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[33] **France**

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[56] **References Cited**

UNITED STATES PATENTS

3,337,733 8/1967 Charpak et al. 250/83.6

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[54] GAS-FILLED SPARK CHAMBER RADIATION DETECTOR

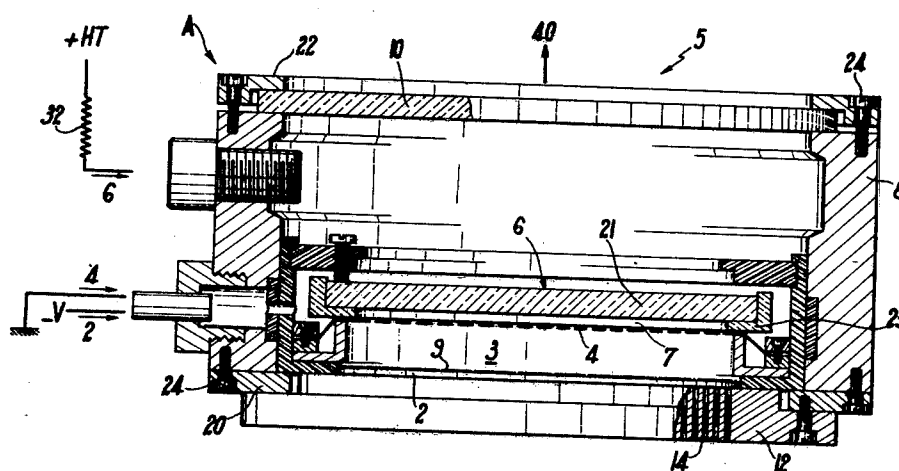
8 Claims, 1 Drawing Fig.

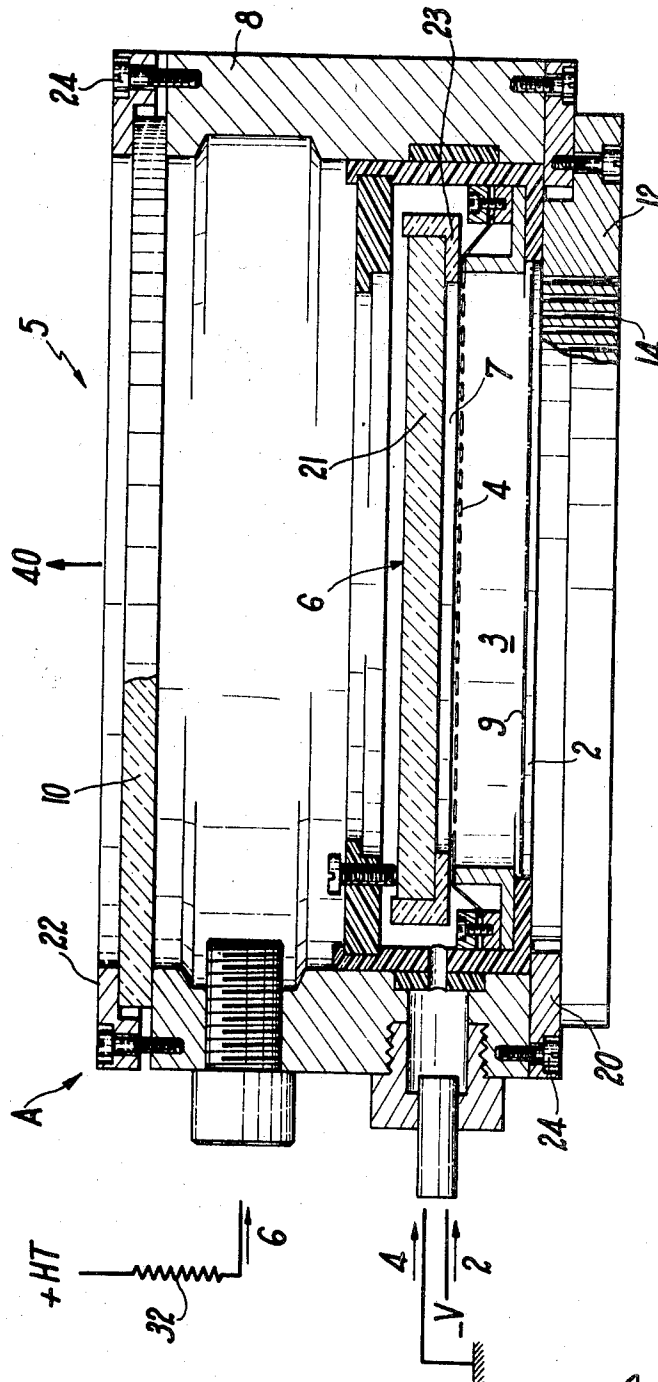
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ABSTRACT: The invention proposes a particle detector comprising a gas-filled chamber in which are disposed an anode and a cathode separated by a grid, these three electrodes being parallel and the gap between the grid and the cathode being of sufficient width for the type of incident radiation. The filling gas is selected in order to ensure that a high proportion of the β radiation which constitutes the incident particles or which is induced by incident particles at the cathode and/or within said gap loses the larger part of its energy by the usual ionization process which results in the release of electrons, said detector further comprising means for establishing between the anode and the grid a potential difference which is slightly smaller than the breakdown voltage and between the cathode and the grid a voltage for collecting said electrons towards the grid-anode gap, said collection voltage being sufficiently low and the mesh of the grid being sufficiently large to ensure that only a negligible proportion of electrons is collected by the grid as said electrons pass through said grid.





