May 5, 1964 R. C. MAGGIO ETAL 3,132,249

DETECTION, SEGREGATION AND COUNTING OF RADIATIONS OF DIFFERENT ENERGIES

Filed Feb. 16, 1961 4 Sheets-Sheet 1

Fig. 1.

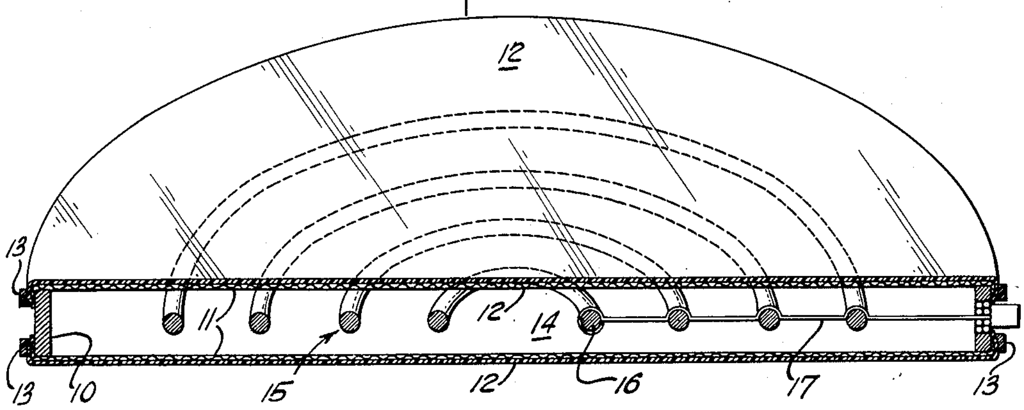


Fig. 2.

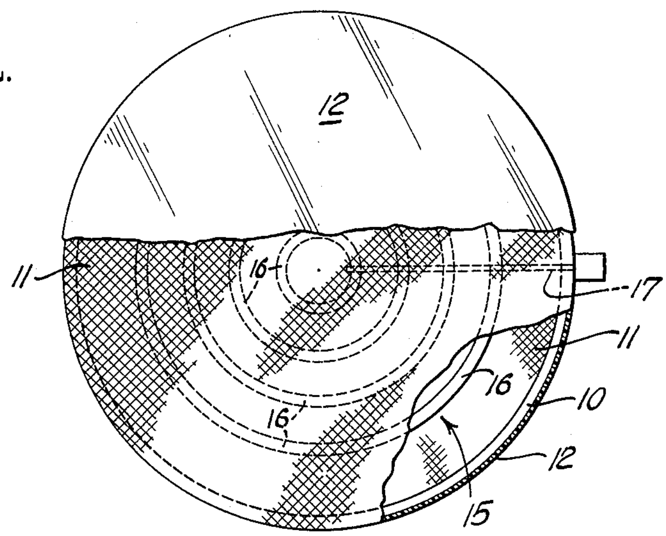
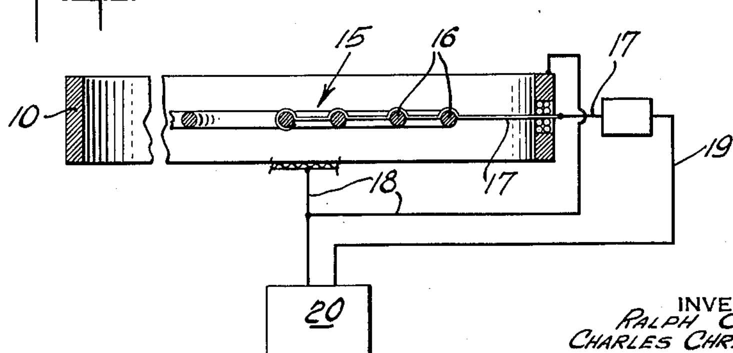


Fig. 3.



INVENTORS:
RALPH C. MAGGIO
CHARLES CHRISTIANSON
BY
Max A. Fearner
ATTORNEY

Fig. 4.

