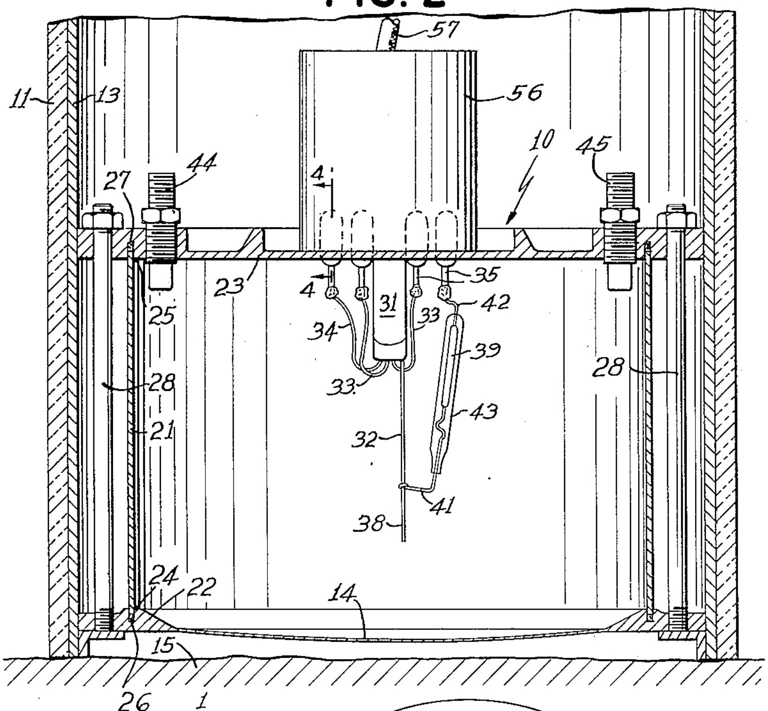
March 13, 1951 J. D. LAHMEYER ET AL 2,544,928

RADIOACTIVITY DETECTOR

Filed Feb. 8, 1949

FIG. 2



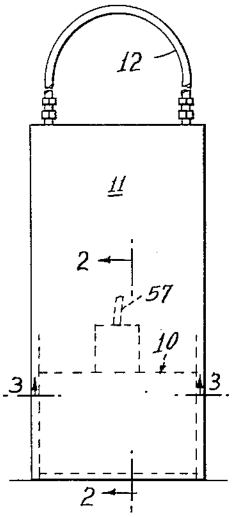


FIG. 1

FIG 4

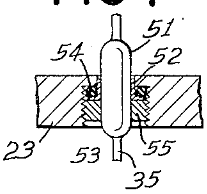


FIG. 3

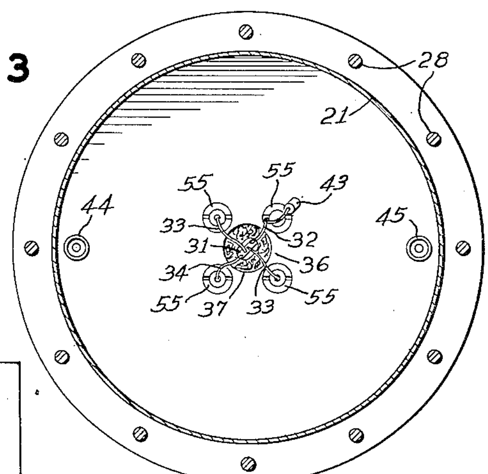
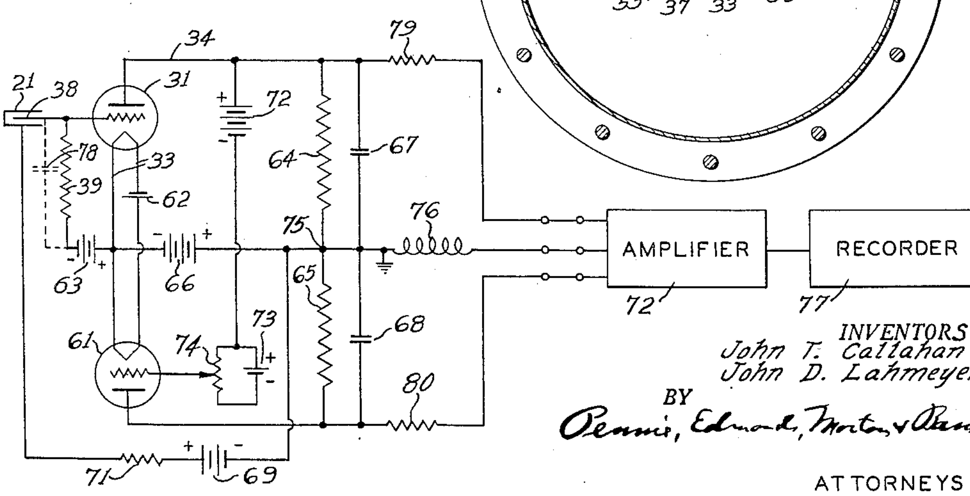


