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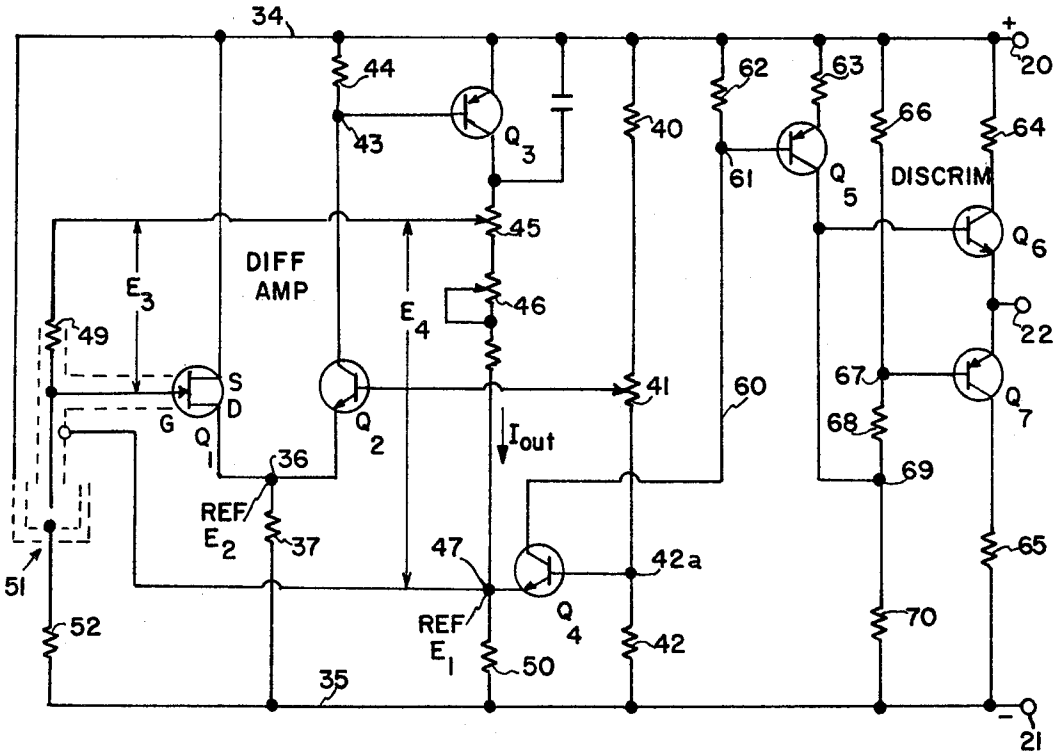
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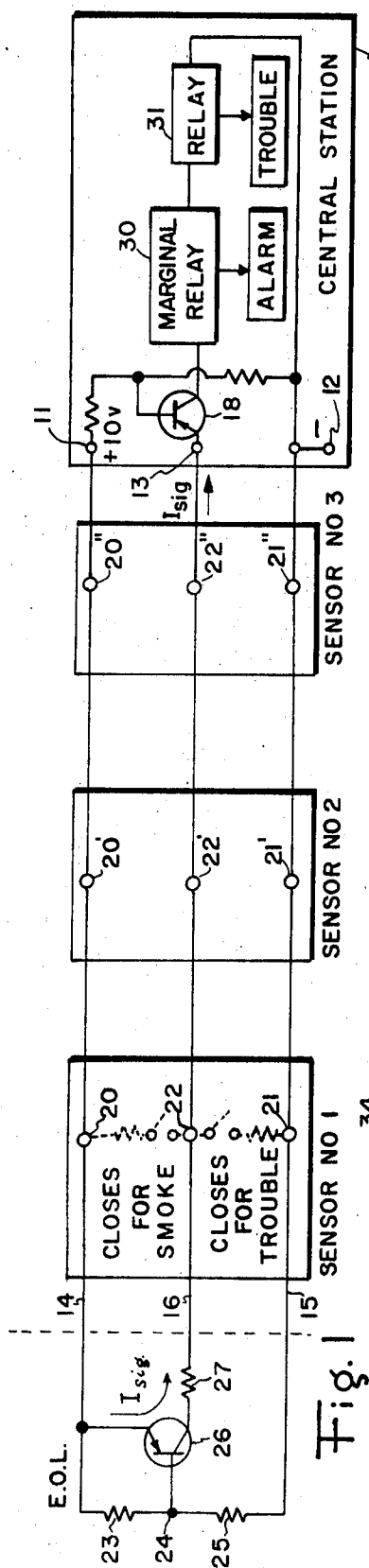