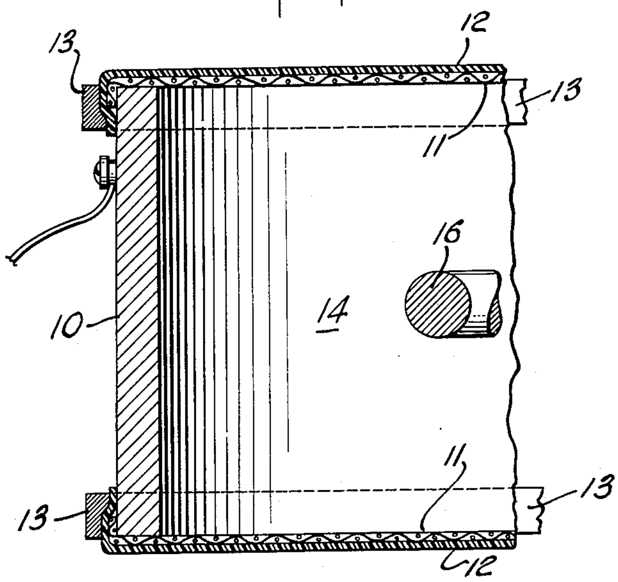


Fig. 5.

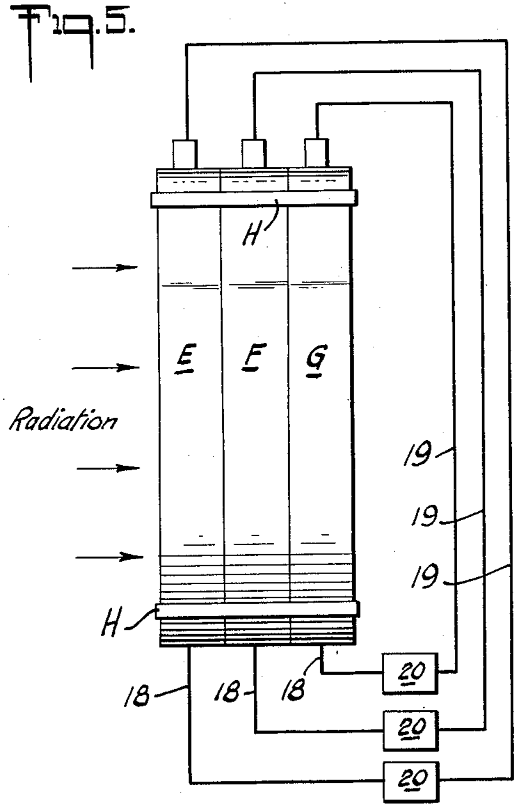
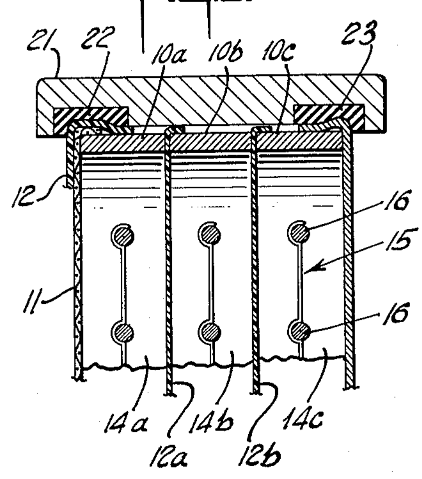


Fig. 6.



INVENTORS:
RALPH C. MAGGIO
CHARLES CHRISTIANSON
BY
Max H. Franner
ATTORNEY

Fig. 7.

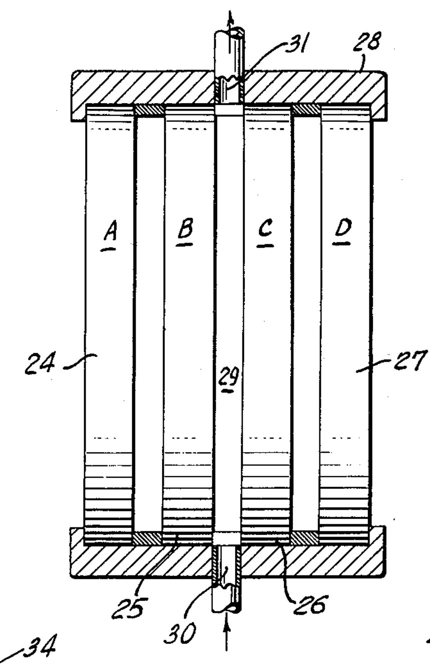


Fig. 8.

