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(54) IONIZATION PARTICLE DETECTOR

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IONIZATION PARTICLE DETECTOR

ABSTRACT

An ionization particle detector for indicating the presence of charged particles in a gas includes a single ionization chamber having two defined regions of electrical field intensity. The first region is of small geometric volume and high electric field intensity while the second region is of large geometric volume and low electric field intensity. The radioactive source for generating the ions is located near one electrode while the second electrode forming the walls of the chamber are located such that the walls are incident near the Bragg ionization peak of the detector. A probe is positioned between the two regions for detecting the maximum electric field change when particles enter the chamber.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to charged particle detectors and more particularly to single chamber ionization detectors applicable to combustion product and smoke detectors.

2. Background of the Prior Art

Ionization smoke detectors utilize a radioactive source to provide charged ions in a sensing chamber having an electric field. When the charged ions of the radioactive source are placed in an electric field, the positive ions migrate to the negative electrode of the field while the negative ions migrate to the corresponding positive electrode. The current generated by the emission of the ions from the source is extremely small, generally in the order of 10^{-11} amps. As the voltage across the electrical field is increased, there is a corresponding increase in the amount of current. However, a saturation current is reached at a specific voltage which is termed Saturation Voltage. Under normal conditions, the current is a function of the following factors: (1) ion mobility, (2) ion density per unit volume, (3) electric field intensity, (4) geometry of the chamber, and (5) the rate of source ion emissions (i.e., ions per unit volume per unit time).

OBJECT OF THE INVENTION

It is an object of the present invention to provide a new and novel device for detecting particles in a gas.

SUMMARY OF THE INVENTION

The above object is met by the present invention which provides a particle detector comprising; a first charged electrode, means for generating ions, a second charged electrode, the second electrode including a chamber formed by an electrically conductive side wall and electrically conductive opposite end walls, the walls of the chamber being positioned at a predetermined distance from the ion generating means within the chamber, the distance being less than the distance of maximum ion density from the generating means, means for directing particles into the region between the first and second electrodes, means located in the region for sensing the change in electric field intensity, and means receptive of the sensed electric field change for generating a signal indicative of the field change.

The present invention comprises a low cost, easy to assemble, highly accurate particle detector which uses a single ionization chamber to contain a reference region and a sensing region. The chamber is geometrically designed so that the radioactive source is located near one electrode and the second electrode is located at a distance less than the distance of maximum ionization from the radioactive source.

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In one embodiment, a second electrode is a rectangular chamber centrally located over the first electrode which is substantially a point source containing the detector mounted on it. The electric field intensity can be separated into two distinct regions. The first region is termed the sensing region having a high geometric volume and low electric field intensity and a second region termed the reference region having high electric field intensity and low geometric

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volume. The juncture between the two regions is termed the "diffused electric field boundary" and an unloaded probe is positioned at this juncture to detect changes in the electric field. Since the ion cloud is maximum at the second electrode and since the geometric volume in the sensing region is high and the electric field intensity is low, and particles entering the chamber will effectuate maximum recombination to occur in the sensing region and minimum recombination to occur in the reference region. The diffused electric field boundary is the area of the chamber in which the maximum electric field intensity change will occur upon the entry of the particles. The unloaded probe positioned at this point detects the electric field intensity change and activates a field effect transistor.

The field effect transistor, the radioactive source, and the probe are mounted on the interior of the chamber thereby eliminating the need for separate electrostatic shielding for the field effect transistor and the unloaded probe. Since the outer electrode forms the housing of a chamber, formed ports

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in the sides of the housing effectively communicate the exterior air into the interior of the chamber. To maintain the electrostatic shielding, deflector shields are arranged on the interior of the chamber behind the formed ports.

The unloaded probe located at the diffused electric field boundary can comprise numerous configurations and shapes, the only requirement being that it does not significantly interfere with the uniform generation of the ions by the radioactive source in the chamber. Furthermore, the geometric shape of the first and second electrodes can also comprise a variety of configurations as hereinafter illustrated.

A second preferred embodiment is also disclosed in which the ion source is elevated above the base of the rectangular chamber. The electric equipotential lines are thus more broadly spaced because the ion source is separated farther from the base then is true of the first preferred embodiment. Thus, the effects of environmental factors such as temperature, pressure, and humidity are reduced.

As a direct result the separation distance of the probe from the ion source is not as critical thereby allowing greater manufacturing tolerances.

Other objects, advantages and capabilities of the present invention will become more apparent as the description proceeds taken in cojunction with the accompanying drawings.

DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a diagrammatic illustration of a particle detector in a room filled with smoke.

FIGURE 2 is a schematic diagram of a single chamber prior art ionization detector.

FIGURE 3 is the output characteristic of the ionization detector of FIGURE 2.

FIGURE 4 is a schematic diagram of a dual chamber prior art ionization detector.

FIGURE 5 illustrates the output characteristics of the prior art approach of FIGURE 4.

FIGURE 6 is a cross-section illustration depicting the formation of the sensing region having a high geometric volume and low field intensity and a reference region having high

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electric field intensity and low geometric volume.

FIGURE 7 is a cross-sectional side view of one embodiment of the detector of the present invention.

FIGURE 8 graphically depicts the Bragg ionization peak of a radioactive source.

FIGURE 9 is an exploded perspective view of the components of the detector shown in FIGURE 7.

FIGURE 10 is a side cross-sectional view of one embodiment of the detector of the present invention.

FIGURE 11 is a side cross-sectional view of a third embodiment of the detector of the present invention.

FIGURE 12 is a side cross-sectional view of a fourth embodiment of the particle detector of the present invention.

FIGURE 13 is a top planar view illustrating the unloaded probe to be a cylindrical or flat rod or cross-bar.

FIGURE 14 is a top planar view illustrating the unloaded probe to be a circular disc.

FIGURE 15 is a top planar view illustrating the unloaded probe to be a rectangular grid.

FIGURE 16 is a top planar view illustrating the unloaded probe to be a combination of the rod or cross-bar of FIGURE 13 and the disc of FIGURE 14.

FIGURE 17 is a side sectional view illustrating the gate lead of the field-effect transistor to be the unloaded probe.

FIGURE 18 is a perspective view of the formed ports in the housing of the detector of the present invention.

FIGURE 19 is a side sectional view illustrating the interior deflector shields behind the ports of FIGURE 18.

