated space between the electrodes, I can utilize my improved apparatus in detecting various gases in the atmosphere, in mines, submarines, etc., because the permeability of a gas to the alpha radiations is in proportion to the square root of the respective atomic weight or molecular weight. The permeability is less in gases of high atomic or molecular weight. Therefore, gases like nitrogen and chlorine and methane are less permeable to said radiations than hydrogen.

Fig. 1 shows a rigid metal base electrode 1, to which insulating supports 2 and 3 are fixed. A wire electrode 4 is fixed to said insulating supports 2 and 3. The wire electrode 4 is of small diameter. Said electrode 4 is parallel to the adjacent planar face 1a of the base electrode 1.

The wire electrode 4 is preferably cylindrical. The face 1a may be cylindrical instead of being planar. In such case, said face 1a is equidistant from the wire electrode 4. It is preferable to utilize a planar face 1a. Instead of using a single wire electrode 4, I can use two or more such wire electrodes, whose axes are in the same plane, which is parallel to the planar face 1a.

Hence whenever I refer to an electrode 4, I include the use of a plurality of such electrodes. The same applies to the wire electrodes 4a which are later mentioned herein. For convenience, it is assumed that the planar face 1a is horizontal, and that wire electrode 4 is located vertically above said face 1a. The height of the gap 11 between the wire electrode 4 and the face 1a may be any desired height. As an example, the height of such gap 11 may be from 2–3 millimeters.

The radio-active material can be located upon a suitable carrier C whose vertical distance above the wire electrode 4 can be adjusted either manually or automatically. The apparatus can be located in the open air, which can be of normal humidity and an ordinary temperature of 15° C. and under normal pressure of 760 millimeters of mercury. The apparatus may be enclosed in an ordinary glass vessel which is filled with air under said normal pressure and humidity and at said normal temperature.

The wire electrode 4 is connected to a terminal 6 of a source of current 5, whose other terminal 7 is connected to electrode 1 through resistor 8. The source of current 5 may be a source of direct current, whose terminal voltage can be 1000 volts to 15,000 volts. I prefer to use a source of direct current, whose voltage is constant or approximately constant. Said source 5 can consist of a number of batteries which are connected in series. The terminal 6 is preferably the positive terminal, although the fine wire electrode 4 can be connected to the negative terminal of source 5. The resistance of resistor 8 may be 10–100 megohms. Whenever any figures are given as an example, the invention is not limited thereto.

A practical embodiment of Fig. 1 is described as follows:

The electrode 1 is made of highly polished brass. Its substantially planar face 1a has a length of about three inches and a width of about two inches. Its face 1a may be convex at its ends, directly below the ends of the fine electrodes 4, in order to prevent flashing at the ends of electrodes 4. Eight wire electrodes 4 are used. Each electrode 4 is a solid cylindrical tungsten wire, whose diameter is about two millimeters. The invention is not restricted to wire electrodes of such diameter, because such diameter is preferably much less, as little as 0.2 millimeter. Each wire electrode 4 is separated from the next adjacent wire electrode 4, by a horizontal gap of about five millimeters. All the wire electrodes 4 are connected to the positive terminal of a source of direct current, of 5,000 volts. The height of gap 11 is 2–3 millimeters.

Such a device was operated with "radium C," a layer of which was located on a carrier C. This carrier C was held vertically above the wire electrodes 4. This device was operated in air at about 15° C., and at normal pressure of about 760 millimeters of mercury. When the vertical distance of said "radium C," above the wire electrodes 4, was 7 centimeters or less, flashes were observed across gap 11, between wire electrodes 4 and electrode 1. These flashes succeeded each other in rapid succession, with only one flash at a time. As the vertical distance between the radio-active material and the wire electrode 4 is decreased, the length of the wire electrode along which the successive flashes take place, is increased. It is well-known that when alpha rays or particles travel through air at atmospheric pressure, said particles are slowed down, until they no longer can produce ionization. In air at normal atmospheric pressure, the maximum range at which the alpha particles can produce ionization, is much less than the length of the wire electrodes. When the vertical distance between the radio-active material and the wire electrode is decreased to a certain minimum, further decrease of said distance does not increase the sparking range along the wire electrode. However, it is a feature of my invention, that I use a wire electrode, instead of a small ball electrode, and that the wire electrode is located between the radio-active material and the auxiliary electrode 1. By locating the radio-active material sufficiently close to the wire electrode, I secure visible sparking along any point of a substantial distance along the length of the wire electrode, depending upon the range at which the alpha rays can produce ionization in the respective gaseous atmosphere. The length of the wire electrode exceeds its diameter. The length of said wire electrode is at least equal to the range of the alpha rays, in the particular gaseous medium.