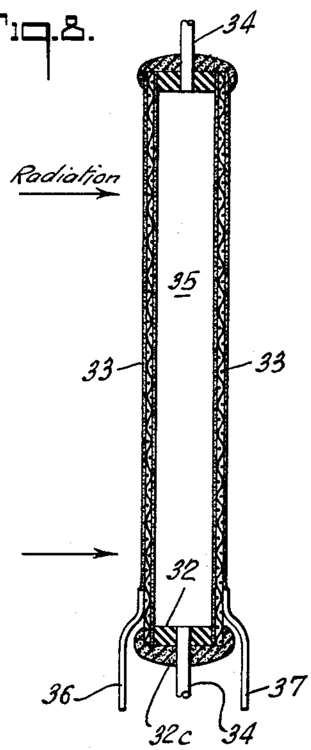
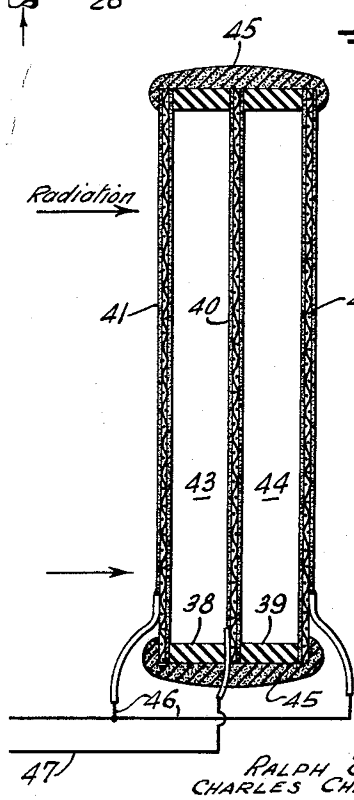


Fig. 9.



INVENTORS
RALPH C. MAGGIO
CHARLES CHRISTIANSON

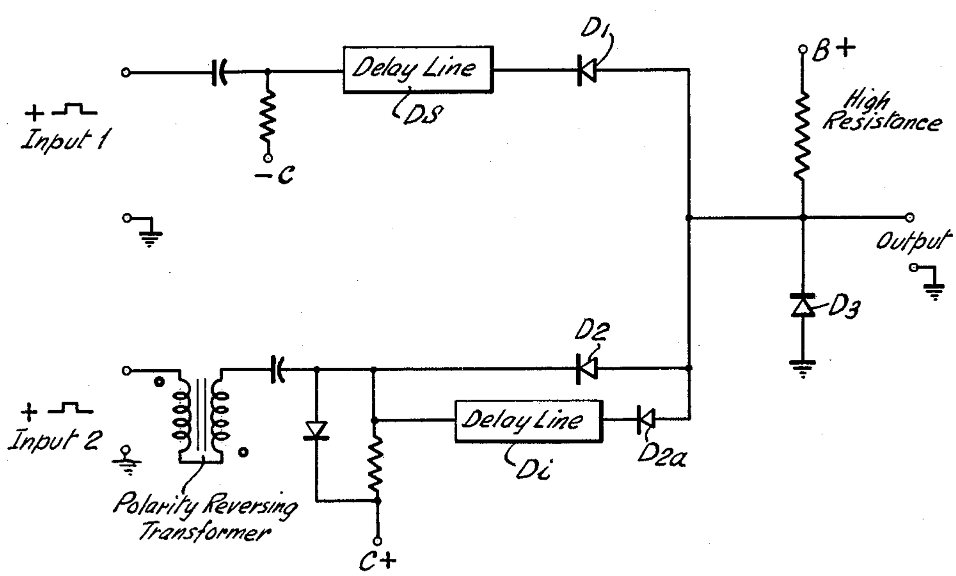
BY

Max D. Farmer

ATTORNEY

Fig. 10.

Anti Coincidence Circuit



Di is greater than Ds to insure overlapping of inhibiter Pulse

INVENTOR.
RALPH C. MAGGIO
CHARLES CHRISTIANSON
BY
Max D. Farmer
ATTORNEY

3,132,249

DETECTION, SEGREGATION AND COUNTING OF RADIATIONS OF DIFFERENT ENERGIES

Ralph C. Maggio, 2175 Hudson Terrace, Fort Lee, N.J., and Charles Christianson, 1192 Walton Ave., Bronx 52, N.Y.

