Feb. 19, 1963 R. E. BRESSLER 3,078,450

PRESSURE COMPENSATED IONIZATION CHAMBER FIRE DETECTOR SYSTEM

Filed Aug. 3, 1961 4 Sheets-Sheet 1

FIG. 1.

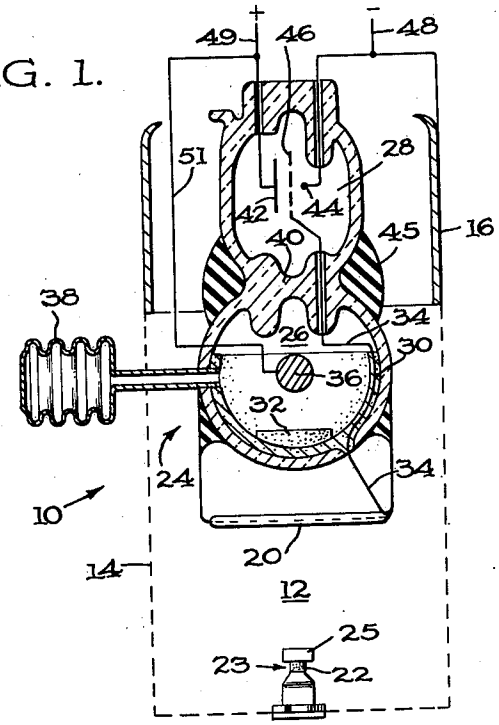
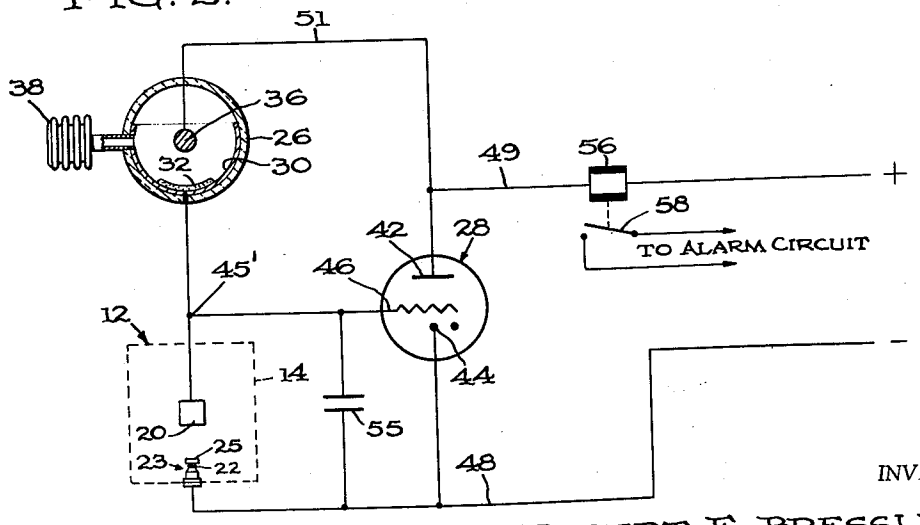


FIG. 2.



INVENTOR

ROBERT E. BRESSLER

BY Garvey & Garvey

ATTORNEYS

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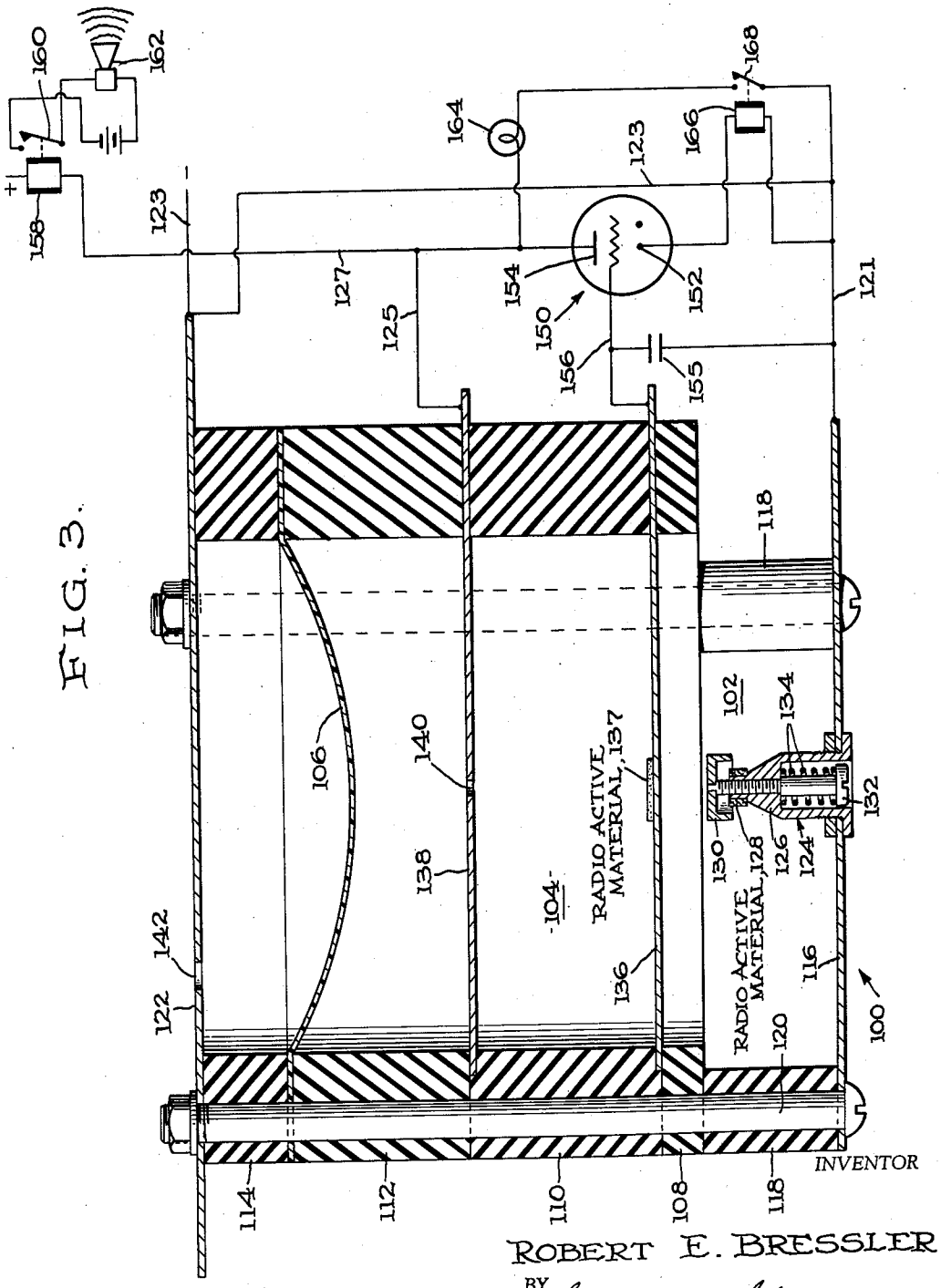


FIG. 3.