FIGURE 20 is a diagrammatic illustration of the field distribution of the detector as shown in FIGURE 10 under no smoke conditions.

FIGURE 21 is a diagrammatic illustration of the field distribution of the detector of FIGURE 10 when smoke is present.

FIGURE 22 illustrates the output characteristics of the device of FIGURE 10 under smoke and no smoke conditions.

FIGURE 23 is a diagrammatic illustration of the field distribution of the device shown in FIGURE 7.

FIGURE 24 is a partial perspective view of one embodiment of the ionization detector of the present invention.

FIGURE 25 is a cross-sectional view of the detector shown in FIGURE 24.

DESCRIPTION OF THE PRIOR ART

A conventional smoke detector 100 operates, by reference to FIGURE 1, as follows. The smoke detector 100 is mounted to the ceiling of room 110. When aerosols 120, generated by combustion of material 130 enter the chamber of detector 100, the aerosols 120 will deposit upon the ions. Generally, the aerosols are many thousand times larger than the emitted ions so that a marked decrease in the mobility of the combined ions and aerosols result in increased recombination (i.e., the combination of attraction of the negative ion with the positive ion) so that the current is correspondingly reduced. Conventionally, the change in current is detected as a voltage by a field-effect transistor which in turn drives an alarm device. The best operation range for the current flowing in the electric field is at a voltage that is substantially midrange between the saturation current and zero

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current. This range is most sensitive to the presence of aerosols.

Some prior art smoke detectors use only a single ionization chamber. A single ionization chamber device is shown in FIGURE 2 to comprise a battery 200 connected in series with resistor 202 and the ionization chamber 204. A field-effect transistor 206 is interconnected across the resistor 202 and chamber 204 so that the gate of the field-effect transistor 206 is connected between the chamber 204 and the resistor 202, and the source and drain of the transistor 206 are connected across battery 200. An output voltage E_0 is generated across resistor 208 which is interconnected between the drain and the negative side of the battery 200. In FIGURE 3 the output 300 generated at E_0 is shown before and after smoke entry in the chamber 204. Curve 300 is the output characteristic of the ionization chamber with no smoke while curve 302 is the output characteristic when smoke is present. Curve 304 represents the I-V characteristic for resistor 202. The disadvantages with the single chamber approach is that the resistor

202 is large being about 10^{11} ohms, is expensive to manufacture and is subject to leakage through contamination. Furthermore, variations in the radioactive source 210 located with chamber 204 causes variation in operating point and as a result sensitivity in chamber operation. Furthermore, if used, the sampling circuitry is complex and costly. Also, resistor 202 does not compensate for changes in humidity, air pressure, and temperature. Finally, calibration in adjustment is difficult since the sensitivity and stability is directly affected by source contamination such as dirt, etc. in the direction of the alarm. A prior art patent disclosing a single chamber device has been issued to McMillin et. al., March 23, 1976, as U.S. Patent No. 3,946,374.

A second type of ionization smoke detector uses two ionization chambers, one example being shown in FIGURE 4. A battery 400 is connected in parallel across the dual chamber configuration 402. The upper chamber 404 is termed the "Reference Chamber" and that chamber is in a saturated current condition. The second chamber 406 is termed the "Sensing

Chamber" and is in the unsaturated condition at the optimum operating point as previously discussed. The field-effect transistor 408 has its gate interconnected at the juncture 410 between the two chambers 404 and 406. A voltage E_0 is developed across resistor 412. The operating characteristics for the two chamber detector is shown in FIGURE 5. The Reference Chamber 404 with output curve 500 is shown to be in saturation condition while the Sensing Chamber 406 with output curve 510 is shown to be at the optimum operating point 520. When smoke enters chamber 406, the output voltage E_0 drops to the curve 530. The signal voltage is shown as ΔV. The use of the two chambers 404 and 406 eliminates many of the problems associated with the single chamber described above. Unfortunately, two radioactive sources are required with the result being a significantly higher manufacturing cost. Furthermore, the two radioactive sources must be matched since if a mismatch results, difficulty in adjustments and calibration occurs. Dust or chemical contaminants on either source can also cause an increase or decrease in sensitivity, depending upon which source is contaminated.

The following United States prior art patents represent variations of smoke detectors using two ionization chambers:

Lampert	3,710,110	January 9, 1973
Scheidweiler	3,714,614	January 30, 1973
Lehsten	3,903,419	September 2, 1975
Scheidweiler et al	3,909,813	September 30, 1975
Eguchi	3,909,814	September 30, 1975
Emerson et al	3,952,294	April 20, 1976
Tipton et al	3,959,788	May 25, 1976
Adachi et al	3,964,036	June 15, 1976

Other types of smoke detector devices are disclosed in the following U.S. patents:

Lecuier	3,922,655	November 25, 1975
Horvath et al	3,922,656	November 25, 1975
Hurd	3,930,247	December 30, 1975
Muller-Girard et al	3,936,814	February 3, 1976
Gacoby	3,938,115	February 11, 1976
Rayl et al	3,949,390	April 6, 1976
Campman	3,950,739	April 13, 1976

One prior art approach is disclosed in the patent issued to Sasaki on September 19, 1972, as U.S. Patent No. 3,693,009. This approach utilizes a single ionization chamber, a pair of spaced electrodes in the chamber, and a grid electrode between the chamber. A potentional is applied between the facing electrodes and a voltage amplifier is connected between the grid and one of the electrodes to detect potential changes. The Sasaki approach utilizes the region between the first electrode and the grid as an internal chamber and the region between the first electrode and the facing electrode as the second external chamber. The Sasaki approach utilizes a direct current battery to bias the two facing plates so that a substantially linear voltage gradient is provided between the facing electrodes. The two facing electrodes are supported appropriately and smoke is directed therebetween upon the event of combustion. The presence of smoke in the external chamber causes a non-linear voltage gradient to exist between the first and second electrodes. The Sasaki device, however, while advantageously eliminating one of the two ionization chambers does not define the chamber response to pressure, temperature and humidity change. If the chamber electrodes are longer than the ion path, an increase in pressure causes an increase in ion collisions with neutral molecules thereby causing increased recombination and less ionization current at the electrodes. This tendency can be compensated by making the collector plate (electrode spacings) shorter than the distance of the ion path. Sasaki simple does not geometrically define the chamber. Furthermore, Sasaki discusses a "space charge limiting effect" due to ion recombination.