FIG. 5




INVENTORS
John T. Callahan
John D. Lahmeyer

BY

Pennie, Edmonds, Morton & Barrows

ATTORNEYS

Patented Mar. 13, 1951

2,544,928

# UNITED STATES PATENT OFFICE

2,544,928

## RADIOACTIVITY DETECTOR

John D. Lahmeyer, Tulsa, Okla., and John T. Callahan, La Feria, Tex., assignors to Industrial Nucleonic Devices, Tulsa, Okla., a corporation of Oklahoma

Application February 8, 1949, Serial No. 75,248

4 Claims. (Cl. 250—83.6)

1

This invention relates to radioactive detectors, and particularly to ionization chambers therefor. The invention is particularly directed to low voltage ionization chambers, but in certain aspects is of more general application.

Nuclear counters for detecting radioactivity may be divided into (1) low voltage ionization chambers, (2) proportional counters operating at higher voltages and (3) Gieger counters operating at still higher voltages. The present invention is particularly designed to provide an improved ionization chamber of the first-mentioned category, although certain features are of broader application. Difficulties have been encountered with ionization chambers due to their relatively low sensitivity, spurious responses, and proneness to drift. It is a primary object of the present invention to provide an ionization chamber which is markedly improved in these respects.

In accordance with the present invention an ionization chamber is provided having a thin diaphragm window and an arrangement of electrodes which give marked directivity to the device, particularly for beta and soft gamma rays. The chamber is formed almost entirely of a single metal, and the construction so designed as to reduce to a minimum the need for different types of metals in the interior thereof. Hence the danger of spurious responses due to electric potentials established by contact between different metals which might give rise to thermocouple or other electrical effects is minimized. In accordance with another feature of the invention, the first tube of the electrometer circuit, together with its input resistance, is mounted inside the ionization chamber in such a manner as to reduce the capacitance shunting the input circuit and also the leakage paths shunting the input resistance. In this manner the sensitivity of the device is markedly increased, the time constant of the input circuit is reduced without requiring a reduction in the input resistance, and the likelihood of spurious responses and drift is greatly reduced.

The invention will be more fully understood by reference to the following detailed description of a specific embodiment thereof, taken in conjunction with the accompanying drawings in which:

Fig. 1 is an elevation of portable apparatus containing an ionization chamber;

Fig. 2 is a vertical cross section of the ionization chamber itself, taken along the line 2—2 of Fig. 1;

Fig. 3 is a cross section of the ionization chamber taken along the line 3—3 of Fig. 1;

Fig. 4 is a detail of a lead-through seal; and

2

Fig. 5 is a circuit diagram of the ionization chamber in an appropriate amplifier and recorder circuit.

Referring to Fig. 1, an ionization chamber 10 is shown mounted in the lower portion of a cylindrical container 11 provided with a handle 12. The container 11 may be of any suitable durable material, preferably nonconductive, and is provided with an inner cylindrical shield 13 which may be of sheet steel. The ionization chamber is mounted in the lower end of the container 11 with a thin diaphragm window 14 at the bottom end thereof. The container is shown resting on the ground 15 so as to pick up radiations emanating therefrom.

The ionization chamber comprises a cylindrical wall 21 of an appropriate metal. It is preferred to employ aluminum since it is readily available in a very pure state and has relatively low alpha emission. This decreases spurious responses and background noise. If desired, other suitable metals could be employed. The cylindrical wall 21 is provided with end plates 22 and 23, advantageously of the same metal. Circular grooves 24 and 25 are provided in the end plates to receive the cylinder 21. Advantageously sealing rings of rubber or other material 26 and 27 are inserted in the circular grooves to provide an air-tight seal. The end plates are secured in position by means of bolts 28 arranged around the periphery thereof.