As an optional element, electrodes 4 can be connected to one terminal of a condenser 60, whose other terminal is connected to electrode 1. The capacity of condenser 60 may be varied. It may be 500 centimeters. Capacity can be stated either in farads as an electromagnetic unit, or in centimeters as an electrostatic unit. One farad equals $9(10)^{11}$ centimeters. Hence a capacity of 500 centimeters equals about 55 $(10)^{-11}$ farads, or about 0.00055 microfarad.

Each flash results from the ionization of the air, directly adjacent a wire electrode 4, by an alpha ray or ionizing particle.

If the condenser 60 is used, it is alternately charged and discharged.

The flashes of light can be readily seen even in daylight, at a distance of several meters, so that it is unnecessary to use a separate source of light in order to provide a visual indication of the respective paths of the alpha rays.

It is not necessary to locate the carrier C, vertically above the wire electrode 4, as long as the alpha rays are free to strike the wire electrode. The carrier C can be located at the level of the wire electrode 4. The important factor is the distance between the radio-active material and the wire electrode 4. If the pressure of the air is greater than the normal pressure of 760 millimeters of mercury, the permeability of the air to the alpha particles is decreased. Hence, using the same radio-active material, it is necessary to locate said radio-active material more closely to the electrode or wire electrodes 4 in order to secure flashes, as the barometric pressure increases. Hence, when the flashes of light begin to take place, the distance of the radio-active material from the wire electrodes 4 can be observed, thus giving an indication of the pressure of the air. The same applies generally to gases, mixtures of gases, vapors, etc. Hence, if it is desired to secure a continuous series of successive flashes of light at respective points of said

gap, the distance of the radio-active material from the wire electrodes 4 must be adjusted, either manually or automatically.

If the radio-active material is polonium, the distance of said polonium from the wire electrodes 4 should be at least about 4 centimeters, in order to secure successive flashes in said gap, if this gap is an air gap under said normal conditions. In the case of "uranium I" the distance is at least about 3.2 centimeters, and in the case of thorium C', the distance is at least about 8.4 centimeters.

Fig. 2 shows two electrodes or two sets of parallel wire electrodes 4 and 4a, which have an intermediate parallel electrode member 9, which is made of thin gold foil. Said gold electrode member 9 is preferably planar and equidistant from the wire electrodes 4 and 4a, whose longitudinal axes are parallel to each other, thus providing gaps 11 and 12 of equal width between the intermediate planar electrode 9, and the wire electrodes 4 and 4a.

The positive terminal 6 is connected to the wire electrodes 4 and 4a through respective resistances 8 and 8a, the value of each said resistance being 10–100 megohms. The gold foil electrode 9 is connected to the negative terminal 7. The thickness of the foil electrode 9 is such that it has the same power to stop the alpha radiations as one millimeter of air at normal pressure. This thickness may be greater or less, if desired.

The wire electrodes 4 and 4a are of the same type as in the preceding example. The circuit of the wire electrodes 4 includes the primary coil 10 of a step-down transformer, which has a secondary coil 11a, which is connected to a relay R. This relay R may be of any conventional type, such as the type which is known as "Weston Miniature 634," which is responsive to very small currents, and which operates a mechanical switch for opening or closing a local circuit.