In "Ionization Dual-Zone Static Detector Having Single Radioactive Source", U.S. Patent No. 4,044,263 issued August 23, 1977, the inventor disclosed an ionization detector also including a single radioactive source having a small volume reference zone and a large volume signal zone set forth in a single ionization chamber. In this approach, a first electrode is preferably unitary in construction with the source of radiation. A second electrode either may be adjacent the walls of the housing or may be formed by the housing itself. A signal electrode is disclosed to extend axially through the axis of the housing disposed above the radioactive source. The reference zone is formed between the signal electrode and the radioactive source while the signal

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zone is defined by the large space separating the signal electrode and the second electrode or housing. A cylindrical housing is specifically disclosed wherein the height h would correspond to the point of maximum ionization from the point source. While this approach represents a vast improvement over the approach taught by Sasaki, the effect of change in pressures is simply not compensated for.

The importance of pressure, humidity and geometry on the operation of a detector is mathematically analyzed and discussed in "Ionization-Type Smoke Detectors", Simon and Rork, Rev.-Sci. Instrum., Vol. 47, No. 1, Jan. 1975, pgs. 74-80, and in "Analysis of an Ionization Chamber-Aerosol and Combustion Sensing System", Klein, Transactions of Instrumentation and Measurement, Vol. IM-20, No. 1, Feb. 1971, pgs. 33-37.

The following invention is a dramatic improvement over the above prior art improvements as will be discussed and brought out below.

DETAILED DESCRIPTION OF THE INVENTION

Figure 6 illustrates the electric field produced in one of the embodiments of the detector 600 of the present invention. Mounted on an insulated base 602 is a rectangular container 604, the center cross-section of which is shown in FIGURE 6. In the center of the rectangular metal container 604 is positioned a metal electrode 606. On top of the metal electrode 606 is a radioactive source 608. The outer metal container 604 is charged to negative voltage while the center circular electrode 606 is charged to a positive voltage, although these polarities may be reversed. An electric field 610 is generated between the circular point source 606 and the outer container or electrode 604. While FIGURE 6 illustrates only the cross-section (i.e., two-dimensions) of a three-dimensional electric field, it is clear that due to the specific geometry of the first electrode 606 with respect to the specific geometry of the second electrode 604, a diffused electric field boundary 612 is created. Above the diffused electric field boundary 612 is a region of high geometric volume and low electric field intensity and below is a region of low geometric volume and high electric field intensity.

Under the teachings of the present invention, through proper use of the geometry of the first electrode 606 with respect to the second electrode 604 and through proper use of the diffused electric field boundary 612, the single chamber 614 defined on the interior of the container (i.e., first electrode) 604 can function as a dual chamber ionization detector. As mentioned in FIGURE 5, the dual chamber device has a "reference" chamber operating in a saturated condition and a "sensing" chamber operating in a non-saturated state. As between the two chambers (i.e., the reference chamber and the sensing chamber), for purposes of this invention, it is only necessary that the reference chamber be much less sensitive to the presence of particles than the sensing chamber while maintaining stability. It is to be expressly understood that the reference chamber need not be in a saturated condition. In FIGURE 6, a reference region in chamber 614, in the direction of arrow 616 can be established in the area between the diffused electric field boundary 612 and the charged radioactive source 608. The reference region has a low geometric volume but high electric field intensity. As mentioned in the above Background of the Prior Art, a region of such low volume and high electric field intensity is insensitive to recombination even in the presence of combustion particles. The ions generated from the source 608 are quickly accelerated to the region of the diffused electric field boundary to present recombination when ion mobility is reduced by ion-particle attachments. However, the region above the diffused electric field boundary 612, as designated by arrow 618, provides a region of low electric field intensity and high geometric volume. This region of a large volume and low electric field intensity is sensitive to ion-particle recombination thereby reducing the ion mobility and recombination. Such a sensing region effectively corresponds to the sensing chamber of a two chamber particle detector. Thus, in FIGURE 6 by analysis of the geometry (i.e., volume and relationship of the electrodes) and of the electric field intensity, a single chamber device can function as a dual chamber device.

When particles are directed into the chamber, the location of the diffused electric field boundary 612 changes in a non-linear manner, as will be subsequently discussed.

An unloaded conductive probe located in the boundary area 612 will sense the change in field intensity by producing an output voltage signal upon the entry of particles into the chamber 614. The magnitude of the signal depends upon the following: (1) the location and shape of the probe for optimum coupling with the electric field change from ambient to particle conditions, (2) the size of the chamber 614, (3) the geometry of the chamber 614, (4) the magnitude of the charge on electrodes 604 and 606 to shape the electric field 610 for an optimum field change upon the entry of particles and (4) the energy of the radioactive source in generating ions.

In FIGURE 7 is shown the cross-section of one preferred embodiment of the particle detector 600 of the present invention. An insulating base or platform 602 is provided with conductive printed circuit material 700 such as copper. The insulating platform 602 has a circularly cut hole 702 and the printed circuit material 700 is not deposited in the circular lip region 704 around the hole 702. As shown in FIGURE 9, the platform 602 is rectangular in shape and the printed circuit material 700 is substantially deposited over the entire outer surfaces of the insulating material 602 by conventional techniques. However, the circular lip region 704 around the formed hole 702 is free of the printed circuit material 700.

An outer container 710 is formed, conventionally, from metal or similar conducting material to have an overall appearance as shown in FIGURE 9. The container 710 is substantially rectangular in shape having an open bottom end 712. The container 710 is affixed to the platform 602 by means of a twist tab protrusion 714 extending down from one end of the container 710 through a formed slot 716 formed through the printed circuit material 700 and the platform 602. As shown in FIGURE 7, this twist tab 714 upon insertion through the formed slot 716 can be twisted to firmly affix the container 710 to the board assembly 602. Opposite the end having the twist tab 714 is a right angle tab 720 having formed therethrough a hole 722. The formed hole 722 aligns itself with a correspondingly formed hole 724 formed in the platform 602 so that when the container is in the position as shown in FIGURE 7 and the twist tab 714 has been twisted to an affixed position, the hole 722 and 724 align so that the container 710 can be conventionally affixed to the platform 602 by a conventional means such as a screw and bolt assembly 726 as shown in FIGURE 7. In this manner, chamber 614 is formed by the upper container

710 and a portion of the printed circuit material 700 designated as 730.