The lower end plate 22 is provided with a thin diaphragm window 14 advantageously formed integrally in the end plate. This may be accomplished by starting with a metal disc of desired thickness and machining away the inner portion thereof to form the window. A diaphragm thickness of about 0.002 inch has been employed with success, and this thickness of aluminum permits beta and soft gamma rays to pass freely into the chamber. Naturally the more penetrating hard gamma and cosmic rays can also enter the chamber.

The upper end plate 23 has mounted on the underside thereof within the chamber an electronic tube 31 which may, for example, be a triode amplifier tube. In the specific embodiment shown the tube has a grid lead 32, filament heater leads 33 and anode lead 34. Seal-through conductors 35 are provided in the end face 23 so as to supply suitable energization to the tube and to obtain the output therefrom for subsequent amplification. With a tube of the miniature type specifically illustrated, the tube leads are directly connected to the lead-through conductors and serve as the tube support. The flexibility of the leads aid materially in preventing damage to the tube due to shock, etc. If desired, a recess 36 (Fig. 3) may be provided in the end plate and soft damping material 37 placed therein in contact with the adjacent end of the tube 31 so as to prevent excessive vibration.

The tube 31 is so mounted that the grid lead 32 extends away from the end plate 23 and toward the window 14 to form a slender central collecting electrode for the ionization chamber. The tip 38 is located near the diaphragm window 14 at a suitable distance therefrom. Advantageously the wire 32 is coaxial with wall 21. The input resistance 39 is also located within the ionization chamber with one end 41 connected to the grid lead 32, and the other end 42 connected to a lead-through conductor. Preferably the junction of wires 41 and 32 is near the tip 38 of the collector electrode. The resistance 39 is of very high value and may be encased in a sealed glass tube 43 to preserve the value of the resistance.

The ionization chamber is filled with a suitable gas by means of valves 44 and 45. Low gas pressures are ordinarily employed, of the order of a few pounds above atmospheric. Any suitable gas may be employed, such as argon, nitrogen, hydrogen, etc. Under some circumstances air alone may be employed. The window diaphragm 14 is shown as slightly dished, due to the pressure in the chamber and slight stretching of the metal during machining. It may, of course, be flat if desired.

It will be observed that the interior of the chamber is bounded by surfaces which are almost entirely of one metal, advantageously aluminum. Due to the type of construction employed, the use of other metals for soldering, etc. is avoided. Also, insulating surfaces within the chamber are kept to a minimum so as to avoid the collection of static charges thereon which might discharge periodically to give spurious responses. The sealing rings 26 and 27 are embedded in the ring grooves so as to minimize any collection of static charges thereon. Advantageously the exposed surfaces of valves 44 and 45 extending within the chamber are of the same metal as the rest of the chamber.

The provision of proper seals for the lead-through conductors 35 is important. It is desirable to avoid the use of different kinds of metal in the lead-through connections in order to avoid electrical action between the metals which might give rise to spurious responses. The lead-through seal shown in Fig. 4 is particularly advantageous. As shown, the conductor 35 is sealed in a glass bead 51. Also sealed to the glass bead 51 is a metal ring 52. The end plate 23 is drilled to receive the glass bead 51, and is provided with an annular threaded socket 53 surrounding the bead. A rubber O ring 54 is seated in the socket 53 and the ring 52 held thereagainst by the annular ring-screw 55. By tightening screw 55 a gas-tight seal can be readily obtained. Ring-screw 55 is on the inside of the chamber and is advantageously of the same material as the end face 23. Hence, when the lead-through connection has been secured in place, the metal ring-screw 55 is exposed to the interior of the chamber. This avoids the necessity for using other types of material for soldering, brazing, etc. Furthermore, the O ring 54 is covered by the metal ring-screw and hence presents no surface which might contaminate the gas in the chamber or collect static charges.

A metal can 56 may be placed around the outer terminals of the lead-through connection and may contain additional amplifying stages. Inasmuch as the output of an ionization chamber is very small, shielding is highly desirable and this is provided by can 56. After the initial amplification, the output may be fed to subsequent amplifier stages through cable 57.