INVENTOR

ROBERT E. BRESSLER

BY Garvey & Garvey

ATTORNEYS

Feb. 19, 1963 R. E. BRESSLER 3,078,450

PRESSURE COMPENSATED IONIZATION CHAMBER FIRE DETECTOR SYSTEM

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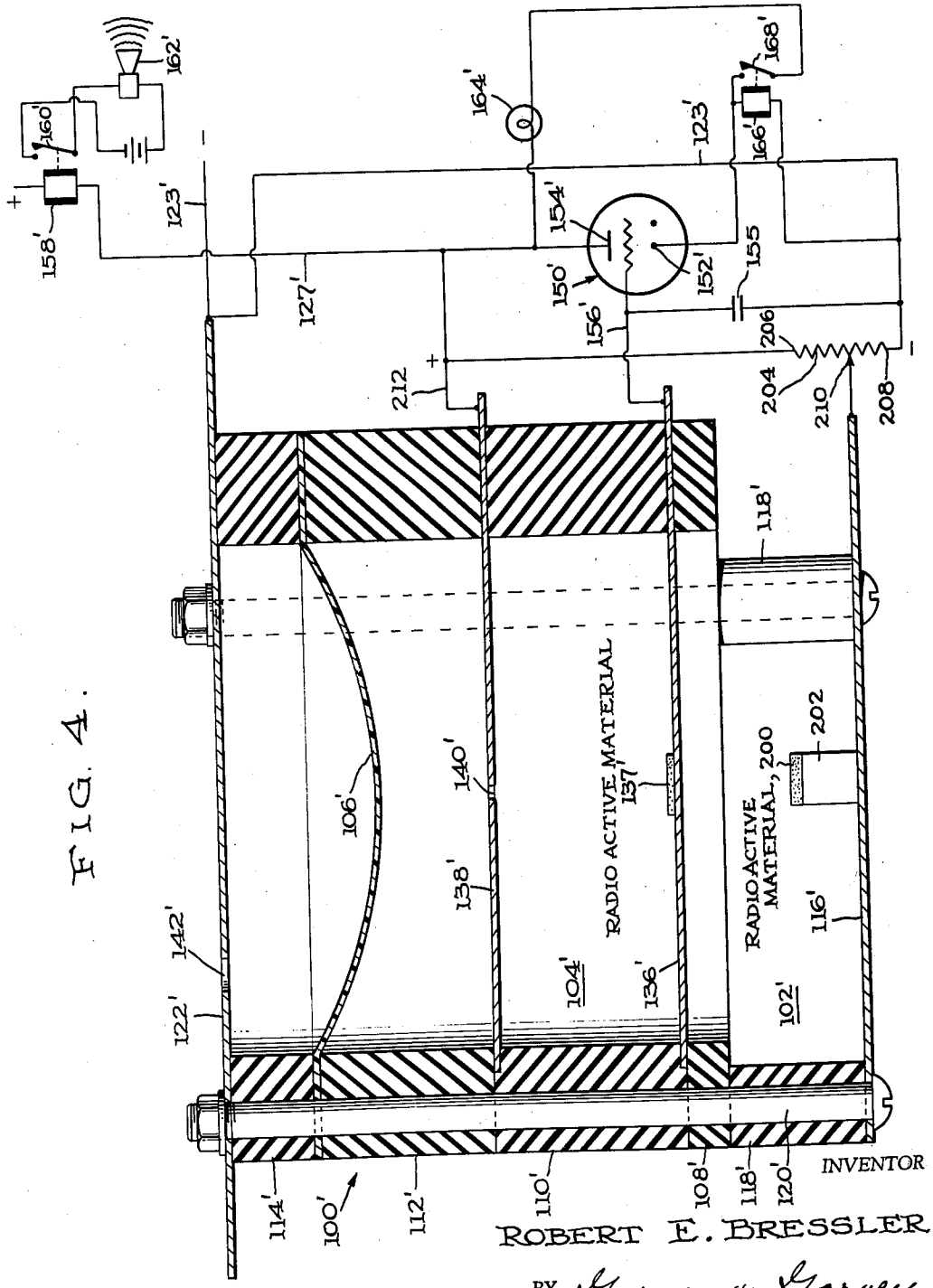


FIG. 4.

INVENTOR

ROBERT E. BRESSLER

BY Garvey & Garvey

ATTORNEYS

Feb. 19, 1963 R. E. BRESSLER 3,078,450

PRESSURE COMPENSATED IONIZATION CHAMBER FIRE DETECTOR SYSTEM

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FIG. 5.

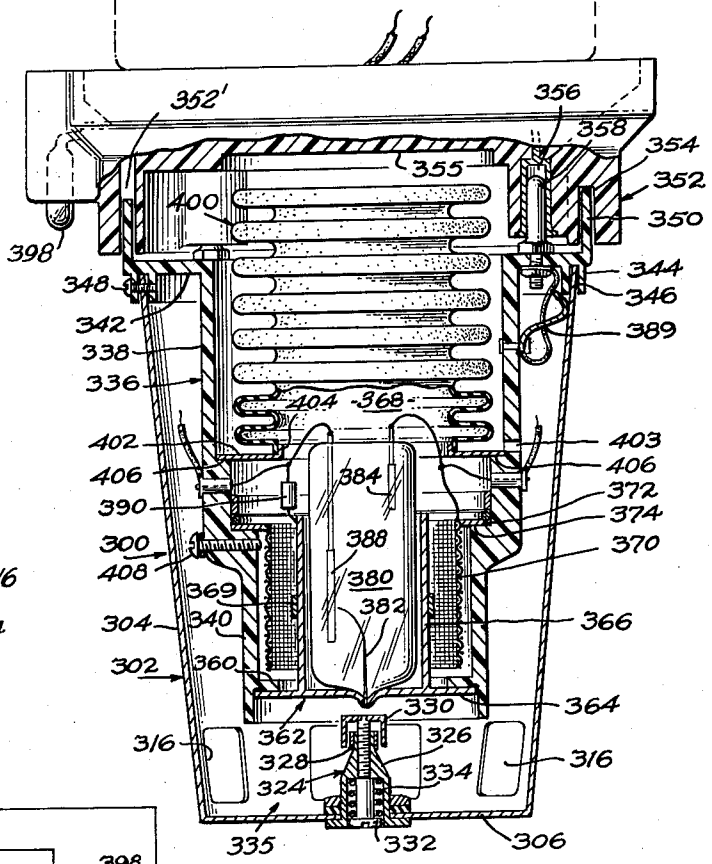
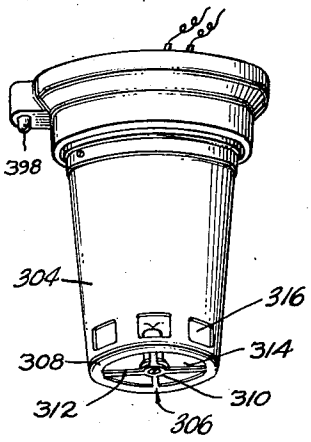


FIG. 6.



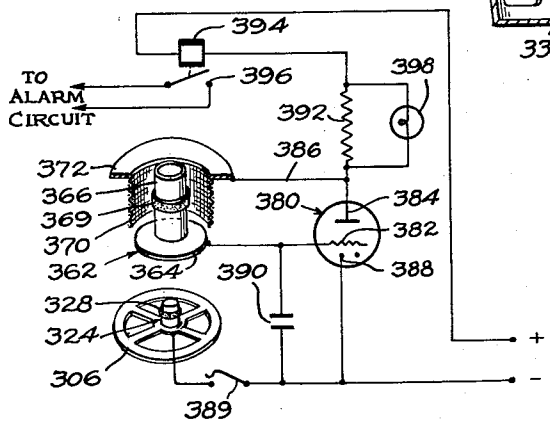


FIG. 7.

INVENTOR

ROBERT E. BRESSLER

BY Garvey & Garvey

ATTORNEYS

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3,078,450

PRESSURE COMPENSATED IONIZATION CHAMBER FIRE DETECTOR SYSTEM

Robert E. Bressler, Oregon, Ill., assignor to Martin J. McGinn, Oregon, Ill.

Filed Aug. 3, 1961, Ser. No. 129,187
19 Claims. (Cl. 340—237)

This invention relates to apparatus responsive to changes in the composition of a gas, and more particularly to an ionization type detection type device for testing air for the presence of smoke and other combustion products. This application is a continuation-in-part of my patent application Serial Number 46,001, filed July 28, 1960, now abandoned.

Ionization type detectors for the presence of smoke and combustion products have the advantage that they detect the presence of combustion during its earliest stages or during what is known as the "incipient period' when combustion gases alone are being produced by the combustion. On the other hand, fire detection devices of the thermostatic or photoelectric type only respond to the later stages of the combustion when the fire has become well established. It is obvious, therefore, that a fire or combustion detection device which operates upon the ionization principle is much more effective in providing an early warning of the presence of combustion than detection devices of other types.