As further shown in FIGURES 7 and 9, a radioactive source 740 is affixed to a metal plug 742 by conventional means. The radioactive source 740 is mounted in a metallic foil so that the connection of the plug 742 to the radioactive source 740 makes the foil of the source 740 electrically conductive with the plug 742. The bottom surface of the radioactive source 740 is mounted to the circular lip region 704 of the insulating material 602. The plug 742 is, therefore, insulated from the printed circuit material 700. The radioactive source 740 is conventional and may be radium 226 Americium 241 with an alpha energy of 4.7 Mev. Other alpha energies may be used with a different sized outside electrode.

As shown in FIGURES 7 and 9, a cylindrically shaped annular support 750 is mounted around the circularly formed hole 702 on the interior of the chamber 614 conventionally fastened or affixed to the printed circuit material 700 on the platform 602. As shown in FIGURE 9, a narrow rod-shaped conductive probe 760 is conventionally attached on the upper surface of the insulating support 750 and aligned to orient directly across the source 740. Attached at one end is a field-effect transistor 770 having its gate lead 772 attached to the probe 760 with its source lead 774 insulated and directed through a formed hole 776 in the printed circuit material 700 and the platform 602. Furthermore, the drain lead 778 is interconnected with the printed circuit material 700.

The conductive probe 760 is unloaded (i.e., not connected to a voltage source) and is positioned in the area of the diffused electric field boundary 612. The probe 760 is oriented and located in the diffused electric field boundary for maximum coupling therewith. The region between the probe 760 and the radioactive source 740 defines the "reference" region of high electric field intensity and low geometric volume. The region between the probe 760 and the container 710 and surface 730 defines the "sensing" region of high geometric volume and low electric field intensity.

In operation, the metal plug 742 is connected to positive voltage and the printed circuit conductive material 700 is connected to negative voltage. An electric field 610 is established in the chamber 614 as shown in FIGURE 6. The probe 760 is unloaded and is positioned in the area of the diffused electric field boundary 612 (i.e., the area of maximum electric field intensity change upon the entry of particles into chamber 614). The source and drain of the field-effect transistor 770 is conventionally interconnected as, for example, shown in FIGURE 4. The gate 772 of the field-effect transistor 770 is interconnected directly to probe 760. Any particles directed into the chamber by means of ports 780 formed around the periphery of the container 710, causes the electric field to change substantially. This change is detected by gate lead 772 of the field-effect transistor 770 and is amplified to produce an output voltage indication as will be discussed later in greater detail. The field-effect transistor 770 also should be high quality and conventionally be of the type manufactured by Siliconix, Motorola, General Instruments, and Intersil, not having a gate leakage of more than about 10^{-12} amps.

The radioactive source 740 uniformly provides praticle emissions as represented by dotted lines 790. The alpha particle emission 790 effectuates ionization as shown in FIGURE 8 and as represented by curve 800. The ion density achieves a peak at a given distance, d, from the source. For purposes of the specification, the curve 800 is termed the Bragg Curve and the peak is termed the Bragg Peak. As shown in FIGURE 6, the Bragg Peak 600 is designed to occur just outside the side walls of the container 710, the walls are, therefore, located at a predetermined distance h from the radioactive source 740 where h is less than d. For environmental compensation, the electrode wall is incident with the left side of the Bragg Curve peak. The wall is located to be within the peak proper but just under the location of maximum ionization. When temperature, pressure, or humidity increases, the Bragg Curve shifts as indicated by curve 810. Such a shift actually increases sensitivity contrary to prior art approaches.

The probe 760 is designed to provide, as mentioned, maximum coupling with the maximum field intensity change when the chamber 614 contains particles. This is determined by experimentation and is termed gap distance g from the source 740. The probe 760 is designed to obstruct as little alpha particles emission from the source 740 as is possible yet maintaining the above mentioned coupling.

The following advantages over the above prior art systems are seen in the above disclosed approach: (1) simplicity, (2) low production costs, (3) a platform 602 serves as one chamber wall and provides for convenient installation of the field-effect transistor 770, the radioactive source 740, the insulating posts 750, and the probe 760, (4) greater reliability is apparent since no close tolerances are required of any parts as is required for dual chamber construction, including the radioactive source, (5) both the sensing and reference regions are open to ventilation preventing the problem of trapped moisture in the separate reference chamber of the prior art devices that often causes false alarms, (6) the detector can operate over a wide range of supply voltage without making conventional changes, since the ratio of field intensity in the two regions is the same -- the supply, for example, can vary between 5 and 20 volts D.C., (7) the housing 710 provides internal electrostatic shielding to protect the field-effect transistor 770, the source 704, and the probe 760 -- no additional compartments, usually found in conventional prior art approaches, are necessary, (8) no radioactive source 740 selection is required -- the source activity can vary more than a ratio of 20 to 1 without changing the detector performance, (9) no internal adjustments are necessary making production calibration extremely simple, and (10) source contamination is extremely tolerant since ion current reduction caused by source contamination changes the ratio of ion current in both the reference and sensor regions resulting in little change in operating point.

The distance between the printed circuit conductive material 700 and the outer circumference of the radioactive source 740 is typically 0.15 to 0.20 inches. The insulating support 750 may comprise any conventional configuration and may be, for example, two opposing upstanding cylindrical posts.

In FIGURE 10 is shown a second preferred embodiment 1000 of the detector of the present invention to provide a substantially hemispherical electric field 1000. In this embodiment, the housing electrode 710 corresponds substantially to that shown in FIGURE 7. The corresponding parts of FIGURE 7 are indicated in FIGURE 10 and will not be further described. The major distinction between the embodiment shown in FIGURE 7 and that shown in FIGURE 10 is the provision that the radioactive source 740 is elevated to a position one-half of less the height h of the housing of 710. Such elevation permits a greater gap g to be obtained than in the approach shown in FIGURE 7. Typically, the probe is elevated 0.4 to 0.5 inches from the platform 602 with a housing height of 0.8 to 1.2 inches. The gap width g is typically 0.05 to 0.3 inches. Such an arrangement reduces possible false alarms from moisture or contamination from the airborne or production sources on the insulating post. The sensitivity of the configuration is more tolerant of geometry and more sensitive to the presence of smoke than the embodiment shown in FIGURE 7. Since ions are generated in a hemisphere, the Bragg Peak is designed to be located outside the walls so that the relation of $h < 1$ is maintained. For the elevated source, the printed circuit board plane 700 may be either V- or V+ as is the source, because the electric field lines below the source have little effect in the important reference chamber diffused volume. This provides two desirable features over FIGURES 6 and 7: (1) Broadening and rounding of the electric field above the source eliminates critical positioning of the probe, and (2) Independence from the printed circuit board V- or V+ plane eliminates tolerance variations of the source and probe assembly caused by mechanical and thermal influences.