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GAS-FILLED SPARK CHAMBER RADIATION DETECTOR

This is the continuation in part of application No. 447,675 filed on Apr. 13, 1965 in respect of: "Particle detector."

The present invention is concerned with particle detectors which are intended especially for the purpose of observing the impact of particles and X-ray or γ -ray photons on such detectors. The invention is particularly directed to a detector of the type known as a "spark chamber," wherein visual detection of an ionizing particle is made possible by producing an avalanche or a spark discharge between two electrodes at the point of impact of the particle.

Spark chambers of conventional design consist of a gas-filled chamber fitted with parallel electrodes between which a voltage is continuously applied for the purpose of scanning the ions produced by the particles. There is associated with said chamber a detector telescope wherein the coincidence of operation which corresponds to the passage of a particle through the chamber has the effect of applying a voltage pulse to the electrodes and igniting a spark along the path which is ionized by the passage of the particle.

A first improvement to the method employed in this conventional arrangement forms the subject matter of the U.S. Pat. No. 3,373,283 filed in the name of Commissariat a l'Energie Atomique and entitled "Method and device for triggering a gas detector which permits the localization of nuclear particles". In the application which is cited, it is disclosed that, on the one hand, the value of the direct-current voltage which is applied between the cathode and anode of the spark chamber is chosen with a view to ensuring that the number of electrons produced within the cathode-anode space of the detector as the result of the passage of a charged particle is increased according to the process which is commonly referred to as electron multiplication and which does not result in the production of a spark but results in the appearance of an electron pulse at one of the electrodes of the detector and that, on the other hand, there is applied between the cathode and the anode with a suitably chosen time lag with respect to this electron pulse a high-voltage pulse which has the effect of initiating a spark between cathode and anode, said spark being localized on the path of the electrons which have produced the electron pulse. The patent application referred to also describes a detector for the practical application of the method.

The present invention is directed to a particle detector of improved design compared with the detector which is described in the above-cited application, insofar as it offers greater simplicity of design, especially of the associated circuits, and at the same time ensures reliable operation as well as at least equivalent efficiency.

To this end, the invention proposes a particle detector comprising a gas-filled chamber in which are disposed an anode and a cathode separated by a grid, these three electrodes being parallel and the gap between the grid and the cathode being of sufficient width for the type of incident radiation. The filling gas is selected in order to ensure that a high proportion of the β radiation which constitutes the incident particles or which is induced by incident particles at the cathode and/or within said gap loses the larger part of its energy by the usual ionization process which results in the release of electrons, said detector further comprising means for establishing between the anode and the grid a potential difference which is slightly smaller than the breakdown voltage and between the cathode and the grid a voltage for collecting said electrons towards the grid-anode gap, said collection voltage being sufficiently low and the mesh of the grid being sufficiently large to ensure that only a negligible proportion of electrons is collected by the grid as said electrons pass through said grid.

In a preferred embodiment of the invention in which use is made of a grid having a lattice pitch of 75 microns and consisting of wires 30 microns in diameter, the collection voltage has a value such that the electric field established within the gap between the cathode and the grid is in the range of 10 to 100 volts per centimeter, the gas which is present within the chamber being at atmospheric pressure.

The invention is also concerned with the composition of the filling-gas mixture which comprises an inert gas and an organic vapor.

It will be noted that the detector of the invention is essentially constituted by a chamber which is filled with the above mixture and in which are formed two geometrical spaces or "gaps" limited by flat and parallel electrodes, viz: a detection gap which is defined between a cathode and a grid in which a fairly weak electric field is established and in which the radiation is detected mainly by photoelectric effect on the gas atoms, and an electron-multiplication gap between the grid and an anode in which a strong electric field is established.