In order to conventionally illustrate the action of said relay R, I have diagrammatically shown the relay armature 52, which is biased away from the contact point 54 by the tension spring 53. The counter 50 has a local battery 51, whose circuit is closed to operate the counter 50 when relay R is energized so that armature 52 touches its contact point 54. In order to make the device even more sensitive, I can use a plurality of relays R, each relay controlling the local circuit of the next suceeding relay, and the last relay controlling the local circuit of the counter. The relay R will receive successive intermittent electrical pulses, so that the circuit of the counter 50 will be intermittently closed and opened. The counter 50 may be of the type knwon as "Genco counter," and its local battery 51 may have a voltage of 50–100 volts. The relay R can be of the type which can be operated by a pulse of alternating current. The embodiment of Fig. 2 has two condensers 60. Said plurality of condensers 60 has the same action as the single condenser 60 of Fig. 1.

In the embodiment of Fig. 2, if the radio-active material, which is located above the wire electrodes 4, as in Fig. 1, is located sufficiently close to the gold foil electrode 9, the alpha radiations will pass through said gold foil electrode 9, thus equally ionizing the respective equal gaps 11 and 12 between the gold foil electrode 9 and the wire electrodes 4 and 4a, so that there will be equal discharges of electrical energy through said respective gaps 11 and 12. This can be observed by the flashes of light across said gaps 11 and 12, said flashes of light being produced by the electrical discharges at the points where the ionizable material in said gaps conducts the electric current. If the radio-active material is sufficiently vertically spaced from the gold foil electrode 9 so that the gap 12 is not ionized, flashes of light will be observed across the gap 11, and no flashes of light will be observed across the gap 12. By using a sufficiently high source of potential 5, as high as 5,000 volts and even more, sufficient energy is delivered to the relay R by the secondary coil 11a, in order to eliminate the necessity of using electronic tube amplifiers and thyratron tubes. The difference of potential which is imposed upon the electrodes of a gap is below the break-down voltage of the gap. There may be a substantial difference between the applied voltage and the break-down voltage, and such difference may be several hundred volts, so that the device operates reliably, even if the voltage of source 5 varies. Instead of using an electrode 9 which is made of gold foil, I can use any conductive material, such as aluminum which is permeable to the alpha radiations or ionizing particles. The coils of the step-down transformer 10—11a have a ratio of about 5 to 1, so that the number of turns in the secondary coil 11a is about 20% of the number of turns in the primary coil 10. Said coils 10 and 11a are closely coupled. I can use the same type of mechanical counter which is now used in the Geiger-Muller system.

The embodiment of Fig. 3 is the same as that of Fig. 1, save that the circuit of the electrode 1 includes the primary coil 10, which is inductively coupled to the secondary coil 11a, these features being the same in Fig. 2. The transformer is also of the step-down type, so that the number of turns in the secondary coil 11a is about 20% of the number of turns in the primary coil 10.

The embodiment of Fig. 4 is similar to that of Fig. 2 in having two sets of wire electrodes 4 and 4a and the intermediate thin electrode 9, thus providing equal gaps 11 and 12.

The positive terminal 6 of the source of electric current 5, which may deliver a unidirectional voltage of 1000–15,000 volts, is connected to the wire electrode or electrodes 4 and 4a through the equal resistors 8 and 8a, as in Fig. 2. The circuit of the wire electrode or electrodes 4 includes a primary coil 16, and the circuit of the wire electrode or electrodes 4a includes another primary coil 17. The primary coil 16 is associated with a secondary coil 18, and the primary coil 17 is associated with a secondary coil 19. The two transformers thus provided are step-down transformers, in which the ratio between the respective primary and secondary coils of each transformer is the ratio which has previously been stated. The coils 18 and 19 are connected to respective ends of the coil of the relay R. The coils 18 and 19 are wound so that their induced secondary voltages are opposed to each other. That is, if the end 18a of the secondary coil 18 is positive during the respective half cycle, then the end 19a of the secondary coil 19 is also positive during said half cycle. Therefore, when the secondary coil 18 urges current to flow through the coil of the relay R in the direction of the arrow 20, the secondary coil 19 will urge current to flow through said coil of relay R, in the direction of the opposed arrow 21. Hence, when the gaps 11 and 12 are equally ionized, the relay R will not be operated because the ends of its coil will be connected to equal and opposed voltages.