Yet another embodiment 1100 is shown in FIGURE 11 wherein the probe 760 is mounted vertically in the chamber 614. In this embodiment, a mounting stand 1102 is provided which is conventionally attached to the platform 602 by means of a screw or the like 1110. The radioactive source 740 is mounted on the side of the support 1102 and the metal plug 742 is mounted through support 1102 and is interconnected to the insulated wire 1120 on the underside of the platform 602. Atop the stand 1102 is an insulating strip 1130 one end of which is connected to the field-effect transistor 770 and the other end of which is connected to a vertical flange 1140 which is connected to the vertically oriented probed 760. Once again, the probe 760 is aligned in the plane of the diffused electric field boundary 612.

Another embodiment 1200 of the detector of the present invention is shown in FIGURE 12 wherein the top of the container 710 is removed. In this embodiment, the electric field lines are shown as 1210 and the diffused electric field boundary is shown as 612. The probe 760 is in the plane parallel with 612 and the particles can be directly inputted into the chamber 614 through the top. Of course, no electrostatic shielding for the field-effect transistor 770 is provided in this embodiment. In all other respects, the embodiment shown in FIGURE 12 is the same as that shown in FIGURE 7.

Various probe configurations are shown in FIGURES 13-17. In FIGURE 13 the probe 760 is shown to be a thin rod which may be conventionally manufactured from conductive wire or ribbon. The diameter of the rod may vary from 0.01 inches to 0.1 inches which is sufficient not to block out a significant amount of the emitted alpha particles from source 740. The length of the rod, at the minimum, must reach just across the diameter of the source 740 and the maximum length, of course, would be just under the length of chamber 614. An additional portion of rod 1300 may be added, as shown by the dotted lines, perpendicular to the first rod to form a cross-bar probe.

In FIGURE 14 is shown yet another embodiment of the probe 760 to contain a circular metallic disc or square having an inner circular hole 1400 formed therein so that the generation of the ions is not blocked. The inside diameter is typically 0.2 to 0.5 inches while the outside diameter is typically 0.8 to 1 inch in diameter.

In FIGURE 15 is shown a probe 760 which may be either a square or circular mesh. The mesh is typically 0.1 inch to 0.2 inch squares with a total size of 0.8 to 1.0 inches on one side.

In FIGURE 16, is shown the circular disc of FIGURE 14 having a rod 1600 disposed across the circularly formed hole 1400. The dimensions are the same as those shown in FIGURES 13 and 14.

Indeed, as shown in FIGURE 17, the field-effect transistor 770 can use its gate lead 772 as the probe 760. Such an approach eliminates miscellaneous leakage paths and is the ultimate approach in component reduction. The above examples of probe geometry are intended to be representative and are not intended to limit or delimit the scope of this invention. Many other probe geometrics can be contrived and yet would still fall under the teachings of the present invention.

The container 710 also serves as the exterior housing portion of the detector of the present invention as shown in FIGURE 18. Air or gas entry is important for reliable particle detection. However, the gas entry must be made such that adequate electrostatic protection with the internal chamber probe and field-effect transistor are maintained. Under the teachings of this invention, if the sensitive internal components cannot be visually seen from the exterior of the housing, then the components have reasonable electrostatic shielding.

In FIGURE 18, ports 1800 are provided in the side of the container 710. As shown in FIGURE 19, these ports have pushed-in cutaways or deflector shields 1900 which allow the incoming gas 1910 to be pushed to the top of the container 710. The incoming gas 1910 with particles, if any, is thoroughly mixed in the sensing region 1920 of the detector, yet, total electrostatic shielding of the internal components is maintained. These ports are typically 0.02 to 0.03 inches wide and 0.5 to 1.5 inches long.

The field-effect transistor 770 being exposed to gas 1910 can absorb residual moisture which may result in dangerous moisture creep into the transistor 770 along its leads thereby reducing its resistance. A potting material can be used to prevent such leakage. One such suitable material is Dow Corning QR-4-3117 Conformal Coating. A coating of this material over the transistor 770 absorbs the residual moisture and seals the outer surface of the transistor. This coating is flexible enough so that installation of the field-effect transistor 770 does not cause cracks therein. The Dow Corning coating actually cures with humidity and moisture and, therefore, substantially prevents moisture creep. None of the known prior art approaches provides such protection for the field-effect transistor 770.

In FIGURE 20, is shown the field distribution of the embodiment 1000 shown in FIGURE 10. The field distribution showing the electric field lines 2000 and the hemispherical equipotentials 2010 are those shown for the condition of no smoke. The probe 760 is located g distance above the source 740. In this embodiment, the outer electrode 710 is charged to 0 volts and the inner electrode 742 is charged to ±15 volts D.C. The gradient of voltage is shown in FIGURE 20. Note the 12 volt potential and the 9 volt potential are close to the radioactive source 740. The probe 760 is located in the region of 7-8 volts and the remaining voltage is distributed in a "sensing" area of the chamber.

Upon the advent of smoke, the field distribution changes to that shown in FIGURE 21. The response curve for the ionization chamber 1000 is shown in FIGURE 22 to reflect the conditions shown in FIGURES 20 and 21. Curve 2200 is the output response curve of the ionization detector before smoke as shown in FIGURE 20, whereas curve 2210 is the output response curve for smoke of the ionization chamber as shown in FIGURE 21. The change in voltage experienced on the probe 760 is shown to be 5-6 volts. It is to be understood that the probe, in this example, is located at the position of maximum voltage change upon the entrance of smoke into the chamber.

The probe, however, could be located in any region of large voltage swing which is physically convenient from the source 740 and is easy to manufacture -- to do so, however, would reduce the sensitivity of the device.

In FIGURE 23, is shown the field distribution of the embodiment 600 shown in FIGURE 7. In this embodiment, the equipotential lines 2300 are closely concentrated in the region above the radioactive source 740. In this approach, the manufacturing tolerances of the various components become more significant whereas in the embodiment shown in FIGURE 10, the manufacturing tolerances of the parts are less critical. Both approaches, however, result in practical operative devices.