Filed Feb. 16, 1961, Ser. No. 89,889
4 Claims. (Cl. 250—83.6)
(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to the detection and segregation of radiations of different energies from a radioactive specimen to be examined, and particularly to radiation counters of the type wherein ionization of a confined body of a counting gas in an electric field by radiations penetrating said body of counting gas, produces counting pulses in a utilization circuit.

The detection of the presence, in the ambient atmosphere, or in a fluid or in any specimen to be examined, of low energy or soft beta particles or radiations, such as in radioactive hydrogen and compounds of hydrogen, has heretofore been difficult and unsatisfactory, especially in the presence of other radioactive materials and compounds. Prior methods commonly in use for this purpose employed ionization chamber and scintillation crystal techniques. These prior methods had a number of disadvantages including the following:

(*a*) They were not satisfactory for the detection of radioactive hydrogen and compounds of hydrogen particularly in the presence of other radioactive contaminants;

(*b*) The equipment employed was large, bulky and required complex electronics;

(*c*) The ionization chamber was sensitive to variations in temperature, humidity, pressure and aersols (smoke);

(*d*) The scintillation techniques require specially designed photo-multiplier tubes; and

(*e*) The scintillation method was not specific for hydrogen, the material must be prepared in very thin layers to respond to the hydrogen gas, and the method and equipment used required a special design for use with radioactive hydrogen and its compounds, to be operated by highly skilled personnel.

In the detection of radioactivity where there is a mixture of different radiations such as alpha, beta and gamma radiations, the segregation, classification, and counting of the different radiations according to their penetrating energy is often desirable, and even radiations of the same kind may vary in different penetrating power or energy. For example, some beta radiations are of "soft" or low energy, and have low penetrating power, while other beta radiations have much greater energy or higher penetrating power. The beta radiations from radioactive hydrogen and hydrogen compounds, such as tritium oxide, are not only dangerous to humans, but their presence is difficult to detect and the quantity determined by prior detection procedures, especially when other alpha, beta and gamma radiations are also present.

An object of this invention is to provide an improved device for the detection of low energy beta radiations, which may be used singly for low sensitivity or in a stacked array for higher sensitivities, which will be relatively insensitive to ambient temperature, humidity and aerosols, which can be made insensitive to beta particles with energies greater than tritium, and which is relatively simple, practical, convenient and inexpensive.

Another object of the invention is to provide an improved method of and apparatus for detecting the presence of and segregating radiations according to their penetrating power or energy, which will be relatively simple and practical, and capable of being easily manipulated by non-scientific personnel.

Another object is to provide an improved detector for radiations, employing very thin windows made of electrically non-conducting material, and which eliminates any insensitive zones of substantial areas such as are characteristic of GM tubes having electrically non-conducting windows.

Other objects and advantages will be apparent from the following description of some embodiments and examples of the invention, and the novel features will be pointed out in connection with the appended claims,

In the accompanying drawings:

FIG. 1 is a schematic perspective of half of a simple radiation detector, constructed in accordance with this invention,

FIG. 2 is a schematic plan of such a detector;

FIG. 3 is a diagram illustrating the manner of connecting a utilization circuit to such a detector;

FIG. 4 is a sectional elevation, on an enlarged scale, of a part of such a detector;

FIG. 5 is a schematic illustration of a stack of such detectors, and their individual utilization and counting circuits;

FIG. 6 is a sectional elevation of part of a stacked group of radiation detectors constructed in accordance with this invention, but having a common window between adjacent chambers of the stacked array;

FIG. 7 is a schematic elevation, with a confining ring in cross section, of a stacked array of detection chambers, which may be employed in accordance with this invention in detecting the presence of low energy radiations in a fluid to be examined;

FIG. 8 is a sectional elevation of a simple radiation detection device in which the cathode and anode elements are different in construction and arrangement than in the embodiment shown in FIGS. 1 and 2;

FIG. 9 is a sectional elevation of another embodiment of single, radiation detection device, employing a modified anode and cathode arrangement and construction; and

FIG. 10 is a diagram of an anti-coincidence circuit that may be employed in connection with the embodiment of FIG. 7.