By virtue of the transparency to electrons exhibited by the grid which forms a separation between the detection gap and the multiplication gap, an electron avalanche which can result in a localized spark discharge is produced immediately above the ionized track of each primary photoelectron.

Images of a radioactive source cannot be obtained if the detector is filled with an inert gas. On the other hand, if there is added a suitable quantity of organic vapor which absorbs the ultraviolet radiations emitted by the gas, discharges and in particular spark discharges corresponding to the source image can be produced on condition that the value of the grid-anode voltage is judiciously determined.

Further consideration will now be given to the triggering process which results in the appearance of discharges. When X-ray or γ -ray photons are transmitted and reach the cathode, they give rise to primary ionizing electrons between the cathode and the grid. The secondary electrons which are produced pass through the grid and penetrate into the field which exists between this electrode and the anode, said field being of substantially greater density than the field which exists between the cathode and the grid. In this multiplication gap, the electrons initiate a process of cumulative ionization or electron avalanche which finally results in the formation of a spark.

Molecules of organic vapor are destroyed each time a particle is detected by the detector. But the production of sparks results in much greater destruction of these molecules and consequently in a limitation of the service life of particle detectors which operate in the spark discharge condition.

It has also been proposed that the gas detector of the type hereinabove described should be utilized for the production of images caused by the formation of electron avalanches with a view primarily to removing the limitation of service life to which gas detectors have been subject heretofore in the type of operation referred to in the foregoing. This form of utilization has already been disclosed in U.S. patent application No. 595,714 now U.S. Pat. No. 3,449,573 as filed by the present Applicant on Nov. 21, 1966 in respect of "Image-amplifying gas detector".

A number of different gas mixtures have already been employed for the purpose of filling a gas detector of this type.

The atmosphere employed at the outset consisted of a mixture of argon and methane but has been replaced by the combination of xenon and methylal. A particle detector which makes use of the second mixture referred to has a counter plateau and makes it possible to obtain in the electron avalanche condition well-contrasted images in which the useful image components can readily be distinguished from the background components. The operating voltage is of a relatively high order.

The present Applicant has found that a counter plateau could be obtained at a lower operating voltage by means of a novel mixture.

The present invention also proposes the use of this novel filling gas at predetermined partial pressures.

A particle detector in accordance with the invention can operate either in the spark discharge condition or in the electron avalanches condition and is characterized in that the filling-gas mixture comprises xenon and diethylamine.

Satisfactory conditions of utilization of this mixture correspond to partial pressures of these gases, the sum of which is in the vicinity of 760 torrs (mm. of mercury).

The partial pressures of the gases employed can vary according to the types of operation of the detector. Thus, the partial pressure of diethylamine is preferably within the range of 8 to 50 torr.

The invention also consists of other arrangements which can advantageously be employed in conjunction with the preceding but which can also be employed independently. All of these arrangements will become more readily apparent from the following description of a preferred embodiment of the invention which is given by way of nonlimitative example.

The description relates to the single figure of the accompanying drawings which shows a detector in accordance with the invention, said detector being represented diagrammatically in cross section on a plane which passes through its axis, as well as the electric circuits which are associated therewith.

The detector proper comprises a leaktight chamber formed of a cylindrical glass casing 8, the top end of which is closed by a transparent glass plate 10 and the bottom end of which is closed by a thin metallic cathode 2. When the detector is intended for the study of the soft γ -radiation of a sample which is placed beneath the cathode, said cathode can consist of a strip 9 of "mylar" 0.5 mm. in thickness and lined internally with aluminum foil 10 to 20 microns in thickness which constitutes the electron source. The "mylar" strip 9 and cathode 2 are supported by a plate 12 which is located outside the chamber and through which are formed closely spaced parallel passages such as the passage 14. Said plate can perform the function of collimator, as will be explained hereinafter.

The leak-tightness of the joints between the tube 8 on the one hand and the cathode 2 and glass plate 10 on the other hand as well as the rigidity of the assembly are ensured by means of two washers 20 and 22 joined to the glass casing 8 by clamping bolts 24 which are spaced around the detector.

A grid 4 and an anode 6 are placed within the chamber above the cathode 2 and parallel to this latter. These two electrodes can consist, for example, of a grid constructed of phosphor bronze wire 35 microns in diameter and forming a square lattice having a pitch of 75 microns. The grid 4 forms with the cathode 2 a collection gap or detection space whilst the grid and the anode define a spark gap or multiplication space.