A final embodiment 2400 is shown in FIGURES 24 and 25. In this embodiment, a one-piece insulating probe support 2410 is used to support a cross-bar probe 2420. The support 2410 is of one-piece construction and, as shown in FIGURE 25, has substantially cylindrically shaped outer walls 2500 with inwardly tapering inward walls 2510. The inward walls 2510 terminate in a bottom wall

2520. The arrangement of the bottom wall 2520, the inwardly tapering inner walls 2510 and the outer wall 2500 serve to form an annular cup-like support. Centrally disposed on the inside of the probe support 2410 is a cylindrically upstanding support 2530. The height of the inward upstanding support 2530 is such that when the radioactive source 740 is press-fitted into a formed cylindrical passageway 2540, the distance from the upper surface of the radioactive source 740 to the upper electrode 710 is h. The height of the outer wall 2500 of the probe 2410 is such that when the cross-bar probe 2420 is press-fitted into the support 2410, or otherwise affixed, the distance from the probe 2420 to the upper surface of the radioactive source 740 is g. Disposed around the upstanding column 2530 are a plurality of drain holes 2550 formed through the bottom wall 2520 to correspond to formed holes in support base 602. In this manner, any water or fluid accumulation can be rapidly disposed of. The embodiment 2400 shown in FIGURES 24 and 25 results in a low cost, easily manufactured structure. A minimum number of parts is utilized.

Although the present invention has been described with a certain degree of particularity, it is understood that the present disclosure has been made by way of example and that changes in details of structure may be made without departing from the spirit thereof.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A particle detector comprising; a first charged electrode, means for generating ions, a second charged electrode, said second electrode including a chamber formed by an electrically conductive side wall and electrically conductive opposite end walls, said walls of said chamber being positioned at a predetermined distance from said ion generating means within said chamber, said distance being less than the distance of maximum ion density from said generating means, means for directing particles into the region between said first and second electrodes, means located in said region for sensing the change in electric field intensity, and means receptive of said sensed electric field change for generating a signal indicative of said field change.

2. The detector of claim 1 in which said first charged electrode is substantially a point source in said chamber, said first electrode being insulated from said second electrode.

3. The detector of claim 1 or 2 in which said first charged electrode is contiguous to said ion generating means within said chamber and in which said sensing means is an uncharged electric field probe, said probe being capable of substantially allowing said ion generating means on said first electrode to generate ions in the region between said probe and said second electrode.

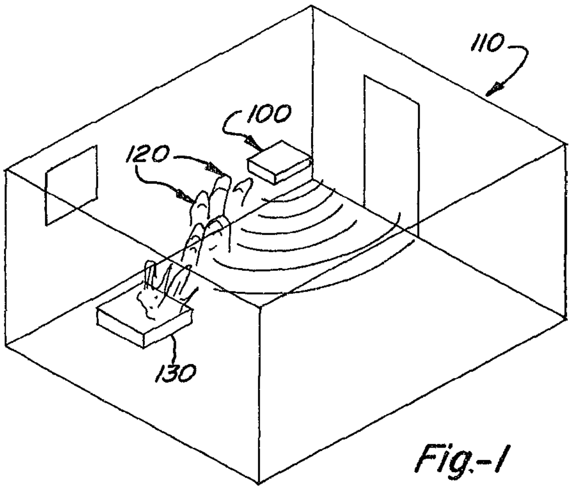

Fig.-1

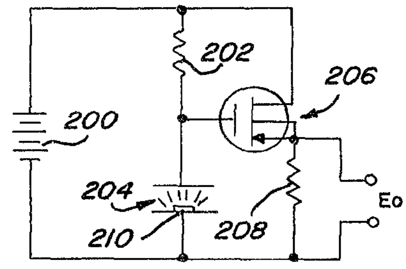

Fig.-2 PRIOR ART

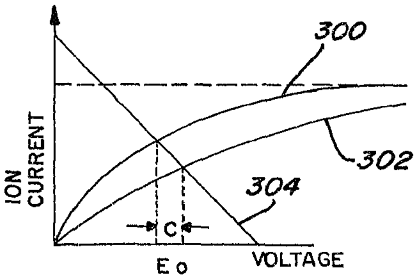

Fig.-3 PRIOR ART

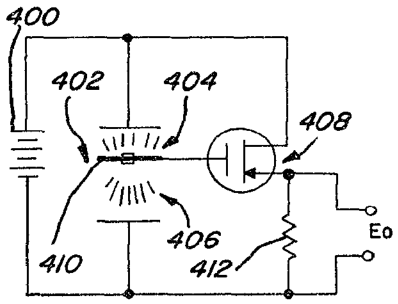

Fig.-4 PRIOR ART

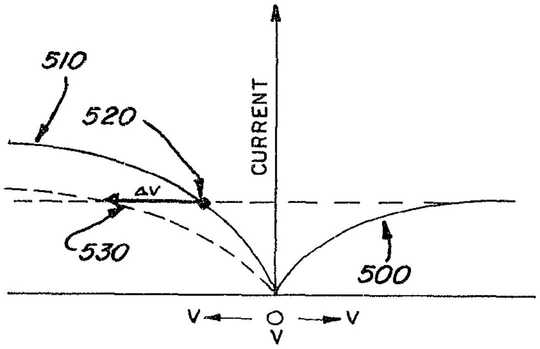

Fig.-5 PRIOR ART

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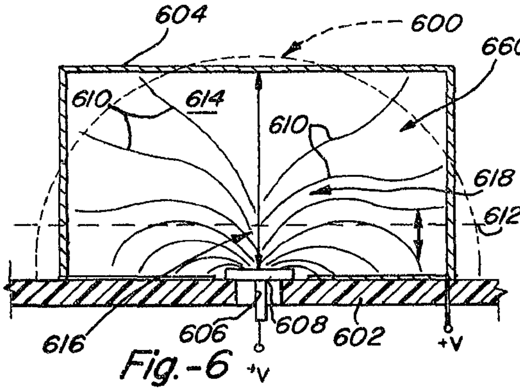