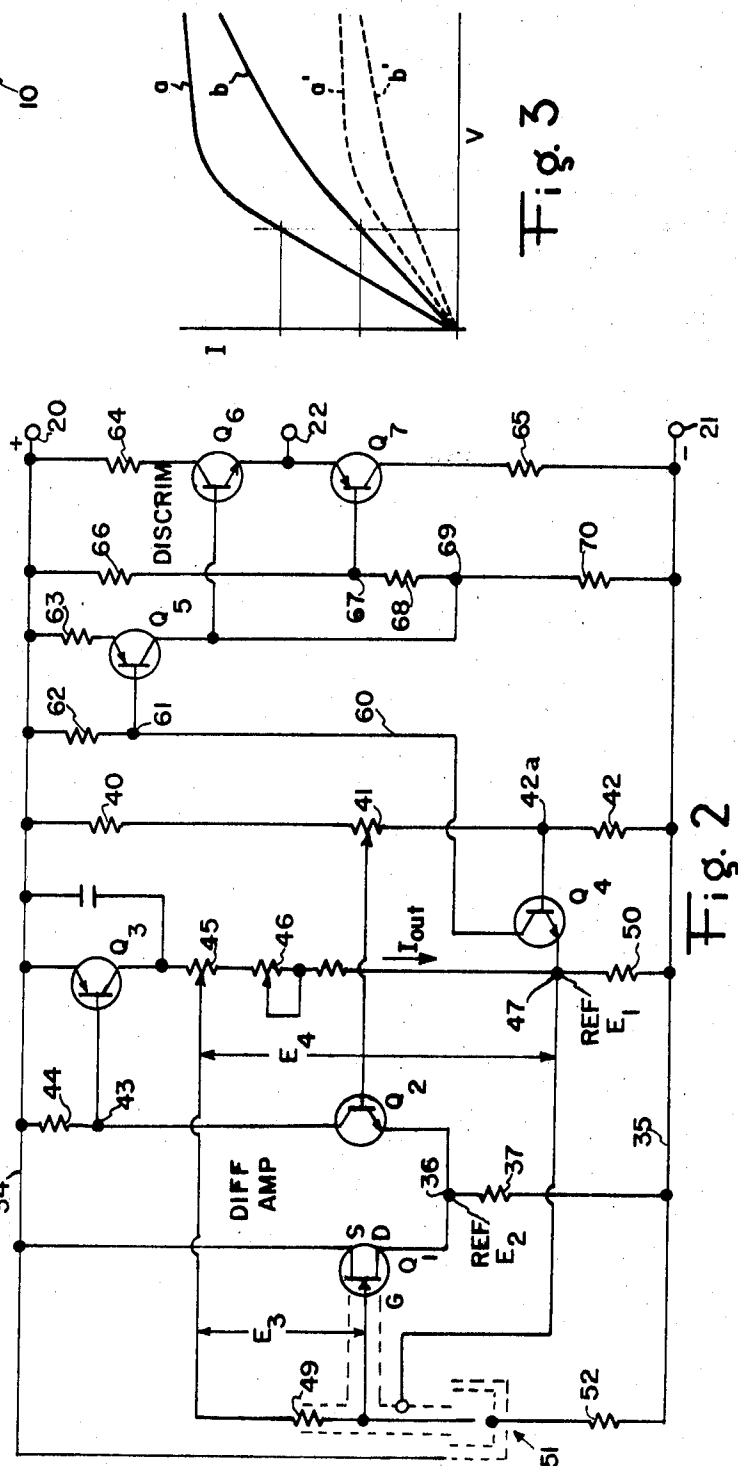
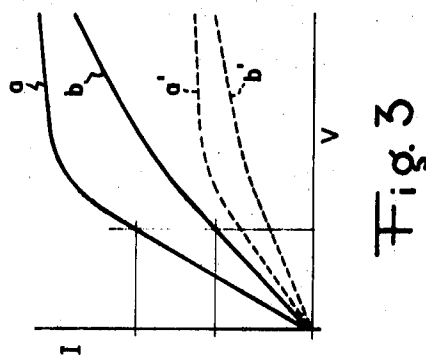
[54] **COMBUSTION PRODUCTS DETECTOR CONTROL APPARATUS**
6 Claims, 3 Drawing Figs.