Ionization type combustion detection devices are known per se and are shown, for example, by United States Patent Number 2,465,377, issued to Walter C. Jaeger, on March 29, 1949, and United States Patent Number 2,702,898, issued to Ernst Meili, on February 22, 1955.

Combustion gas detection devices of the type shown by the Jaeger and Meili patents include a test ionization chamber which is open to the atmosphere in which the combustion gases are being detected, and containing therein a small quantity of a radioactive material, such as radium, which emits alpha particles to render the air in the ionization chamber conductive by ionizing air molecules in the chamber. The test ionization chamber is connected electrically in series with a reference chamber which also contains radioactive material similar to that contained in the test chambers. The reference chamber should be constructed in such manner as to prevent the entrance therein of the combustion products or smoke particles. The reference chamber is in effect a resistance element electrically connected in series with the test chamber.

In the presence of visible or invisible smoke particles in the atmosphere being monitored, the smoke particles entering the open test ionization chamber impede the passage of the alpha radiation emitted by the radioactive source in the test chamber, and reduce the number of electrons and ions formed from the air molecules in the chamber by the ionization action of the radiation source. This results in a decrease of ionization current in the presence of combustion gases caused by the incipient fire. Since the ionization chamber is connected electrically in series with the reference chamber across a direct current voltage source, a change in ionization current in the test chamber causes a redistribution of the voltages across the reference chamber and the ionization chamber, which always must equal the total applied voltage. Thus, if the control electrode of a gaseous discharge tube is connected at the electrical junction between the test chamber and the reference chamber, the change in potential at the point of connection of the control electrode due to the redistribution of voltages across the test and reference chambers in the presence of combustion products can be used to trigger the firing of the tube. The firing of the control gas tube may be used to actuate a

suitable signaling device which indicates the presence of the combustion gases and the incipient fire.

In the operation of ionization detection devices for detecting presence of combustion gases, it has been noted that the conductivity of the ionization chambers are influenced to an important degree by density changes in the gases present therein. Normal atmospheric pressure and temperature fluctuations change the density of the atmospheric air sensed by the test chamber so that unless compensated for, the combustion gas detecting device must be adjusted for low sensitivity with respect to smoke to insure against false operation due to temperaure or barometric variations. This problem becomes paricularly acute where the detection device is used on aircraft or under other conditions of extreme density variations. Thus, in the device of the Jaeger Patent 2,465,377, since the interior of the reference chamber is hermetically sealed while the test chamber is open to atmospheric pressure, variations in atmospheric pressure influence only the test chamber and do not similarly influence the reference chamber, with the result that with the device of Jaeger, barometric pressure changes can cause a false indication of the detection device.

In the installation and operation of ionization type combustion detection devices, it is frequently necessary and desirable to make adjustments for manufacturing variations in the triggering voltage of the control tube used in conjunction with the device, and also to adjust the sensitivity of the detection device.

Another problem which arises in connection with the operation of ionization type combustion detection devices is that a number of such devices are frequently installed at spaced locations and have their outputs electrically connected in parallel so as to actuate only a single alarm device, with the result that it is sometimes difficult to identify the particular detector device which detected the combustion products.

Accordingly, it is an object of this invention to provide a combustion gas detection device of the ionization type which is not sensitive to changes in the density of the atmosphere being monitored.

It is another object of the invention to provide a combustion gas detection device of the ionization type which is compensated for changes in atmospheric pressure while still remaining hermetically sealed.

It is still another object of this invention to provide a combustion gas detection device of the ionization type including a reference chamber and a test or sensing chamber in which the reference chamber is compensated for changes in the atmospheric pressure while, at the same time, maintaining the reference chamber hermetically sealed.

It is a further object of the invention to provide in combination with an ionization type combustion detector, a convenient and accurate means for permitting adjustment of the sensitivity of the detection device and permitting compensation for manufacturing variations in the triggering voltage of the control tube.

Still a further object of the invention is to provide in combination with an ionization type combustion detection device, an indicating light which is part of the detection device assembly to give a visual indication directly at the location of the indicating device of the detection of combustion products.

Still a further object of the invention is to provide an ionization type combustion detector including a hermetically sealed and totally enclosed reference chamber which is compensated for changes in atmospheric pressure, and in which the electronic control tube of the combustion detection device is housed within the hermetically sealed reference chamber to thereby eliminate the possibility of condensate deposit on the tube due to temperature changes

which would adversely affect the operating characteristics of the tube and of the combustion detection device.

Still a further object of the invention is to provide adjustment means for equalizing the internal pressure of the reference chamber with that of the atmosphere at any time, and to permit equalizing the reference chamber pressure with the atmospheric pressure of various localities in which the fire detection device may be installed.

In achievement of these objectives, there is provided in accordance with this invention, a combustion gas detection device of the ionization type including a test chamber having radioactive material therein and open to the atmosphere, and a reference chamber electrically connected in series with the test chamber across a source of electrical potential, the reference chamber also containing a source of radioactive material therein. In accordance with an important feature of the construction, the reference chamber is hermetically sealed, but includes a means such as a flexible diaphragm or bellows for communicating variations in the external atmospheric pressure to the interior of the reference chamber, whereby the gas pressure inside the reference chamber is always compensated for changes in the external atmospheric pressure, or of the gaseous medium in which the detection device is immersed, and equalized with the gas pressure in the test chamber.

In further achievement of these objectives, there is provided in accordance with one embodiment of the invention, the combination with an ionization type combustion detector of an adjustable shielding means for the radioactive material in the test chamber to permit controlling the strength of the radiation of the test chamber. This, in turn, can be used to adjust the operating potential on the control electrode of the gaseous discharge control tube and to adjust the sensivity of the detection device. In another embodiment of the invention, there is provided the combination of an ionization type detector with a fixed source of radioactive material in the test chamber, together with the connection of the outer electrode of the test chamber to the adjustable tap of a potentiometer to permit adjustment of the total voltage across the test and reference chambers. By connecting the cathode of the gaseous discharge control tube to an end of the potentiometer, adjustment of the potentiometer tap connection to the test chamber electrode can be used to adjust the operating potential on the control electrode of the gaseous discharge tube to compensate for manufacturing variations in the triggering voltage of the control tube, or to adjust the sensitivity of the detection device.

In accordance with another feature of the invention, there is provided as part of the combustion detection device assembly, an indicating lamp which is connected between the anode and cathode of the gaseous discharge control tube in series with a normally open contact which is moved to closed position upon energization of a relay connected in series with the cathode of the control tube, to thereby energize the indicating light. Alternatively, the indicating lamp may be connected in parallel with a resistance in the anode circuit of the gaseous discharge control tube.

In accordance with a further embodiment of the invention, the gaseous discharge electronic control tube used with the combustion detection device is housed within the hermetically sealed reference chamber, thereby preventing the deposit of condensate on the control tube which would adversely affect the operation of the control tube and of the combustion detection device.

A still further feature of a modified embodiment is the provision of a screw valve member which may be opened when the combustion detection device is initially installed in any given location to equalize the pressure between the interior and exterior of the bellows, after which the screw valve is closed. This initial adjustment permits the internal pressure of the bellows to be conformed to the mean pressure at any locality where the fire detection device may be installed.

Further objects and advantages of the invention will become apparent from the following description taken in conjunction with the accompanying drawings in which:

FIGURE 1 is view of a combustion gas detection device in accordance with the invention;

FIGURE 2 is a schematic wiring diagram of the electrical circuit connections of the device shown in FIG. 1;

FIGURE 3 is a view in elevation, and partially in section, of a modified combustion gas detection device in accordance with the invention, including a schematic diagram of the electrical circuit connections;

FIGURE 4 is a view in elevation, and partially in section, of another modified combustion detection device in accordance with the invention, including a schematic diagram of the modified electrical connections therfor;

FIGURE 5 is a view in vertical section, and partially in elevation, of a modified hermetically sealed fire detection device in which the electronic control tube is housed within the hermetically sealed reference chamber;

FIGURE 6 is a perspective view of the device of FIG. 5; and

FIGURE 7 is a wiring diagram of the modified combustion detection device of FIGS. 5 and 6.