In the embodiment of the invention illustrated in FIGS. 1–4, the detector is of pancake shape, and cylindrical with a very short axial length. It has a peripheral, annular, metallic cathode **10**, and a fine wire, mesh screen **11** is disposed across and covers each end face of the annular cathode **10**. Superposed on the outside face of each screen **11** and also covering each end face of the cathode ring is a film **12** of an electrically non-conducting material that is impervious to the passage through it of fluids, but is thin enough to pass through it any incident radiation from a radioactive material whose radiations it is desired to detect, classify, or segregate. The thickness of such a film should not exceed approximately 30 micrograms per square centimeter. Films or walls of the desired thinness so as to freely pass desired radiations usually are so weak mechanically for areas of desired size, that they are easily ruptured or broken. For this reason, the fine wire, mesh screen **11** serves to support the very thin film against rupture and enables one to use films of quite large face areas successfully. Mica is used quite extensively as a film-like wall and can be made extremely thin, but with this construction using the screen to support such a film, it is now possible to use extremely thin films of various electrically non-conducting materials such as films of mica and synthetic plastics. An example of such plastics suitable for films is an air-dry lacquer enamel formed of netrocellulose containing varying amounts of hard gums and alkyds, which can be formed into films by sprays or dips, such as is sold under the trade mark "Zapon." Another example of a film material which has been found to be particularly useful and practical for this purpose is a film of polyester material such as is sold under the trademark "Mylar" by DuPont Co. Such polyester films are commercially available in the market in thicknesses varying from .00025" to .0075" and their properties are described in detail in a bulletin published by Insulation Manufacturers Corporation having an office at 565 West Washington Blvd., Chicago 6, Illinois, and copyrighted in 1953 by that corporation. Such films are also disclosed in a bulletin A-530 (September 1955) of E. I. DuPont de Nemours & Co. (Inc.) of Wilmington, Delaware. Films of fluorocarbon polymer dispersions are also suitable for this purpose. One such polymer is tetrafluoroethylene resin. Any synthetic plastic material that can be made into very thin, fluid impervious films can be employed. The polyester films are particularly useful for this purpose because they are relatively strong against rupture even in very thin films. Films of nylon and cellulose acetate can be made very thin and can be used when supported by the wire screens.

The margins of the screens **11** and films **12** are bent over upon the exterior peripheral surface of the cathode ring and secured thereto by encircling, adjustable confining clamp rings **13** or by suitable cements or adhesives. The cathode ring **10** and the films **12** provide a closed chamber **14** in which, about midway between the film faces, is an anode element **15** of open skeleton shape such as a plurality of concentric metal rings **16** of different diameters, mechanically and electrically connected together and supported by a conductor bar **17** that extends through but is insulated from the cathode ring. This bar **17** is enclosed, after connection to the rings, in an electrically insulating coating of plastic material. The closed chamber **14** containing any suitable counting and quenching gas mixture, such as is commonly used in GM counters and other radiation detectors and counters. The screens **11** may be in contact with the annular cathode ring and, hence, also act as cathode elements. When radiation from a radioactive material penetrates either of the films **12** and enters chamber **14**, it will ionize the counting gas therein if there is an electric field in such chamber. Such a field is created when a substantial voltage differential is established between the anode and cathode elements; such as through connection to the anode and cathode elements of a utilization circuit (FIG. 3) employing wires **18** and **19** connected respectively to the elements **10** and **15**, and including therein means **20** for establishing such voltage differential across the anode and cathode elements and for counting the pulses created in the utilization circuit. This means **20** is commonly used in Geiger counters and other radiation detectors, and hence, is not here illustrated or described in detail. The chamber **14** is filled with the counting gas in any suitable manner, such as is employed to fill other counting chambers of GM tubes with such a gas. For example, the chamber may have spaced apart ports that can be opened and closed to enable the counting gas to be introduced into the chamber and flushout and replace the air previously therein.