In the case which is illustrated in the drawings, the anode is made up of a disc 21 of conductive glass which is supported by a metallic ring 23.

The chamber is filled with a gas which is intended to be ionized by the passage of particles. For the detection of soft photons, it is possible in particular to employ a mixture of 90 percent argon and 10 percent methane under atmospheric pressure. An orifice 26 is provided for the purpose of modifying the atmosphere of the chamber as may be required.

The grid being connected to ground, the anode is connected to a positive high-voltage source by means of a lead-wire 32 which comprises a high-resistance resistor. The cathode is brought to a negative direct-current polarizing voltage. The high voltage is slightly lower (by 100 to 150 v.) than the breakdown voltage.

The arrangement which has been described thus far is comparable with that of the detector according to the patent application which has been cited earlier. However, it should be noted that, on the one hand, no provision is made between the grid and the anode for a circuit which produces high-voltage pulses and that, on the other hand, the polarizing voltage of the grid with respect to the cathode has a lower value. The present inventors have in fact found that, for an optimum value of the electric field within the detection gap, the passage of electrons within the multiplication gap is assisted and sparks are accordingly produced spontaneously without any need to apply a pulse.

An attempt can be made to explain the reason for this condition of operation, although it will be understood that the following explanation is largely conjectural and has no incidence on this patent. It can be assumed that the spark is triggered by the arrival of a number of electrons which is higher than a

minimum value within the multiplication gap (that is to say, the grid-anode space). If a high polarizing voltage is applied between the grid 4 and the cathode 2, a substantial proportion of the electrons produced within the collection gap is captured by the grid 4 as a result of the high electric field and the number of electrons penetrating within the multiplication gap is smaller than the minimum value, with the result that no spark is produced. If the polarizing voltage is lowered, thereby reducing the strength of the field produced within the collection gap, the capture of electrons by the grid 28 is reduced and the number of electrons penetrating within the spark gap becomes higher than the minimum value, with the result that a spark is produced.

The correct operation of the chamber evidently makes it necessary to ensure that the electric field within the collection gap is restricted to a small domain. In fact, if the negative polarizing voltage is too high, the electrons formed within the collection gap will be absorbed by the grid and the spark output will be low or even zero. If, on the contrary, this voltage is too low, there will be no acceleration of electrons appearing at the time of impact of a particle to be detected.

By way of example, a detector according to the invention was filled with a mixture of 90 percent argon and 10 percent methane at atmospheric pressure and operated at a high voltage of 6,000 v., a cathode polarization voltage of -30 v., a spark or multiplication gap (between grid and anode) of 5 mm. and a collection gap (between cathode and grid) of 10 mm; by way of comparison, the polarizing voltage under operating conditions in accordance with the patent cited earlier was of the order of -300 v.

The operation of the detector when carrying out the γ -scintigraphy of a sample which is placed underneath the plate 12 has become clear from the foregoing description. Photons emitted by the sample in a direction substantially at right angles to the plate 12 pass through the passages 14 of this latter so as to impinge upon the cathode 2 and the atmosphere of the collection and multiplication gap. The absorption of these photons results in the appearance of a β -ray which ionizes the gas. The electrons thus released are accelerated towards the grid 4 and pass into the multiplication gap and initiate a spark if the quantity of electrons is sufficiently large. The sparks produced are recorded by means of a camera 40 which is not illustrated in the figure and which operates with a sufficient time exposure.

The efficiency of the detector depends on a large number of parameters, especially the yield of β -ray photons and on the dead time of the chamber. The dead time varies essentially with the value of the load resistance which is interposed on the lead-wire 32: a resistance of 20 megohms results in a dead time of the order of 50 ms., therefore in a maximum production of sparks at a rate of 20 per second. This rate is usually sufficient since the samples usually constitute low-activity sources.

The lower limit of the load resistance is fixed by the chamber since a spark is liable to be reignited at the same place within the chamber if the voltage is reapplied to the electrodes too soon. The nature of the electrodes and that of the gas have a marked influence on this value.

By way of example, a detector according to the invention has been employed for the purpose of carrying out a γ -scintigraphy of phantoms of elements charged with iodine-125, the X-ray emission of which is carried out at 27.3 Kev.: the theoretical absorption rates are then of the order of 0.64 percent within the detection gap (argon and methane atmosphere), of 0.2 percent in the aluminum cathode and 0.2 percent in the spark gap: the theoretical total absorption rate is then established at approximately 1 percent.