Referring now to the drawings, and more particularly to FIGS. 1 and 2, there is shown a combustion gas detector device generally indicated at 10, including a test chamber 12 which is immersed in the gas being monitored for the presence of combustion products, such as the atmosphere of a room. Test chamber 12 is bounded by a perforated metallic wall 14 made of metallic wire mesh or otherwise suitably perforated to admit the ambient atmosphere. Perforated wall 14 is mechanically and electrically connected at its upper end to a generally cylindrical metal wall 16 which, in turn, is suitably supported by a mounting base through which extend electrical connections for the various elements of the device, as will be described hereinafter. The perforated wall 14 is suitably connected through wall 16 and conductor 48 to the negative side of the direct current power source and forms the outer electrode of test chamber 12. A source of radioactive material indicated at 22, such as radium, is suitably supported upon the inner surface of wall 14 by a holder generally indicated at 23, having an adjustable shielding cap 25 and shown and described more fully in connection with the embodiment of FIG. 3.

The inner electrode 20 of test chamber 12 is positioned in chamber 12 in spaced relation to perforated wall 14. Inner electrode 20 is suitably supported by the wall of a hollow envelope generally indicated at 24, made of a dielectric material such as glass. Envelope 24 is divided into two separate compartments which respectively house a reference or comparison chamber 26 and a cold cathode gas discharge tube 28.

The reference or comparison chamber 26 has positioned on the inner wall surface thereof a conductive coating which defines an electrode 30, and a radioactive material 32 is positioned on a portion of the surface of electrode 30. Electrode 30 and radioactive material 32 are electrically connected by conductor 34 to electrode 20 positioned in test chamber 12.

A second or inner electrode 36 is positioned in reference chamber 26 in spaced relation to the walls thereof and in spaced relation to electrode 30 defined by the conductive coating. Inner electrode 36 is connected by conductor 51 to the positive side of the source of direct current electrical potential, as will be seen by reference to the wiring diagram of FIG. 2.

In accordance with an important feature of the invention, a bellows generally indicated at 38 is positioned on the outside of envelope 24 adjacent reference chamber 26 and communicates variations in the pressure of the gas being monitored to the interior of reference chamber 26, so that the gas pressure interiorly of reference cham-

ber 26 varies in the same manner as, and is equalized with, the gas pressure in test chamber 12. The volume of the bellows should be proportional to the size of the reference chamber 26 as related to the pressure of the environment in which the detection device will be used, so that the bellows can continuously equalize the pressure interiorly of reference chamber 26 with the pressure in test chamber 12.

Mounted in the same insulating envelope 24 as reference chamber 26, but separated from chamber 26 by a barrier wall 40 is cold cathode gaseous discharge tube 28 having positioned therein an anode 42, a cathode 44, and a control grid 46.

Control grid 46 of gaseous discharge tube 28 is connected by conductor 34 to the inner electrode 30 defined by the conductive surface inside reference chamber 26 and to the coating of radioactive material 32 carried by electrode 30. Control grid 46 is also connected to inner electrode 20 of test chamber 12. Thus, electrode 20 of test chamber 12 and electrode 30 and radioactive material 32 of reference chamber 26, and control grid 46 of gaseous discharge tube 28 are all at a common electrical potential. In order to prevent any external electrical influences from affecting the potential of grid 46, envelope 24 is heavily insulated in the region of barrier wall 40 of the envelope as indicated at 45.

Cathode 44 of gas tube 28 is connected to the negative side of the power source by conductor 48 and is at the same potential as the perforated screen outer electrode 14 of test chamber 12. Anode 42 of gaseous discharge tube 28 is connected to the positive side of the D.C. power source by conductor 49. A condenser 55 is connected between grid 46 and cathode 44 of gas tube 28.

A relay coil 56 is interposed in series with the output of anode 42 of gas tube 28 and when energized, operates to closed position, a normally open contact 58 in a suitable alarm or signaling circuit which, when energized, indicates that combustion products are present in the gaseous atmosphere being monitored by test chamber 12.

In the operation of the device, assuming that there are no combustion products present in the atmosphere being monitored, a current will flow through the series circuit comprising test chamber 12 and reference chamber 26, due to the potential applied between the pair of electrodes 14—20 and 30—36 of each of the respective chambers 12 and 26 and due to the presence of the radioactive material 22 or 32 in each of the respective chambers 12 and 26 which causes ionization of the air in the respective chambers and, in combination with the potentials applied to the electrodes of the respective chambers, causes a current to flow through each of the series-connected chambers.

When there are no combustion products present in the gas being monitored by test chamber 12, the voltage drops across the respective chambers 12 and 26 are such that the potential of junction point 45' to which trigger grid 46 of gaseous discharge tube 28 is connected, is such that the potential of grid 46 is not sufficiently positive with respect to cathode 44 to cause discharge and consequent ionization of gas in tube 28. However, in the presence of combustion products in the gas monitored by test chamber 12, the combustion gases in test chamber 12 present an impedance to the flow of current in test chamber 12 which causes the potential of grid or trigger 46 to become relatively more positive with respect to cathode 44, to thereby trigger the firing of tube 28, causing a current flow through relay coil 56 in the circuit of anode 42, which, in turn, closes contact 58 in the alarm circuit. When the potential of grid or trigger 46 becomes sufficiently positive to fire tube 28, condenser 55 discharges between grid 46 and cathode 44 and aids in striking an arc between cathode 44 and anode 42.

Due to the use of bellows 38, the gas pressure inside reference chamber 26 is always equalized with the pressure of the gas environment in which test chamber 12 is immersed, thereby avoiding any erroneous signals due to a mere change of barometric pressure of the surrounding atmosphere, and permitting the fire detection device to be adjusted for high sensitivity to smoke or other combustion products.

Another embodiment of the invention is shown in the drawing of FIGURE 3, which shows a combustion gas detection device generally indicated at 100 including a test chamber 102 open to the atmosphere and a reference chamber 104 which is sealed from the atmosphere, but which is subjected to atmosphereic pressure due to the use of a flexible diaphragm 106 which closes one end of reference chamber 104.

The combustion gas detection device 100 in the embodiment of FIG. 3 includes a plurality of cylindrical sections or rings 108, 110, 112, and 114 each of the same inner and outer diameter and stacked in superposed relation to each other to define a hollow cylindrical body. Rings 108, 110, 112, 114 are all made of a non-hygroscopic insulating material having a high dielectric constant, and may be made of hard rubber, for example. Axially spaced from and below the bottommost ring 108 is a metal disc electrode member 116 having the same diameter as the outer diameter of the insulating rings and axially spaced from the bottom surface of ring 108 by insulating bushings or sleeves 118, three of which may be positioned at equally circumferentially spaced points about the periphery of the device 100. Disc electrode 116 forms the bottom wall of open test chamber 102.

Insulating bolt member 120 extend through axial passages in sleeves 118 and rings 108, 110, 112, and 114, and also through an upper disc-shaped closure 122 which is clamped against the upper end of topmost ring 114, with respect to the view shown in FIG. 3, by nut members on the ends of bolts 120. Closure 122 has an aperture 142 therein which admits atmospheric pressure to the upper surface of diaphragm 106.

A holder 124 for radium or other radioactive material is rigidly fixed to the disc electrode 116, support 124 projecting upwardly into the interior of test chamber 102. Support 124 includes a post member 126 having a reduced neck portion at the upper end thereof about which is positioned the radioactive material 128. In order to control the amount of radiation of the radioactive material 128, an adjustable cap member 130 is secured to and turns with the upper end of a screw member 132, the lower end of screw 132 being received within the hollow interior of post 126 and the threaded portion of screw 132 passing through a threaded passage in the upper portion of post 126. By adjusting screw 132 against the pressure of a spring 134 positioned within the hollow interior of post 126, the position of shielding cap 130 relative to the radioactive material 128 may be adjusted to control the degree of radiation from material 128.