If methane or chlorine, either pure or intermixed with other gases, is located in any of the gaps of any of the embodiments, this can be de-

tected by the maximum distance between the carrier C and the electrode or electrodes 4, which is necessary to produce ionization and discharge. For example, it can be assumed that the carrier C is located sufficiently close to the electrode or electrodes 4, in the embodiment of Figs. 1 and 3, in order to secure discharges of electrical energy which can be observed either visually or by the mechanical counter and that the respective gap then contains air under normal conditions. If even a small quantity of methane or chlorine is intermixed with the air in said gap, this will be manifested by the cessation of the electrical discharges, due to the smaller permeability to the radio-active radiations of methane and chlorine, as compared with the permeability of nitrogen. The amount of electrical energy which is utilized in the discharges can be limited by using high resistance in the circuit, so that the electrical discharges will not produce an explosion. Therefore, if the presence of methane or other dangerous gases is suspected in a mine, the test can be made directly in the mine, or a sample of the suspected mixture of gases can be tested outside of the mine. This can be done by approaching the carrier to the wire electrodes 4 until flashing is observed, and then measuring the distance between carrier C and the wire electrodes 4. By enclosing the device in a suitable casing, the danger of explosion can be further minimized. The apparatus is also valuable in detecting the presence of small proportions of chlorine in submarines and for many other purposes.

In the practical apparatus which I have operated and which is shown more particularly in Fig. 1, the voltage of the source of direct current 5 was 5000 volts. While using "radium C" as a radio-active material, and while observing continuous successive sparks, the consumption of energy was extremely small.

The source of current 5 can be connected to the wire electrode or electrodes 4 or 4a at any part thereof, instead of at the end or ends thereof.

When I refer to an ionizable gas, I include an ionizable vapor, mixtures of gases and/or vapors. Likewise, I do not limit the use of the apparatus to any particular temperature or pressure, as long as the ionization current is sufficient to produce visible flashes of light or to operate a relay of the mechanical type, thus eliminating thermionic amplifying systems, the use of an electrometer, and other delicate and expensive parts.

The improved method and apparatus can thus be used for a delicate qualitative or quantitative determination of the presence of various gases and vapors, because the minimum distance between the radio-active material and the wire electrodes, which is necessary to secure flashes, depends upon the square root of the molecular or atomic weight of the gas and the percentage of such gas in the gap.

In the embodiment of Fig. 5, a wire electrode 4 is located between an electrode 1 and an electrode 9. The carrier C is located vertically above the vertically superposed electrodes 1, 4, and 9. The electrode 9 is a planar gold foil electrode. When the radio-active material is sufficiently close to the gold foil electrode 9, the alpha rays will penetrate said electrode 9, to ionize the air directly adjacent the wire electrode 4. The wire electrode 4 is connected to the positive terminal of the source 5 and the brass plate 1 and the gold foil electrode 9 are connected to the negative terminal. The connections in Fig. 5 are not shown, as they are exactly the same as in Fig. 4, with the same effect as if the wire electrode 4 of Fig. 5 replaced the electrode 9 of Fig. 4, the electrode 9 of Fig. 5 replaced the electrode 4 of Fig. 4, and the electrode 1 of Fig. 5 replaced the electrode 4a of Fig. 4.

Whenever I refer to the use of a radio-active radiation in a claim, I include rays which have the same high ionizing power, such as canal rays or recoil atoms produced by neutrons in metal or gases.

The electrode 9 is designated as the shielding electrode, because it shields one or both of the other electrodes 4a or 1 from the radiations, unless said radiations penetrate said shielding electrode. The area of said shielding electrode is sufficiently large to produce said shielding effect.