Referring now to Fig. 5, the ionization chamber is shown diagrammatically with the outer wall indicated as 21 and the central collecting electrode indicated as 38. The electronic tube 31 is shown separate from the ionization chamber for convenience, but will be understood to be actually inside the chamber as shown in Fig. 2. A second thermionic tube 61, preferably identical with tube 31, is provided to balance the no-signal current of tube 31 so that the output signal represents essentially only the A.-C. signal. The heater filament leads 32 of tube 31 are connected in series with the heater filament of tube 61 and energized by suitable battery 62. Grid resistor 39 is connected from grid to filament through a C battery 63 which provides suitable negative bias. Load resistors 64 and 65, preferably of equal value, are connected to the anodes of tubes 31 and 61, and to the filaments through the B battery 66. Resistors 64 and 65 are shunted by large electrolytic capacitors 67 and 68. A suitable potential is applied between the chamber wall 21 and collector electrode 38 of the ionization chamber by means of batteries 63, 66 and 69, through grid resistor 39 and resistor 71. An adjustable grid bias potential is applied to tube 61 through battery 72 and battery 73 shunted by potentiometer 74. A balanced output signal is supplied to amplifier 72 through resistors 79 and 80. The mid-point 75 between plate resistors 64 and 65 is grounded and connected to amplifier 72 through an RF choke 76. The output of amplifier 72 is fed to a suitable recorder 77.

Potentiometer 74 is initially adjusted so that the anode currents from tubes 31 and 61 flowing through respective resistors 64 and 65 provide equal and opposite voltages so that the resultant signal applied to amplifier 72 is substantially zero. When the ionization chamber is subjected to radiation, the signal is amplified by tube 31 and supplied to amplifier 72. The general arrangement of the circuits in Fig. 5 are well known and need not be described further.

Resistor 39 is of very high value, a value $2\times10^{12}$ ohms having been employed successfully. The capacitance of the ionization chamber and associated wiring results in a distributed capacitance which is effectively in shunt with resistor 39 as shown by the dotted condenser 78. It is desirable to keep the capacitance of the chamber and associated wiring as low as possible in order to obtain maximum sensitivity in the device. Generally speaking, the sensitivity varies in inverse proportion to the capacitance. Also, the time constant RC of capacitance 78 and resistor 39 is important. If, for example, R were $2\times10^{12}$ ohms and C were 59 mmf., a time constant of 100 seconds would result. Such a capacitance would ordinarily be obtained when the tube 31 and resistor 39 are placed outside the ionization chamber and the collector electrode is led through the end face 23. It is difficult to obtain lead-through capacitances much less than 50 mmf. On the other hand, when, in accordance with the invention, the tube 31 is placed inside the chamber as shown in Fig. 2, the capacitance from the collecting electrode 38 to the chamber wall is exceedingly low. By placing resistor 39 inside the chamber also, the net capacitance in shunt with the resistor is greatly reduced. Values of 4 mmf. or less are readily obtained. With such a low capacitance, time constants of eight seconds or less are easily obtained, thereby greatly increasing the speed of taking readings. At the same time the sensitivity of the chamber is increased. It will therefore be understood that the reduction in capacity obtained in accordance with the present invention greatly increases the sensitivity and usefulness of the ionization chamber.

A further advantage in the present arrangement is that leakage currents which would decrease the sensitivity of the device are largely avoided. Consider again the case in which the tube 31 and resistor 39 are placed outside the ionization chamber, thereby requiring the collector electrode to be led through the chamber wall to the grid of the tube. Representative voltages which have been employed with success are +45 volts to ground for the chamber wall and −25 volts to ground for the grid of tube 31. This gives a total of approximately 70 volts from the collector electrode to the chamber wall. The currents resulting from ionization in a chamber of the type described are very minute and the input resistor 39 is very large. Hence, even with a low voltage such as 70 volts the magnitude of leakage current which could flow from the collector lead through the chamber wall might easily be of the same order of magnitude as the ionization current. This leakage current would by-pass the resistor 39 and hence reduce the sensitivity of the device. When, in accordance with the invention, tube 31 and resistor 39 are placed inside the chamber, this leakage path is eliminated. Considered from another viewpoint, in the arrangement shown in Fig. 2 any current which could flow between the grid lead-through conductor and the end wall 23 must first pass through resistor 39 and hence yield a signal voltage. The protecting glass tube 43 may be carefully cleaned before inserting it into the ionization chamber so as to reduce any leakage therealong to a negligible value, and the ionization chamber wall protects the resistor from contamination during use.

As mentioned before, the ionization chamber of the invention has marked directivity, particularly for beta and soft gamma rays. This results from the employment of the thin window 14 at one end of the cylindrical wall 21 forming the outer electrode, in conjunction with the tip 38 of the inner collecting electrode extending toward and fairly close to the window. The combination of this arrangement with a direct connection between the inner electrode and the grid of tube 31 and resistor 39 results in an ionization chamber of excellent sensitivity to beta and gamma rays, with relatively low spurious response. Furthermore, by placing the tube and resistor inside the chamber so as to reduce distributed capacitance and leakage, the chamber is made less susceptible to drift, inasmuch as changes in the values of the circuit constants are minimized.