A metal disc 136 is received betwen the surfaces of insulating rings 108 and 110 and defines a common electrode for both the test chamber 102 and reference chamber 104. Radioactive material 137 is positioned on electrode 136 in reference chamber 104.

A second electrode in reference chamber 104 is provided by a metal disc 138 secured between the adjacent surfaces of rings 110 and 112. The disc 138 has an opening 140 therein so that there is free gaseous communication between the portion of reference chamber lying between electrodes 136 and 138 and the portion of chamber 104 lying between electrode 138 and flexible diaphragm 106.

The top wall of reference chamber 104 is formed by the flexible diaphargm 106 having its outer periphery secured between the adjacent surfaces of insulating rings 112 and 114. The flexible diaphragm 106 may be made of any suitable material such as plastic or leather which has the necessary flexibility to respond to changes in pressure of the atmosphere in which the device 100 is posi-

tioned, so as to constantly equalize the pressure between reference chamber 104 and the atmosphere surrounding the combustion detection device 100. Equalization of the gas pressures as just described of course results in constantly equal gas densities in the reference chamber 104 and test chamber 102, thereby preventing any false actuation of gas tube 150 due merely to a differential between the density of the gas in the reference chamber 104 and the gas in test chamber 102. Furthermore, the flexible diaphragm 106 maintains reference chamber 104 hermetically sealed, preventing the entrance of moisture and foreign matter which would adversely affect the operation of the device, and yet permits constant equalization of the pressure and density of the gas in reference chamber 104 to that of the surrounding atmosphere.

Metal disc 122 forms the top wall of the device 100 and is provided with an opening 142 which permits a free communication of the gaseous atmosphere outside the device 100 into the space above the flexible diaphragm 106.

The disc electrode 116 of open test chamber 102 is connected to the negative side of the direct current source of power by conductors 121, 123, while the disc electrode 138 of reference chamber 104 is connected to the positive side of the direct current source of power by conductors 125, 127. Thus, the test chamber 102 and the reference chamber 104 are connected in series across the direct current power source, with the conductive path between electrode 116 of test chamber 102 and the common electrode 136 being provided by the ionized particles due to the radiation from source 128 in test chamber 102, while the conductive path in reference chamber 104 between common electrode 136 and electrode 138 is provided by the ionized particles due to the radiation from radiation source 137 in chamber 104.

Immediately adjacent the test and reference chambers is a cold cathode gaseous discharge tube 150 including a cathode 152, an anode 154, and a control grid or trigger 156. Cathode 152 is connected to the negative side of electrical power in parallel with electrode 116 of test chamber 102, while control grid or trigger 156 is connected to the common electrode 136 of test chamber 102 and reference chamber 104. A condenser 155 is connected between grid 156 and cathode 152 and helps to initiate the arc discharge across tube 150 when the potential of grid or trigger 156 becomes sufficiently positive to fire the tube. Anode 154 of gas tube 150 is connected to the positive side of power by conductor 127 in series with a relay coil 158 which, when energized, operates a contact 160 to closed position to energize a suitable alarm device 162.

In order to provide directly at the location of the detection device 100 a visual indication of the firing of tube 150 and consequently of the presence of combustion products, an indicating light 164 is connected across anode 154 and cathode 152 in series with a normally open contact 168 which is operated to closed position upon the energization of a relay coil 166 connected in series with cathode 152 of tube 150. When tube 150 is not conducting, relay coil 166 remains unenergized, and contact 168 remains open. Consequently, indicating light 164 remains unlighted. However, if gas tube 150 becomes conducting due to the presence of combustion products, relay coil 166 is energized to close contact 168, thereby energizing indicating light 164 to provide a visual indication of the presence of combustion gases. Since a plurality of detection devices 100 may be connected to only a single alarm device 162, operation of the alarm device 162 would not necessarily indicate which one of the plurality of detection devices 100 had detected the presence of combustion products. However, by providing an indicating lamp 164 as part of the assembly of each detection device 100, the energization of any indicating lamp 164 will indicate when its associated detection device has detected the presence of combustion products.

The operation of the detection device 100 is substantially the same as that previously described for the detection device of the embodiment of FIGS. 1 and 2 and will not be described again in detail. When combustion products are not present in the vicinity of the device 100, the distribution of voltages across the series-connected test and reference chambers 102 and 104 is such that the potential of control grid or trigger 156 connected to common electrode 136 is not sufficiently positive to permit firing of gaseous tube 150. However, in the presence of combustion products in test chamber 102, the impedance to flow of ionization current in chamber 102 increases to cause a redistribution of voltages across the chambers 102 and 104 such that the potential of control grid or trigger 156 becomes sufficiently positive to trigger the firing of gaseous discharge tube 150. Conduction of tube 150 causes energization of relay coil 158 in the anode circuit of the tube to thereby close contact 160 and energize alarm device 162. Conduction through tube 150 also energizes relay coil 166 to close contact 168 and energize indicating light 164.

There is shown in FIG. 4 a modified embodiment including a combustion gas detection device generally indicated at 100' which is generally similar to the detection device shown in FIG. 3, with parts of the device 100' which are similar to the device 100 of FIG. 3 being indicated by primed reference numerals corresponding to those of FIG. 3. The device 100' will not be described in detail except to point out that it includes a test chamber 102', a reference chamber 104', a disk electrode 116' forming the bottom of text chamber 102', a common electrode 136' for the test chamber 102' and reference chamber 104', and an electrode 138' for the reference chamber 104'. A non-adjustable source of radioactive material such as radium indicated at 200 is positioned on a metal support 202 extending upwardly from the inner surface of the disk electrode 116' of test chamber 102'. A cold cathode gaseous discharge tube generally indicated at 150' forms part of the detection device assembly and includes an anode 154', a cathode 152' and a control electrode 156'.

In accordance with an important feature of the embodiment of FIG. 4, a potentiometer 204 has one of its ends 206 connected to the positive side of the direct current power source, while its opposite end 208 is connected to the negative side of the direct current power source. Disk electrode 116' of test chamber 102' is directly connected to a movable tap 210 on potentiometer 204, while electrode 138' of reference chamber 104' is connected directly to the positive side of power by conductor 212 and is thus at the same potential as the end 206 of potentiometer 204. It will be seen that the total voltage across the two series-connected chambers 102' and 104' can be adjusted by moving the position of tap 210 along the potentiometer 204.

Control electrode 156' of gaseous discharge tube 150' is directly connected to the common electrode 136' of the chambers 102' and 104'.

It will be noted in the embodiment of FIG. 4 that the potential between control electrode 156' and cathode 152', unlike the embodiment of FIG. 3, is not always equal to the potential drop across test chamber 102', since the voltage difference between control electrode 156' and cathode 152' is equal to the sum of the voltage drops across chamber 102' from electrode 136' to electrode 116', which is connected to tap 210 of potentiometer 204, plus any voltage drop which may exist across potentiometer 204 between tap 210 and end 208 of the poteniometer, depending upon the position of tap 210. By adjusting the position of tap 210, the potential of control electrode 156' with reference to cathode 152' can be adjusted to provide the proper operating voltage level at the control

electrode 156' to compensate for any manufacturing variations in the triggering voltage of the tube 150' and also to adjust the sensitivity of the detection device. Thus any necessary adjustment of the voltage level on the control electrode 156' or of the sensitivity of the detection device can be made by adjusting the posiiton of tap 210 on potentiometer 204, permitting the use of a non-adjustable source of radioactive material 200 in test chamber 102'.

In the embodiment of FIG. 4, relay coil 158' is connected in series with anode 154' to close contact 160' to energize alarm device 162' when the control tube 150' becomes conductive, as in the embodiment of FIG. 3.

Also, an indicating lamp 164' is directly connected between anode 154' and cathode 152' in series with a normally open contact 168'. Relay coil 166' is connected in series with cathode 152' and is energized when tube 150' becomes conductive to close contact 168', thereby completing the circuit of indicating lamp 164'. Since indicating lamp 164' is directly connected between anode 154' and cathode 152', the voltage which energizes lamp 164' is the voltage drop which exists across tube 150' after breakdown has occurred.