In the embodiment illustrated in FIG. 5, a plurality of such detector units, E, F and G, such as are shown in FIGS. 1–4, may be assembled in close proximity to one another in face to face, stacked relation and confined in that face to face relation by any suitable means such as encircling straps H adjustable in encirclement length to confine the units against separation from one another. The anode and cathode of each unit are connected in series in an individual utilization and pulse counting circuit, such as was described in connection with FIG. 3. When radiation, such as alpha, beta and gamma rays, is incident on the exposed face wall of and end cell or unit in the stack, the rays, if able to penetrate into the stack will be segregated and stopped progressively in the units according to their penetrating power. The pulses counted in the different successive, chambers or units will indicate how many radiations of any penetrating range have their energy absorbed and counted in each unit. The low energy beta particles or radiations, such as are emitted from radioactive hydrogen or its compounds, such as tritium oxide, for example, are largely absorbed and counted in the first chamber in the stack, whereas the gamma particles or radiations will pass on through more than one unit and be absorbed and counted in further chambers in the stack, but not counted in the first chamber penetrated.

In the embodiment illustrated in FIG. 6, chambers **14***a*, **14***b* and **14***c* are similar to the chamber **14** of FIGS. 1–4, except that they have a common film face wall between adjacent chambers. In this example, a plurality of annular metal cathode rings **10***a*, **10***b* and **10***c* are assembled edge to edge with a film of electrically non-conducting material **12***a* and **12***b* between and separating the rings and insulating them electrically from one another. The exposed end faces of the end ones of the group of cathode rings are covered by fine metal wire screens **11** and superposed against their outer faces are films **12** of electrically non-conducting material, like the films **12** of FIGS. 1 to 4. The margins of films **12***a* and **12***b* are bent over against the outer peripheries of the cathode rings, as shown, and the margins of screens **11** and films **12** are likewise bent over against the outside peripheries of the end cathode rings. A confining clamp band **21** that is adjustable in circumference surrounds the group of rings **10***a*, **10***b* and **10***c* and confines them in their assembled relation as shown in FIG. 6. Elastic annular insulating gaskets **22** and **23** are preferably interposed between the inner periphery of ring **21** and the bent over margins of screens **11** and films **12**, so that when tightened they will clamp the cathode rings together and provide elastic pressure seating the films to the cathode rings. The films **12** extend at their margins further than the screens **11** so that such film margins are pressed firmly into contact with the cathode rings to close the chambers **14***a*, **14***b* and **14***c*. One exposed end wall for the cathode ring at one end of the stack, such as the outside face wall of chamber **14***c*, may, when desired, be made of impervious metal to stop and enable counting of gamma radiations in chamber **14***c*. In each chamber **14***a*, **14***b* and **14***c* are anode elements **15** as in the chamber **14**. The band **21** has apertures (not shown) through which access may be had to openable and closable passages through rings **10***a*, **10***b* and **10***c* for replacing air in the chambers with a counting gas mixture, as done in prior detectors and counters. The cathode and anode for each chamber **14***a*, **14***b* and **14***c* are included in an individual utilization circuit (not shown), as explained for the individual detector units in FIG. 5.

In the embodiment of FIG. 7, a plurality of four individual units **24**, **25**, **26** and **27**, each like the unit of FIGS. 1–4, are assembled in face to face or stacked relation and confined in that relation by an encircling ring **28**. There is a closed space **29** between the faces of the interior units **25** and **26**, and the ring **28** has spaced apart inlet and outlet parts **30** and **31** leading to that space **29** through which a fluid having suspected radioactivity can be passed. Radiation from such suspected fluid, if it enters unit **25**, will have its low energy particles absorbed and counted therein, and the higher energy particles will pass on through that unit into unit **24** and be stopped and counted in that chamber. Similarly, if radiations from the suspected fluid enter unit **26**, the low energy particles thereof, such as the low energy beta rays, will be stopped and counted in that unit, and the higher energy particles or radiations that pass on into unit **27** will be stopped and counted there. Each unit will, of course, have an individual counting and utilization circuit, and the circuits of units **24** and **25** will be embodied in an anti-coincidence circuit, so that if the radiation particles cause concurrent countings in both branches of the anti-coincidence circuits, no count will be indicated, as they cancel one another out in the circuits. A similar arrangement is provided for units **26** and **27**. With the four units, one obtains a counting for the radiations emitted at both sides of the suspected fluid under examination in the space **29**, and thus the counts are more accurate and complete than if only one pair such as units **24** and **25**, or **26** and **27** were employed. The ring **28** may be split in order to apply it to the units, and the edges along the split coupled and drawn together after assembly of the units in the face to face relation.