It is sometimes found that when the equipment is operated under different temperature conditions, tube 61 can advantageously be placed inside the ionization chamber along with tube 31. Tube 61 will then be in the same environment as tube 31 and the change in balance of



the circuit of Fig. 5 due to temperature and atmospheric conditions are minimized.

The invention has been described hereinbefore in connection with a specific embodiment thereof. It will be obvious to those skilled in the art that many variations are possible within the spirit of the invention, the scope of which is defined in the accompanying claims.

We claim:

1. A radioactivity detector comprising a cylindrical wall and end plates therefor cooperating to define a closed ionization chamber, said cylindrical wall forming one electrode of the chamber, a thin diaphragm window in one of said end plates, an electronic tube having at least an anode, cathode and control grid mounted inside said chamber and centrally located with the other of said end plates, a slender inner electrode extending from said grid toward said diaphragm window with the end thereof substantially coaxial with the cylinder, and an input resistance mounted in said chamber and connected to the grid of said tube, whereby a directional radioactivity detector of high sensitivity may be obtained.

2. A radioactivity detector comprising a cylindrical wall and end plates therefor of a selected metal cooperating to define a closed ionization chamber, said cylindrical wall forming one electrode of the chamber, a thin diaphragm window in one of said end plates, a plurality of lead-through conductors sealed in the other end plate, an electronic tube having at least an anode, cathode and control grid mounted inside said chamber centrally of said other end plate, a slender inner electrode extending substantially coaxially from said grid toward said diaphragm window, an input resistance mounted in said chamber and connected to said inner electrode near the end thereof toward the window, and electrical connections from said lead-through conductors to said anode, cathode and resistance respectively, whereby a directional radioactivity detector of high sensitivity and low capacitance and leakage may be obtained.

3. A radioactivity detector comprising a cylindrical wall and end plates therefor of a selected metal cooperating to define a closed ionization chamber, said cylindrical wall forming one electrode of the chamber, a thin diaphragm window in one of said end plates, a plurality of lead-through conductors sealed in the other end plate, an electronic tube comprising an envelope and at least anode, cathode and control grid, said tube being mounted inside the chamber centrally of said other end plate, a slender inner electrode extending substantially coaxially from said grid toward said diaphragm window, an input resistance mounted in said chamber and connected to said inner electrode near the end thereof toward the window, electrical connections from said lead-through conductors to said anode, cathode and resistance respectively, an ionizable gas at low gauge pressure in said chamber, and means for applying a relatively low voltage between said electrodes to form an ionization chamber whose response varies with the ionizing ability of incident radiation.

4. A radioactivity detector comprising a cylindrical wall and end plates therefor of a selected metal cooperating to define a closed ionization chamber, said cylindrical wall forming one electrode of the chamber, a thin diaphragm window in one of said end plates and integral therewith, a plurality of lead-through conductors, each con-

ductor having an insulating bead sealed therearound and an annular disk sealed around the bead, threaded annular sockets in the other end plate receiving said conductors from the interior surface thereof, a resilient sealing ring between the annular disk of each conductor and the bottom of the respective socket, a ring-screw of said selected metal clamping each of said conductors in the respective socket, an electronic amplifier tube comprising an envelope and at least anode, cathode and control grid, said tube being mounted inside the chamber centrally of said other end plate, a slender inner electrode extending substantially coaxially from said grid toward said diaphragm window, an input resistance mounted in said chamber and connected to said inner electrode near the end thereof toward the window, electrical connections from said lead-through conductors to said anode, cathode and resistance respectively, an ionizable gas at low gauge pressure in said chamber, and means for applying a relatively low voltage between said electrodes to form an ionization chamber whose response varies with the ionizing ability of incident radiation.

JOHN D. LAHMEYER.
JOHN T. CALLAHAN.

## REFERENCES CITED

The following references are of record in the file of this patent:

### UNITED STATES PATENTS

| Number | Name | Date |
|---|---|---|
| 2,288,718 | Kallmann et al. | July 7, 1942 |

### OTHER REFERENCES

Copp et al.: Review of Scientific Instruments, July 1943, pp. 205–206.

Brubaker and Pollard: Review of Scientific Instruments, July 1937, pp. 254–256.