There is shown in FIGS. 5, 6 and 7 a modified fire detection device generally indicated at 300, including an outer metal shell or casing generally indicated at 302 having a downwardly tapered wall 304 terminating at its lower end in a normally horizontal base 306. As particularly shown in FIG. 6, the base 306 is cut away to leave a circular flange 308 at the outer periphery of the base, a central hub portion 310, and a plurality of radiating spoke portions 312 connecting hub 310 and outer flange 308. The surface area of base 306 not occupied by flange 308, hub 310, or radial spokes 312 defines openings 314 which permit passage therethrough of the air or gas which is being monitored for the presence of the combustion products. The tapered wall 304 is also provided adjacent the lower end thereof with a plurality of circumferentially spaced openings 316. The air or gas which is being monitored circulates through the openings 314 in base 306 and through the openings 316 in the lower portion of tapered wall 304. The outer metal casing 302, including its tapered wall 304 and its base portion 306 comprises one of the electrodes of the combustion detection device as will be described more fully hereinafter in the explanation of the electrical circuit of the device.

A holder 324 for radium or other radioactive material is rigidly fixed to the hub portion 310 of base 306. Support 324 is generally similar to the holder 124 described in connection with the embodiment of FIG. 3 and includes a post member 326 having a reduced neck portion at the upper end thereof about which is positioned the radioactive material 328. In order to control the amount of the radiation of the radioactive material 328, an adjustable shielding cap 330 is secured to and turns with the upper end of screw member 332. The lower end of screw 332 is received within the hollow interior of post 326 and the threaded upper portion of screw 332 is in screw-threaded engagement with a screw-threaded passage in the upper portion of post 326. By adjusting screw 332 against the pressure of spring 334 positioned within the hollow interior of post 326, the position of shielding cap 330 relative to the radioactive material 328 may be adjusted to control the degree of radiation from the radioactive material.

The space bounded by the base 306 of metal casing 302, by the lower end portion of the inner surface of tapered wall 304 of casing 302 adjacent openings 316, and by the lower surface of base portion 364 of common electrode 362, to be described, constitutes the test chamber 335 of the combustion detection device.

Positioned within the outer metal casing 304 and coaxially thereof, is an inner insulating housing generally indicated at 336 of a suitable plastic or other insulating material, which houses the reference chamber and the gaseous discharge control tube, as will be explained more fully hereinafter. Inner housing 336 is of hollow interior and includes an upper portion 338 of larger internal diameter and a lower portion 340 of smaller internal diameter. An annular horizontal flange 342 extends radially outwardly from the upper end of inner housing 336. A channel-shaped annular flange 344 extends downwardly from adjacent the outer peripheral edge of horizontal flange 342 of housing 336, annular channel-shaped flange 344 having a circumferential groove 346 therein which receives the upper peripheral edge of outer metal casing 304. Screws or other suitable fastening means 348 extend through apertures in channel-shaped flange 344 and through the upper edge of metal casing 304 in order to secure metal casing 304 to the inner insulating housing 336. An annular flange 350 extends vertically upwardly from the outer peripheral edge of horizontal flange 342 and is received in an annular groove 354 in an insulating base member generally indicated at 352 which is secured to the ceiling or other supporting surface on which the combustion detection device 300 is mounted. The insulating base 352 also includes a plurality of plug-in receptacles 356 which receive bayonet-type contact plug members 358 carried by housing 336 of the combustion detection device 300 to effect the various electrical connections shown in the wiring diagram of FIG. 7.

An annular flange 360 extends radially inwardly from the inner surface of lower portion 340 of insulating housing 336, and a metal electrode member generally indicated at 362 has its disk-shaped base 364 seated against and hermetically sealed to the under surface of flange 360. Integral with the disk-shaped base 364 of electrode 362 is an upstanding hollow cylindrical electrode portion 366 which extends vertically upwardly from the upper surface of base portion 364 of electrode 362. Base portion 364 of electrode 362 bounds the lower end of the reference chamber generally designated 368, the upper end of the reference chamber being bounded by the top end of the bellows 400 to be described hereinafter. Radioactive material, indicated at 369, similar to the radioactive material 328 of the test chamber, is positioned on the radially outer surface of cylindrical electrode portion 366.

Positioned coaxially outwardly of cylindrical electrode portion 366 and defining a second electrode in the reference chamber 368 is a cylindrical electrode 370 which is preferably formed of wire mesh screen metallic material. Outer cylindrical electrode 370 is radially spaced outwardly from cylindrical electrode portion 366 of electrode 362, to provide an annular space between the two electrodes 370 and 362. Fixed to the upper end of electrode 370 is a radially outwardly extending annular flange 372 which rests on and is suitably secured to a shoulder 374 in the inner wall of insulating housing 336 adjacent the junction between large diameter portion 338 and small diameter portion 340 of insulating housing 336.

The use of the wire mesh metallic screen material for outer cylindrical electrode 370 has the advantage over a solid surface electrode that the length of the travel path of the alpha particles is extended, since the alpha particles pass through the screen of which electrode 370 is formed, but return to the screen due to the electrical potential thereon. The longer travel path thus provided for the alpha particles increases the ionization in the reference chamber and insures that the reference chamber operates in its saturated range.

A cold cathode gaseous discharge control tube 380 is positioned vertically within the upstanding hollow cylindrical electrode portion 366 of electrode 362. The location of tube 380 within the hollow interior of electrode portion 366 serves to shield the tube from the radioactive material 369 positioned on the outer surface of hollow electrode portion 366, this shielding being particularly important in the region of control grid 382 of tube 380.

The control tube 380 includes a control grid 382 which extends through the lower end of tube 380 with respect

to the view shown in FIG. 5, grid 382 being electrically connected by soldering or the like to base portion 364 of common electrode 362. Tube 380 also includes anode 384 which, as best seen in the wiring diagram of FIG. 7, is connected by conductor 386 to the outer cylindrical electrode 370 in the reference chamber 368. Control tube 380 also includes a cathode 388 which is directly connected to the negative side of the power supply. The outer casing 302, including tapered wall 304 and base 306 of test chamber 335 is connected to the negative side of the power supply through a spring clip contact 389. The negative side of the power supply is conducted through the upper mounting base 352 to the insulating housing 336 through the engagement of bayonet contact plug members 358 and plug-in receptacles 356, and thence is connected to the outer metal casing 302 by spring clip contact 389 to thereby cause the casing 302 and its base 396 to become an electrode of test chamber 335.

Outer casing 302 instead of being made of electrically conductive metal may instead be made of plastic or other suitable insulating material. In this case, spring clip 389 would be eliminated and post member 326 in test chamber 335 would be directly connected to the negative side of the electric power supply through a conductor connected to a bayonet plug member 358 which in turn engages a plug-in receptacle 356 connected to the negative side of the electric power supply.

As best seen in the wiring diagram of FIG. 7, a condenser 390 is connected between control grid 382 and cathode 388 to initiate the arc discharge across gaseous discharge tube 360 when the potential of grid or trigger electrode 382 becomes sufficiently positive to fire the tube.

Anode 384 of tube 380 is connected to the positive side of the power supply in series with a resistance 392 and a relay coil 394. Relay coil 394, when energized by current flow through the output circuit of anode 384, closes contacts 396 in a suitable alarm circuit.

A signal lamp 398 which is carried by the mounting base 352 is connected across resistance 392 in the circuit of anode 384. Thus, when the potential drop across resistance 392 becomes sufficient due to the firing of tube 380 and consequent conduction through the output circuit of anode 384, the signal lamp 398 is energized to indicate that the combustion detection device 300 has been actuated by the presence of combustion products. As previously pointed out, a plurality of combustion detection devices such as 300 may be connected in parallel with each other in the circuit of a single alarm device, and the signal lamp 398 provided on each of the combustion devices 300 serves to identify which of the combustion detection devices actuated the alarm.