In the case of a phantom having a radioactivity of 100 μ c. which is placed at a distance of 3 cm. from the collimator and a detector which makes use of a resistance of 20 megohms (resulting in the production of 5 sparks per second at a maximum) there have been obtained during a time exposure of a few minutes photographs which could be analyzed with great

ease and which were comparable with those previously obtained from samples having a level of radioactivity which was several times higher.

It will be readily apparent that the composition of the cathode and of the atmosphere of the detector are preferably adapted to the characteristics of the radiation to be detected. The use of xenon instead of methane makes it possible to increase the gas detection efficiency. This efficiency is improved if the pressure is increased. A gold coating on the cathode also serves to increase the efficiency with which X-ray or γ -ray photons are detected by virtue of a wall effect. The use of methylal as organic vapor makes it necessary to produce a field of 20,000 v. cm.⁻¹ within the multiplication gap in order to initiate the production of sparks. The total pressure of the gas mixture is atmospheric pressure.

It is then necessary to make use of high operating voltages corresponding to high energies stored in the grid-anode capacity of the multiplication gap.

This circumstance has induced the present Applicant to seek another organic vapor which also absorbs the ultraviolet rays produced by the avalanches but which plays a more effective part in the ionization of the mixture, an essential requirement being the fact that the ionization potential of said vapor must be lower than the minimum energy of the metastable states of xenon.

Diethylamine (C_2H_5)₂NH satisfies these conditions inasmuch as its ionization potential is 8.02 e.v. whilst the minimum energy of the metastable states of xenon is 8.2 e.v.

After carrying out a large number of tests during which the present Applicant endeavored to obtain localized spark discharges as well as a counter plateau, the optimum partial pressure of the diethylamine was found to be equal to 40 torr, the pressure of the xenon being 720 torr in the case of a multiplication gap of 3.3 mm.

Under these conditions, the counter plateau in the spark discharge condition is obtained in respect of a mean electric field of 13,000 v. cm.⁻¹, which represents a substantial improvement compared with the case of utilization of methylal.

It has already been explained that the partial pressures of the components of the gas mixture employed are determined according to the type of operation and the geometrical characteristics of the chamber.

Whereas the study of a source in the spark discharge condition (a source of iodine-125, for example) has been carried out with the xenon-diethylamine mixture, the partial pressures of the two gases being respectively 720 torr and 40 torr, the study of a source operating in the controlled-avalanche condition (source of iron-55, for example) has also been carried out with the same filling gases and partial pressures of 750 torr and 10 torr.

But in all cases, the simplicity of the device remains re-

markable since only a single high voltage is necessary.

It is apparent that the invention is not limited in any sense to the mode of operation which has been described and illustrated and it will be understood that the scope of this patent extends to alternative forms of either all or a part of the arrangements herein described which remain within the definition of equivalent means.

We claim:

1. A nuclear particle detector for the identification of X-ray, γ -ray and β radiation comprising:
 - an accelerating chamber defined between a cathode and a grid oriented in parallel;
 - a spark chamber defined between said grid and an anode oriented in parallel with said grid;
 - a gas-filled enclosure surrounding said anode, grid and cathode;
 means for imposing an electrical potential between said anode and said grid having a value slightly less than the breakdown voltage of said spark chamber; and
2. means for imposing an electrical potential between said cathode and said grid for accelerating electrons towards said grid; and
 whereby radiation incident upon said cathode will ultimately cause a spark discharge in said spark chamber.
2. A nuclear particle detector as described in claim 1 wherein the potential imposed between the cathode and grid is of a value sufficient to establish an electric field in the range of 10 to 100 volts per centimeter in the acceleration chamber; the gas within said enclosure is argon-methane maintained at atmospheric pressure; and said grid is composed of a lattice of wires having a lattice pitch of approximately 75 microns, said wires having a diameter of one-third to one-half of said pitch.
3. A nuclear particle detector as described in claim 1 wherein said cathode is composed of a thin layer of metal for producing β -ray emission as it absorbs photons.
4. A nuclear particle detector as described in claim 1 wherein the gas within said enclosure is chosen to produce β ray emissions as it absorbs X-ray and γ -radiation.
5. A nuclear particle detector as described in claim 1 wherein a plate having parallel holes therethrough is fixed adjacent to a surface of said enclosure to form a collimator for radiation directed towards said cathode from a sample.
6. A nuclear particle detector as described in claim 1, the enclosure of which is filled with a gas mixture of xenon and diethylamine.
7. A nuclear particle detector as described in claim 6, wherein the pressure of the gas mixture is approximately 760 mm. of mercury.
8. A nuclear particle detector as described in claim 7, wherein the partial pressure of diethylamine is comprised between 8 and 50 mm. of mercury.

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