Another method of determining the presence of a gas, is by determining the break-down voltage of a gap in which said gas is located, which is required to produce the desired pulses of ionization current, when the radio-active material is held at a specified distance from the electrode or electrodes at which the ionization is initiated. For example, it can be assumed that the pulses of ionization current start in the apparatus of Fig. 1, when the "radium C" is located at seven centimeters from electrode 4, when the applied voltage to the gap 11 of Fig. 1 is 5,000 volts, and said gap is filled with air at normal temperature and humidity and pressure. If methane is introduced into said gap 11, so that said gap is filled with pure methane, or a mixture of methane and air, a different break-down voltage will be operative. The break-down voltage will be above or below 5,000 volts, depending upon the gas or mixture of gases in said gap 11.

When the ionization current pulses are produced in an atmosphere of oxygen, there is a substantial generation of ozone. Hence the device can be used for purifying the atmosphere, or whenever it is desired to produce ozone for any purpose. The same effect can be used on gases other than oxygen. The current consumption is small, so that the device is not dangerous.

The energy of each flash is about 10^5 ergs, or .01 joule. This is sufficient to produce visible flashes or to operate a sensitive mechanical relay.

It is well-known that in electrical conduction through gases, using a cold cathode which does not emit electrons, there is an initial range in which an increase in voltage does not produce an increase in current. The current in this range is sometimes designated as the "dark current" because it is not accompanied by appreciable emission of light. In this initial range, residual ions are removed from the gas. This dark current is usually of the order of a microampere. Since the energy of each flash has the value of about 0.01 joule, this shows that the current is dependent wholly upon the ionization which is produced by the radio-active material, without any emission of electrons from the cathode. That is, I increase the current above the dark range, in order to secure visible flashes, solely by supplying ions by means of the radio-active material, thus preventing a continuous discharge between the electrodes.

I claim:

1. A device for detecting and counting the ionizing radiations of radio-active material, said device comprising a first electrode, a second electrode, and a third electrode which is located between the first electrode and the second electrode, a mass of radio-active material, one of said elec-

trodes being a shielding electrode, said shielding electrode being located between said mass and at least one of the other electrodes, said shielding electrode being permeable to said radiations, said shielding electrode being shaped and located to stop said radiations unless said radiations exceed a predetermined intensity, the gaps between said electrodes having ionizable gas, the electrodes of each gap being respectively connected to the opposed terminals of a source of electric current whose voltage is less than the respective discharge voltages of said gaps when the gas in said gaps is non-ionized, a relay which has a coil, the coil of said relay being coupled at its ends to the respective circuits of said gaps, said respective circuits applying opposed voltages to said coil, so that said relay will remain inoperative if equal voltages are applied, by said respective circuits to said coil.

2. A device according to claim 1, in which said shielding electrode is located between said mass and the other two electrodes.

3. A device for detecting and counting the ionizing radiations of radio-active material, said device comprising a first electrode of substantially cylindrical shape, an auxiliary electrode which is spaced from said first electrode by an intermediate gap in which an ionizable gaseous medium is located, said gap being of substantially constant width, said electrodes being respectively connected to the respective terminals of a source of electric current, the voltage of said source being less than the discharge voltage across said gap when said gaseous medium is non-ionized, a mass of radio-active material located to ionize said gaseous medium directly adjacent said first electrode, to cause the discharge of current from said source across said gap only in the form of successive respective separated flashes, said mass being closer to said first electrode than to said second electrode, said source having sufficient voltage and said gaseous medium having sufficient density and said gap having sufficient width to produce successive and intermittent visible flashes, the energy of each said discharge being at least about 0.01 joule, the length of said wire electrode being at least approximately equal to the maximum range at which said mass can produce ionization in said gaseous medium, the voltage of said source being sufficiently low to prevent any discharge across said gap when said gaseous medium is thus ionized, with the exception of separated flashes which correspond to respective successive ionizing radiations of said mass.

4. A device according to claim 3, in which said first electrode is located between said mass and said auxiliary electrode.

5. A device according to claim 3, in which the pressure of said gaseous medium is substantially 760 mm. of mercury.

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