An anti-coincidence circuit such as may be employed in connection with the embodiment of FIG. 7 is illustrated schematically in FIG. 10.

In the embodiment of FIG. 8, an annular ring **32** of electrical insulating material has each of its end faces covered by a fine wire screen **33** that has been sprayed with or dipped in a liquid film-forming agent of electrical insulating material so that the wires of the screen are coated with such film agent, and such agent forms thin bridging films across the openings or meshes of the screen. Since the face area of each opening or mesh is quite small, a thinner film can be safely used to bridge it, because a thinner film of smaller area has the necessary mechanical strength. The thinner the bridging films, the more of the radiations that are able to pass through it, and the more sensitive the device is to radiations of low energy. The ring **32** may have small conduits **34** passing through it, by which a counting gas may be passed through the chamber **35** between the screen **33** to flush out and replace the air in that chamber. These conduits **34** are sealable after the air in the chamber **35** has been replaced by the counting gas. A conductor **36** is connected to one screen **33**, and another conductor **37** is connected to the other screen, so that when these conductors **36** and **37** are included in a utilization circuit, one screen acts as a cathode and the other screen acts as an anode. This arrangement makes it possible to make the thickness of the chamber **35** between screens **33** very small. A suitable sealing compound **32*c*** may be applied over the margins of the screens and the exterior of the ring **32** to seal the screen to the ring **32**.

In the embodiment of FIG. 9, the construction is similar to that of FIG. 8, except that two of such detection units are arranged in face to face relation as a stack, and one film-coated wire mesh screen is used as a common electrode and screen for two of the detection units. This common screen is used as the anode element for the two adjacent chambers. To this end two annular rings **38** and **39** are arranged in end to end relation, with an anode, fine wire mesh screen **40** carrying the fluid-impervious thin film clamped between adjacent ends of the rings. The other screens **41** and **42**, each also carrying a fluid-impervious, thin film, are secured across and close the exposed ends of the rings **38** and **39** to complete the two closed chambers **43** and **44**. A sealing compound **45** is applied around the peripheries of the rings and over the margins of the screens to aid in confining the parts in this assembled relation. The chambers **43** and **44** have their air flushed out and replaced with a counting and quenching gas as usual in radiation detectors, and as described in connection with FIG. 8. Wires **46** are connected to the cathode screens **41** and **42** and a wire **47** is connected to the anode screen common to the two adjacent chambers **43** and **44**. The wires **46** and **47** are connected in the usual or any suitable utilization and counting circuit.

This construction of FIG. 9 has the advantages that the chambers 43 and 44 can be made rather shallow, since no space in the centers of the chambers is required for an anode, and the device is sensitive since it responds to radiations incident on either exposed face of the double chamber unit.

The thin films of electrically non-conducting material may be formed in any suitable manner or purchased in the open market. As a few examples, the material in fluid but congealable form may be sprayed as a thin layer on a solid or liquid surface from which it may be stripped, or the screen may be dipped in the film material in fluid form and then lifted and held in air until it hardens, dries or sets. The film material in fluid form also may be sprayed on the screen and then it forms film bridges across the mesh openings and coats the wires of the screens. This coated screen is then dried or handled carefully until the film bridges set or harden. Other suitable ways of forming the films may also be employed. The film material may be any available film forming resin, such as a plasticized synthetic resin that can be made available in fluid form in order to form the film, and then caused to cure or harden. Solutions of such resins using a vaporizable solvent are useful, as are resins that may be made very fluid by heat. The resin or material, however, should be one which can be penetrated by radiations from radioactive materials.

The window films must be thin enough to pass or transmit therethrough beta particles or radiations with an average energy of 6 k.e.v. (kilo-electron volts) where E is the average for radioactive hydrogen and its compounds.

It will appear from the foregoing that the detection, segregation, classification and counting of nuclear radiations in accordance with this invention is substantially insensitive to variations in the temperature, humidity, and aerosols of the ambient atmosphere, and is sensitive and useful for the detection, segregation and counting of low energy radiations thus making relatively simple, practical and inexpensive the detection of radioactive hydrogen and an indication of the relative amount of such hydrogen radiations. The wire mesh support also eliminates the insensitive zone which is characteristic of GM tubes having non-conductive windows.