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[51] Int. Cl. G08b 17/10
[50] Field of Search 340/227, 228, 237, 228. (1), 237 (S); 356/207

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ABSTRACT: A combustion products detector system having a central station and one or more remote ionization type sensing stations interconnected to the central station by a three conductor line and further having a solid-state end-of-line supervision circuit which reports back on one line that all three lines are in good condition. The remote station has an ionization detector across which is maintained a substantially constant voltage and through which a current flows, the current being reduced in the presence of combustion products. The circuit is specially designed to provide an output current which changes in direct proportion to the sensor current.





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COMBUSTION PRODUCTS DETECTOR CONTROL APPARATUS

SUMMARY OF THE INVENTION

A combustion products detector system having an ionization type sensor which is to be operated at a constant voltage and through which a current flows, the current being reduced as the presence of combustion products increases. The circuit associated with the sensor is especially designed to provide an amplified output current the magnitude of which changes in direct proportion to the sensor current.

DESCRIPTION OF THE DRAWINGS

In the drawings, FIG. 1 is a diagrammatic representation of the system of a combustion products detector;

FIG. 2 is a schematic representation of the combustion products detector sensing head and the associated electronics; and,

FIG. 3 is a graphical representation of certain operating characteristics of the apparatus disclosed in FIG. 2.

DETAILED DESCRIPTION

This apparatus is concerned with a superior alarm which will provide reliable fire alarm and more specifically will provide an alarm in the presence of combustion products such as smoke visible or invisible. A solid-state end-of-line circuit provides line supervision of all three conductors between central station and the remote sensing stations, this line supervision intelligence being transmitted back to the central station on one of the three lines. The remote sensor stations have an ionization type detector which is maintained at a constant voltage and through which a minute current flows, the current being reduced in the presence of combustion products. The ionization detector current amplifier circuit is of a special stabilized type to provide an output current which changes in direct proportion to the sensor current.

Referring now to FIG. 1, there is disclosed a supervisory or central station receiver 10 and a plurality of remote sensing units or remote sensing stations coupled by a three conductor line and terminating in a unique end-of-line line supervision apparatus. The central station has a pair of power terminals 11 and 12, terminal 11 being positive with respect to terminal 12 and providing a regulated voltage, and a third terminal 13 for receiving the signal current which is indicative of sensed conditions. Remote conductors 14, 15 and 16 are connected to terminals 11, 12 and 13, respectively, and make contact with terminals 20, 21 and 22, respectively, of each of the remote sensors which here have been identified as sensors No. 1, No. 2 and No. 3.

At the end of the remote line, here shown at sensor No. 1, there is connected an end-of-line (E.O.L.) unit which comprises connected between conductors 14 and 15 a series circuit including an impedance means or resistor 23, a junction 24 and an impedance means or resistor 25. Connected in parallel with the resistor 23 is an emitter-base circuit of a PNP transistor 26. Transistor 26 operates as a current control means and the collector circuit of the transistor 26 is connected through a current limiting impedance means or resistor 27 to the conductor 16. This end-of-line unit is effective to provide a current on line 16 to terminal 13 of the receiving unit which indicates that all three lines 14, 15 and 16 are in good condition. Under normal conditions, that is, conditions of clean air free from combustion products or smoke, the only current flowing in the conductor 16 is due to the E.O.L. circuit. If any one of the three lines 14, 15 or 16 becomes open, the current from the collector of transistor 26 is interrupted. An open condition of line 15, for example, would remove the bias from transistor 26 turning it off and reducing the current to receiver terminal 13.

The central station receiver 10 has apparatus which is sensitive to and responds to either an increase in current on conductor 16 to terminal 13 or a decrease in such current as is known in the art. Although this apparatus may take many

forms and be in the form of solid-state circuitry or relays, for explanatory purposes, the circuit within station 10 from terminal 13 is a voltage source transistor 18, a marginal relay 30 and a normally energized relay 31 to the negative terminal 12. Relays 30 and 31 might also be in the form of a three position relay which is normally biased to the center position and which will move to a third position with an increase in current and drop to a first position with a decrease in current. In the embodiment shown, the normal current flowing through transistor 26, resistor 27 and conductor 16 is sufficient to maintain relay 31 energized but is not sufficient to energize marginal relay 30. An increase in current will cause marginal relay 30 to be energized to indicate alarm and a decrease in current will cause the normally energized relay 31 to drop out and indicate trouble. By referring to sensor No. 1, it can be seen that in the event of the sensing of smoke or combustion products, a partial short will be placed across the conductors 14 and 16. This is, in effect, a resistive circuit in parallel with transistor 26 and resistor 27 so that the current flowing in conductor 16 towards terminal 13 will be increased.