Fig.-6

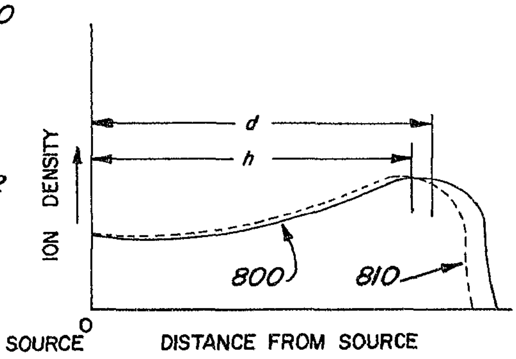

Fig.-8

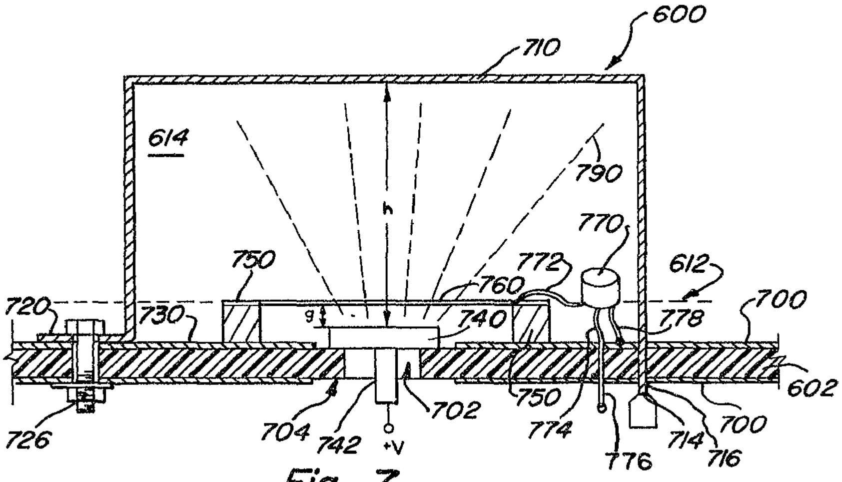

Fig.-7

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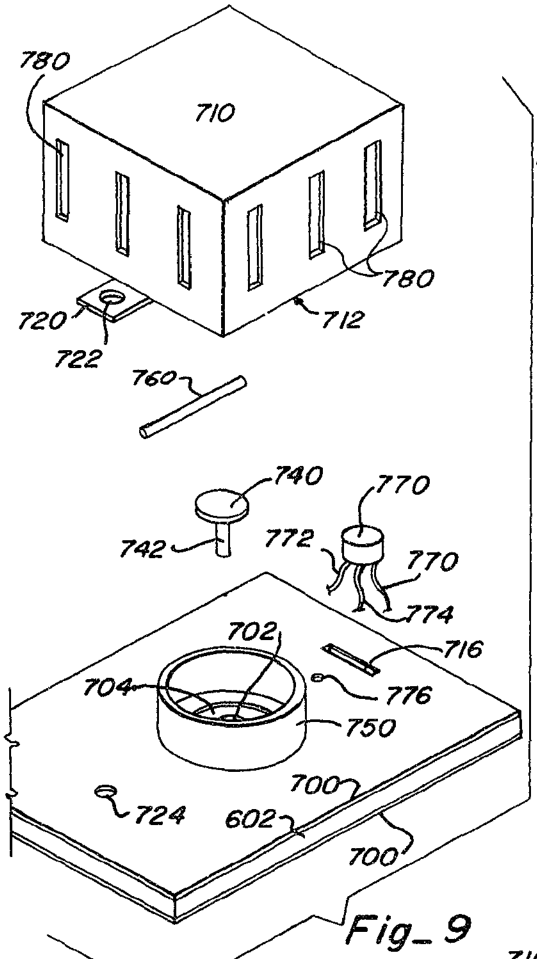

Fig_9

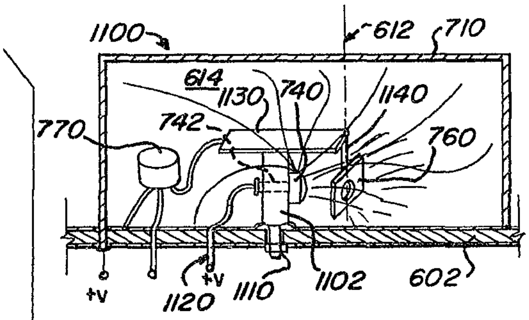

Fig_11

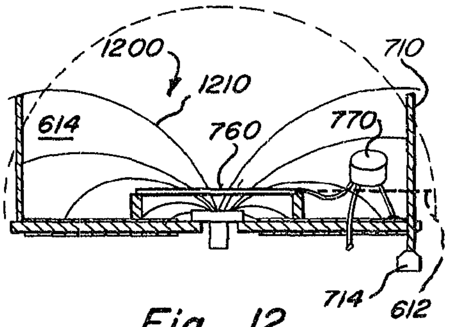

Fig_12

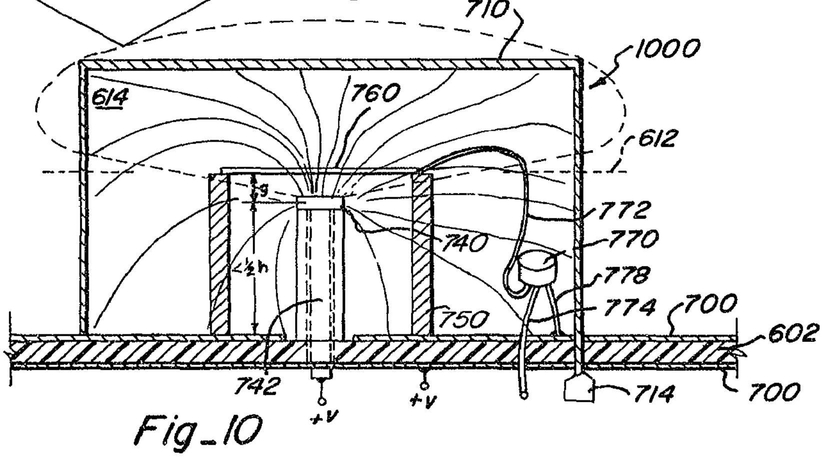

Fig_10

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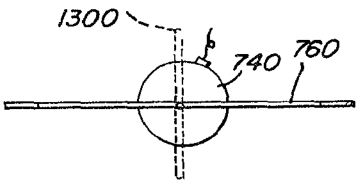