In order to hermetically seal the reference chamber 368 to prevent the entrance of moisture and foreign matter therein which would adversely affect the operation of the device, and also to hermetically seal the gaseous discharge tube 380 to prevent condensation of moisture and other matter thereon which would adversely affect its operating characteristics, a bellows 400 is positioned within the hollow interior of the upper portion of insulating housing 336. In addition to the functions just mentioned, the bellows 400 of course serve the important function of continuously equalizing the pressure and density of the reference chamber 368, as explained in connection with the previously described embodiments. During its pressure-equalizing movements, the bellows 400 can expand up into the recessed mounting base 352 as far as the limiting surface 355.

The bellows 400 is made of rubber or other suitable flexible material and is connected at its lower end to a vertical annular flange 404 of a mounting ring 402 whose outer periphery rests on and is sealed to the upper surface of a shoulder 406 extending radially inwardly from the inner wall surface of the upper portion 338 of insulating housing 336.

When the combustion detection device 300 is secured to its upper mounting base 352 as shown in FIG. 5, the external atmospheric pressure is communicated to the enclosed space surrounding bellows 400 by means of suitable passages 352′ in mounting base 352 which place the enclosed space surrounding the exterior surface of bellows 400 in communication with the external atmosphere.

In order to eliminate any accumulation of moisture between the outer surface of the lower end of the bellows 400 and the inner surface of insulating housing 336, a "weep hole" 403 is provided through the wall of insulating housing 336 to drain condensate in this region to the exterior of housing 336, from whence it may drain through passages 314 and 316 in outer casing 302.

In order to equalize the pressure within the interior of bellows 400 with the external atmospheric pressure when the combustion detection device 300 is first placed in operation in a given location, screw valve 408 is provided in the lower portion of insulating housing 336 below bellows 400, screw valve 408 being in screw-threaded engagement with a threaded passage in the wall of housing 336. To equalize the internal pressure of bellows 400 with that of the external atmosphere, screw valve 408 is removed, permitting pressure equalization through the threaded passage which receives the screw valve. When the pressure has ben equalized within the reference chamber, screw valve 408 is replaced in the position shown in FIG. 5.

The operation of the combustion detection device 300 is substantially the same as that previously described for the embodiments of FIGS. 1–4. When combustion products are not present in the vicinity of the device 300, the distribution of voltages across the series-connected test and reference chamber 335 and 368 is such that the potential of the control grid or trigger electrode 382 connected to common electrode 362 is not sufficiently positive to permit firing of gaseous tube 380. However, in the presence of combustion products in test chamber 335, the impedance to flow of ionization current in test chamber 335 increases to cause a re-distribution of voltage across the test and reference chambers 335 and 368, such that the potential of control grid or trigger electrode 382 becomes sufficiently positive to trigger the firing of gaseous discharge tube 380. The conduction through tube 360 causes energization of relay coil 394 in the anode circuit of the tube to thereby close contact 396 to energize a suitable alarm device. Conduction through tube 380 also provides sufficient potential drop across resistance 392 in the output circuit of the tube to energize signal lamp 398.

It will be understood, of course, that the electrical circuitry shown in FIG. 7 for use with the modified embodiment of FIGS. 5 and 6 can be used interchangeably with any of the other illustrated embodiments of the combustion detection device, and that similarly the electrical circuitry shown with the other embodiments can be used with the embodiment of FIGS. 5 and 6.

The detection device of each of the embodiments of the invention described hereinbefore is so designed and proportioned that the test chamber which is open to the atmosphere operates in the non-saturated range of its current-voltage characteristic while the closed reference chamber works in the saturated region of its current-voltage characteristic.

It can be seen from the foregoing that there are provided in accordance with the embodiments of the invention, a combustion gas or fire detector device of the ionization type which is self-compensating for changes in the density of the atmosphere being tested by the provision of a flexible bellows or diaphragm which communicates the external pressure of the gaseous atmosphere being tested to the interior of the reference chamber of the testing device, thereby equalizing the pressures in the test chamber which is open to the atmosphere and in the reference chamber which is hermetically sealed from the external atmosphere. The equalization of the pressures of the test and reference chambers with respect to each

other prevents any false operation of the device due to mere changes in the density of the surrounding atmosphere and permits the device to be used under conditions of extreme gas density variations. Furthermore, the use of a flexible diaphragm or bellows which maintains the interior of the reference chamber sealed from the external atmosphere and yet communicates any pressure changes in the external atmosphere due to changes in density of the surrounding gaseous medium, prevents the entrance into the reference chamber of any moisture or foreign matter which would adversely affect the operation of the device. The flexible bellows and flexible diaphragm disclosed in the embodiments of the invention maintain the reference chamber hermatically sealed at all times and yet permit equalization of the gas pressures and densities of the reference chamber and the test chamber.

There are also practical advantages to the several embodiments in which means are combined with the combustion detection device for adjusting the sensitivity of the detection device and for compensating for variations in the triggering voltage of the gaseous discharge control tube. Also, the provision of the indicating lamp as part of the detection device assembly, and which is energized when the gaseous discharge tube becomes conductive, provides a convenient and efficient means directly at the location of the detection device for indicating that the detection device has sensed the presence of combustion products. This is of particular value where a number of the detection devices are connected in parallel to a single alarm device, since the use of the indicating lamp as part of the detection device assembly permits a ready indication of which one of a plurality of detection devices has detected the presence of combustion products.

The embodiment shown in FIGS. 5, 6 and 7 has the further advantage that the gaseous discharge control tube is hermetically sealed in the reference chamber, thereby preventing condensation of moisture or other matter on the tube which might adversely affect the operating characteristics of the tube. Also, the embodiment of FIGS. 5, 6 and 7 has the advantage that it includes a valve device to permit equalization of the pressure interior of the reference chamber with that on the exterior of the reference chamber when the combustion detection device is first placed in operation in any given locality, to thereby permit the internal pressure of the bellows to be conformed to the mean pressure at the particular locality where the combustion detection device is installed. This adjustment is normally made only at the time of the initial installation of the combustion detection device.

While there have been shown and described particular embodiments of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention and, therefore, it is aimed to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What I claim is:

1. Apparatus responsibe to changes in the composition of a gas, comprising a first ionization chamber readily accessible to the gas to be tested and including a first electrode, a second ionization chamber including a second electrode, said second electrode including a first portion thereof forming an end closure for said second chamber, said second electrode also including a hollow cylindrical electrode portion upstanding from said first portion and extending into said second chamber, a gaseous discharge control tube positioned in said hollow cylindrical electrode portion, said control tube including an anode, a cathode and a control electrode, means connecting said control electrode to said second electrode, said second electrode defining a common electrode intermediate said first and second chambers, a third electrode, said third electrode being positioned in said second chamber coaxially of said hollow cylindrical electrode portion, means for ionizing the gases in said chambers, flexible wall means positioned at one end of said second chamber and hermetically sealing said second chamber, said flexible wall means communicating changes in pressure of the surrounding atmosphere to the hermetically sealed interior of said second chamber whereby the density of the gas in said second chamber is equalized with that of the density of the surrounding atmosphere, and power supply means connected across the anode and cathode of said control tube and across said first and third electrodes, said control tube being disposed to be energized by said control electrode upon change in the composition of the gas being tested.