A typical anti-coincidence circuit is illustrated in FIG. 10 which is operative to pass and count radiation pulses in one input circuit when no radiation pulse is concurrently applied to the other circuit, but which will not pass and count radiation pulses applied to the other or second input circuit alone or radiation pulses applied concurrently to both input circuits. The illustrated anti-coincidence circuit and others are well known, and a more complete disclosure of them is found in a book entitled "Pulse and Digital Circuits," by Millman and Taub, chapter 13, page 404, FIGURES 13–16, published in 1956 by McGraw-Hill Book Company of New York, New York. One of these anti-coincidence circuits is connected to the utilization circuits of units **24** and **25**, the utilization circuit of cell **25** (FIG. 7) being connected to input **1** of FIG. 10 and the utilization circuit of cell **24** (FIG. 10) being connected to input **2** of FIG. 10, so that if the radiation pulses penetrate unit **25** and not unit **24**, they will be counted, but if they are strong enough to penetrate both units **24** and **25** they will cancel out one another and will not be counted. In this way only the gamma rays of low energy will be counted. Another similar anti-coincidence circuit is similarly connected to the units **26** and **27** so that the radiation pulses that penetrate only the unit **26** will be counted, and those that penetrate into both units **26** and **27** will cancel one another and not be counted.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

We claim:

1. A device for detecting the presence in a fluid to be examined of low energy beta radiations, which comprises an enclosure having a group of four relatively thin, closed

chambers arranged in face to face relation in a stack and each chamber containing a counting gas, each of the adjacent face walls defining said chambers being formed of a film impervious to the passage therethrough of fluids, but thin enough to pass therethrough low energy beta radiations, anode and cathode elements arranged in spaced apart relation in each chamber for creating, when a substantial voltage differential is established between the anode and cathode elements of each chamber, an electric field in each such chamber, said enclosure also having passage means for introducing a quantity of said fluid between the adjacent faces of the center pair of said chambers, and anticoincidence circuits including the anode and cathode elements of each pair of said chambers at one side of said passage means, whereby when radiations from said fluid in said passage means enters the first chamber at either side of said passage mean and its energy is absorbed there, a count pulse will occur in the circuit of that chamber, and if such radiation entering said first chamber also passes through it into the second chamber of that pair, it will be counted in both chambers, but such double counting cancelled in the anticoincidence circuits for that pair of chambers.

2. A device for detecting the presence in a specimen to be examined of low energy beta radiations, which comprises an enclosure having two relatively thin, closed chambers arranged in close proximity to one another in a face to face, stacked relation, and each chamber containing a counting gas, the face walls defining said chambers being thin films impervious to the passage therethrough of fluid but thin enough to pass therethrough low energy beta radiations, each of said chambers having anode and cathode elements arranged therein in spaced apart relation to one another for creating, when a substantial voltage differential is established between such

anode and cathode elements in each chamber, an electric field in that chamber, and means including an anticoincidence counting circuit for each chamber including therein the anode and cathode elements of that chamber, said circuits being coupled together to cancel counting pulses created in both circuits concurrently by radiation entering one of said chambers from any such specimen that may be adjacent an outside face wall of the pair of chambers and passing into and creating counting pulses in both of said chambers.

3. The device according to claim 2, wherein said thin films are electrically non-conducting films each mechanically reinforced against pressure against its outer face by an abutting fine wire mesh sheet.

4. The device according to claim 2, wherein said thin films are of polyester material and have a thickness not exceeding about 30 micrograms per square centimeter.

References Cited in the file of this patent

UNITED STATES PATENTS

2,465,821	Smoluchowski	Mar. 29, 1949
2,715,684	Schwarz	Aug. 16, 1955
2,716,523	Driver	Aug. 30, 1955
2,755,391	Keyes	July 17, 1956
2,881,328	Hendee	Apr. 7, 1959
2,899,582	Hermsen	Aug. 11, 1959
2,925,509	Hayes	Feb. 16, 1960
2,976,421	Bayfield	Mar. 21, 1961
3,019,363	Wiechering	Jan. 30, 1962

OTHER REFERENCES

A Thin, Wire-Aperture Proportional Counter, by Eisberg et al., The Review of Scientific Instruments, vol. 25, No. 11, November 1952, page 1129.