Fig.-13

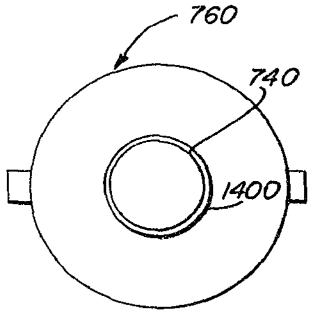

Fig.-14

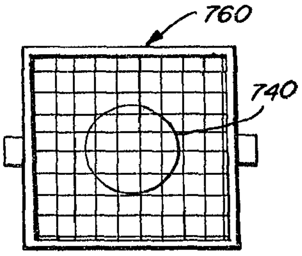

Fig.-15

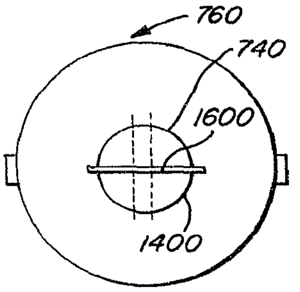

Fig.-16

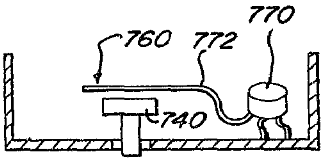

Fig.-17

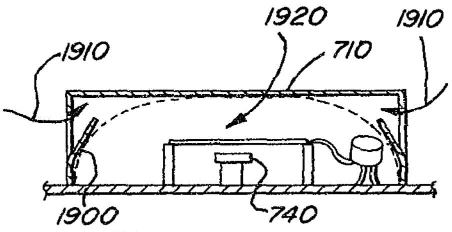

Fig.-19

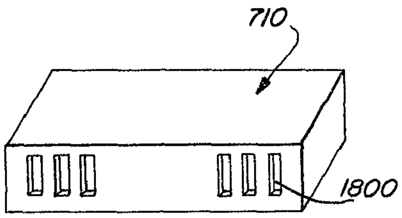

Fig.-18

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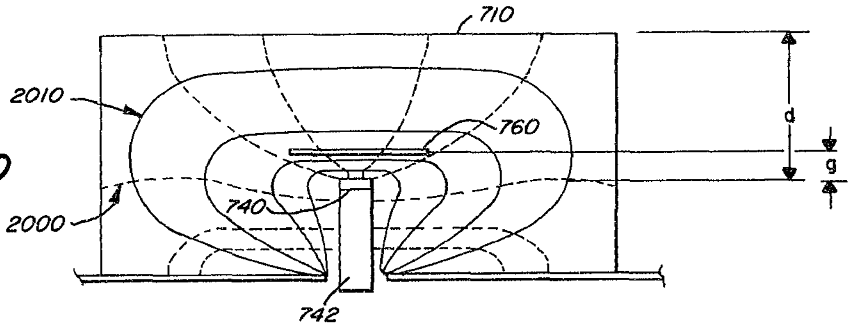

Fig.-20

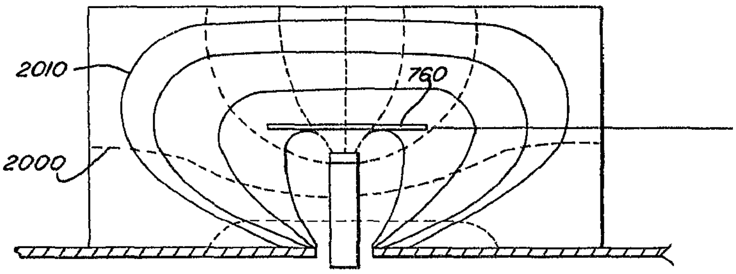

Fig.-21

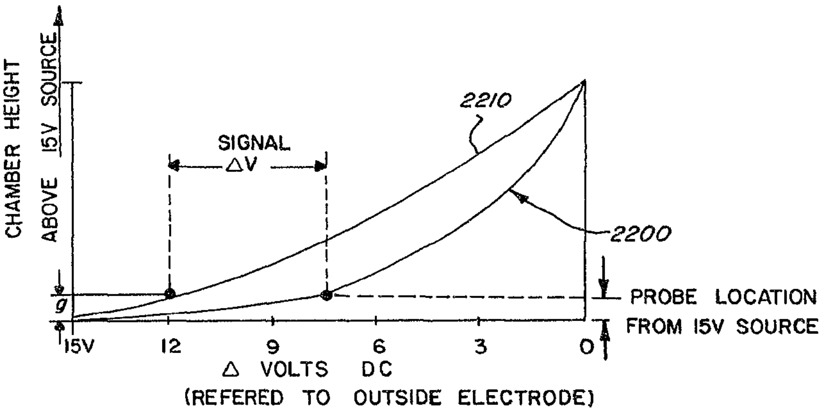

Fig.-22

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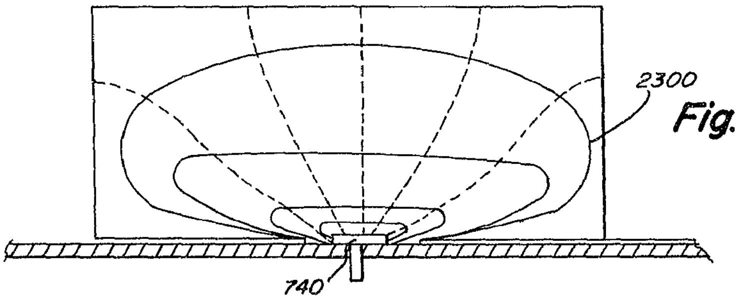

Fig.-23

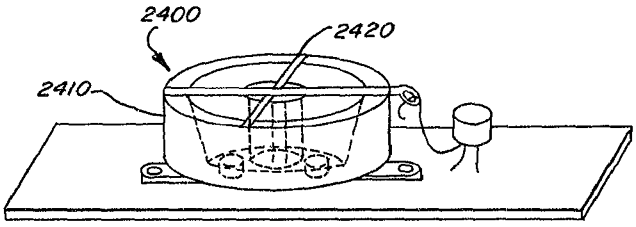

Fig.-24

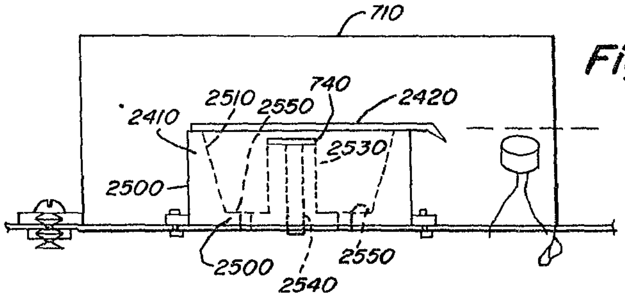

Fig.-25

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