2. Apparatus as defined in claim 1 in which said flexible wall means is a bellows.

3. Apparatus responsive to changes in the composition of a gas, comprising an electrically conductive hollow casing, said casing including an apertured base portion and apertures in the wall of said casing adjacent said base portion to define a first ionization chamber readily accessible to the gas to be tested, means supporting a source of radioactive material in said first ionization chamber, an insulating housing positioned in said casing substantially coaxially of said casing, said insulating housing having a hollow interior open at opposite axial ends thereof and housing in the lower portion thereof a second ionization chamber, a second electrode including a first portion thereof forming an end closure for the lower end of said insulating housing and second ionization chamber adjacent said base portion of said casing, said second electrode also including a hollow cylindrical electrode portion upstanding from said first portion and extending into said insulating housing and into the second ionization chamber therein, said second electrode defining a common electrode for said first and second ionization chambers, a gaseous discharge control tube positioned in said hollow cylindrical electrode portion, said control tube including an anode, a cathode and a control electrode, means connecting said control electrode to said common electrode of said first and second ionization chambers, a third electrode, said third electrode being positioned in said second ionization chamber coaxially of and radially outwardly of said hollow cylindrical electrode portion, a source of radioactive material in said second ionization chamber for ionizing the gas therein, flexible wall means closing the upper end of said second ionization chamber and hermetically sealing said second ionization chamber, said flexible wall means communicating changes in pressure of the surrounding atmosphere to the hermetically sealed interior of said second ionization chamber whereby the density of the gas in said second ionization chamber is equalized with that of the density of the surrounding atmosphere, and power supply means connected across the anode and cathode of said control tube and across said electrically conductive hollow casing and said third electrode, said control tube disposed to be energized by said control electrode upon change in the composition of the gas being tested.

4. Apparatus as defined in claim 3 in which said flexible wall means is a bellows.

5. Apparatus responsive to changes in the composition of a gas comprising a test chamber open to the atmosphere of the gas being tested, a first electrode being positioned in said test chamber, a hermetically-sealed gas-filled reference chamber including a hollow body member in axial alignment with said test chamber, said body member being closed at an end thereof adjacent said test chamber by an electrically conductive closure member which forms a common electrode of said test and reference chambers, flexible wall means closing the opposite end of said body member for communicating changes in pressure of the gas to be tested to the interior of said reference chamber whereby the density of the gas in the reference chamber is equalized with that of the density of the surrounding atmosphere, a third electrode positioned in said reference chamber intermediate the axial length thereof and in

axially spaced relation to said common electrode, a source of electric power, said first and third electrodes connected across said source of electric power to connect said test and reference chambers in electrical series, means for ionizing the gases in said chambers and promoting current flow therethrough, and sensing means responsive to voltage variations connected across said first and third electrodes and including a control electrode connected to said common electrode for rendering an indication of unbalanced current flow through said chambers when a change occurs in the composition of the gas being tested.

6. Apparatus responsive to changes in the composition of a gas as set forth in claim 5, in which said means for ionizing the gases in said chamber is radioactive material, and axially displaceable means for adjustably shielding the radioactive material in said test chamber to selectively control the emission from said material.

7. Apparatus responsive to changes in the composition of a gas as set forth in claim 5, including support means connected within said reference chamber, and said sensing means positioned within and supported by said support means within said reference chamber to shield said sensing means from the means for ionizing the gas in said reference chamber and to prevent moisture condensation on said sensing means when the apparatus is subjected to varying atmospheric conditions.

8. Apparatus responsive to changes in the composition of a gas as set forth in claim 7, in which said support means comprises an extended portion of said common electrode protruding interiorly of said reference chamber.

9. Apparatus responsive to changes in the composition of a gas as set forth in claim 5 in which said flexible wall means is a bellows.

10. Apparatus responsive to changes in the composition of a gas as set forth in claim 5, in which said third electrode is also disposed in concentric spaced relation with said common electrode.

11. Apparatus responsive to changes in the composition of a gas comprising a test chamber open to the atmosphere of the gas being tested, a first electrode positioned in said test chamber, a hermetically-sealed gas-filled reference chamber including a generally cylindrical body member formed of insulating material and in axial alignment with said test chamber, said body member being closed at an end thereof adjacent said test chamber by an electrically conductive disk member which forms a common electrode of said test and reference chambers, said body member being closed at the opposite end thereof by a flexible wall means which communicates changes in pressure of the gas to be tested to the interior of said reference chamber whereby the density of the gas in the reference chamber is equalized with that of the density of the surrounding atmosphere, a third electrode positioned in said reference chamber intermediate the axial length thereof and in axially spaced relation to said common electrode, a source of electric power, said first and third electrodes connected across said source of electric power to connect said test and reference chambers in electrical series, means for ionizing the gases in said chambers to inhibit current flow therethrough, and a gaseous discharge tube including an anode and a cathode connected across said third and first electrodes, and a control grid for said tube connected to said common electrode of said test and reference chambers for controlling the operation of said tube upon a change in the composition of the tested gas.

12. The apparatus defined in claim 11, including an indicating light positioned immediately adjacent said chambers and connected across said discharge tube, and relay means connected to respond to conduction of said gaseous discharge tube and connected in the light circuit to energize said indicating light upon a change in the composition of the tested gas.

13. Apparatus responsive to changes in the composition of a gas as set forth in claim 11, and including potentiometer means connected between said third electrode, first electrode and the cathode of said discharge tube, with the first electrode connected to the adjustable tap thereof for varying the responsive sensitivity of the apparatus.

14. Apparatus responsive to changes in the composition of a gas, comprising a first ionization chamber provided with spaced electrodes and readily accessible to the gas to be tested, a second ionization chamber provided with spaced electrodes, an electrode of each of said chambers commonly connected to form a series junction to connect said chambers in electrical series, said second ionization chamber acting as a comparison chamber, said second chamber being hermetically-sealed and filled with gas, said second chamber including a flexible wall portion which communicates changes in pressure of the gas to be tested to the hermetically-sealed interior of said second chamber whereby the density of the gas in the second chamber is equalized with that of the density of the surrounding atmosphere, means for ionizing the gases in said chambers, a control tube means responsive to voltage variations and including an anode and a cathode, and having a control electrode connected at the electrical junction between the series-connected chambers, a source of direct current power, said anode connected with the other electrode of said second ionization chamber and with said source of direct current power, said control electrode being adapted to trigger current conduction through said control tube means upon change in current flow through said chambers, a resistance element, means connecting opposite ends of said resistance element across said source of direct current power, an adjustable tap movable to adjusted positions along said resistance element, means connecting the other electrodes of said first and second ionization chambers between one end of said resistance element and said adjustable tap, and means connecting said cathode of said control tube means to the other end of said resistance element, whereby movement of said tap along said resistance element is effective to vary the potential of said control electrode with respect to said cathode for varying the responsive sensitivity of the apparatus.

15. Apparatus responsive to changes in the composition of a gas, comprising a first ionization chamber provided with electrode means and readily accessible to the gas to be tested, a second ionization chamber provided with electrode means, said second ionization chamber acting as a comparison chamber, said second chamber being hermetically sealed and filled with gas, said second chamber including a flexible wall portion in communication with the gas to be tested which communicates changes in pressure of the gas to the hermetically sealed interior of said second chamber whereby the density of the gas in the second chamber is equalized with that of the density of the surrounding atmosphere, means for ionizing the gases in said chambers, a voltage source connected across selected electrode means of said ionization chambers, to connect said chambers in electrical series, and means sensitive to voltage variations connected across the selected electrode means of said chambers and across said voltage source and including control means connected with the remaining electrode means of the said chambers for controlling said means sensitive to voltage variations to render an indication when a change occurs in the composition of the gas being tested.

16. Apparatus responsive to change in the composition of a gas as set forth in claim 15 with the addition of openable normally closed valve means connected to said second ionization chamber for initially setting the internal pressure of said second ionization chamber with the external atmospheric pressure of the locale to initially position said flexible wall portion in a substantially unstressed state.

17. Apparatus responsive to changes in the composi-

tion of a gas as set forth in claim 16 in which said openable normally closed valve means is a screw.

18. Apparatus responsive to changes in the composition of a gas as set forth in claim 15 in which said electrode means in said first ionization chamber and said electrode means in said second ionization chamber each comprises an individual pair of electrode members.

19. Apparatus responsive to changes in the composition of a gas as set forth in claim 15 in which the selected electrode means of the ionization chambers comprise an electrode member disposed in said first ionization chamber and an electrode member disposed in said second ionization chamber, and the remaining electrode means comprises a single electrode member common to both of said chambers.

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