Referring now to the schematic diagram of FIG. 2 which discloses the individual condition sensor circuits, power input terminals 20 and 21 are connected respectively, to conductors 34 and 35. Connected across conductors 34 and 35 is a multistage direct coupled amplifier means including a differential amplifier comprising a field effect transistor Q1 and NPN transistor Q2. The FET provides a high impedance input current, and has a potential sensitive signal or gate electrode. The drain D of transistor Q1 is directly connected to the emitter of transistor Q2 at a junction 36 which is further connected through a common impedance means or resistor 37 to the negative conductor 35. A bias circuit for the transistor Q2 is a tapped voltage divider network from conductor 34 to conductor 35 including a resistor 40, a potentiometer 41 and a resistor 42. The adjustable wiper of potentiometer 41 is directly connected to the base electrode of the transistor Q2. The collector electrode of transistor Q2 is connected through a junction 43 and resistor 44 to the positive conductor 34.

In parallel with resistor 44 is the emitter-base circuit of a PNP transistor Q3, the base electrode being directly connected to junction 43. The collector electrode of transistor Q3 is connected through further impedance means including a potentiometer 45, and a variable resistor 46 to a reference potential junction 47. A resistor 50 connects junction 47 to the negative conductor 35. The junction 47 is connected to the emitter of an NPN transistor, the base of which is connected to the junction 42a of the voltage divider, whereby current flows through the base-emitter of transistor Q4 and resistor 50 to keep the potential at junction 47 maintained at a reference potential or fixed level E1.

The adjustable wiper of potentiometer 45 is connected through a high impedance resistive feedback means 49, which may be in the order of 10,000 megohms, to the gate electrode of FET transistor Q1. The gate electrode of the transistor Q1 is also connected through a high impedance ionization chamber 51 to the negative conductor 35. This combination by suitable adjustment of potentiometer 41 biases the gate electrode to a predetermined potential magnitude which is the same as E1. The sensor 51 is a combustion detector of the ionization chamber type, and may be, for example, of the type shown in the copending application of Skildum, Ser. No. 657,826, filed Aug. 2, 1967, and assigned to the same assignee as the present invention.

The sensor 51 has a single sensing chamber formed by a cylindrical cathode and a centrally located pinlike anode which carries a radioisotope serving as a source of beta particles. In operation, when smoke enters the interelectrode space, a decrease in current is observed. A guard ring for the high impedance anode of the sensor 51, the feedback resistor 49 and the gate of Q1 is connected to the junction 47 and is biased by the reference potential E1 developed across resistor 50.

The collector electrode of transistor Q4 is connected by means of a conductor 60, a junction 61 and a resistor 62 to conductor 34. The resistor 62 provides the bias for a further transistor Q5, which has its base directly connected to junction 61 and its emitter connected by a resistor 63 to the conductor 34. The collector of transistor Q5 is connected to the input of a discriminator to be described below. The discriminator comprises two normally nonconductive transistors Q6 and Q7, transistor Q6 being an NPN type transistor and Q7 being a PNP type. A circuit path may be traced from the conductor 34 through a resistor 64, the collector-emitter of transistor Q6, output terminal 22, the emitter-collector circuit of transistor Q7, and through a resistor 65 to the negative conductor 35. A further biasing portion of the discriminator may be traced from the conductor 34 through a resistor 66, a junction 67 which is directly connected to the base electrode of transistor Q7, a resistor 68, a junction 69, and resistor 70 to the negative conductor 35. The collector electrode of Q5 is directly connected to the base electrode of transistor Q6 and to the junction 69.

OPERATION

In considering the operation of the system disclosed in FIG. 1, let it be assumed that all of the sensors are enveloped in clean air, that is, there is an absence of products of combustion such as smoke in the environment of the sensors. Under these conditions, the current I_{sig} flowing into terminal 13 is determined by the magnitude of resistance 27 and the voltage between terminals 11 and 13. It may be seen that a current will flow from positive terminal through conductor 14, resistors 23 and 25 and conductor 15 to terminal 12 to thereby bias to a saturated state of conduction the E.O.L. transistor 26. The resulting current flowing in the conductor 16 will be limited not by the transistor but by resistor 27. The magnitude of I_{sig} is of such a value that relay 31 is energized and marginal relay 30 is not energized. If any of the sensors detects the presence of combustion products there will be, in effect, a resistive path connected between terminals 20 and 22 to parallel the E.O.L. current and increase the value of I_{sig} on conductor 16. An increase in current on conductor 16 will be effective to actuate the marginal relay and operate the alarm controlled by the marginal relay. A decrease in the value of I_{sig} caused by an open in one of the conductors 14, 15 or 16 or by trouble in one of the sensors will allow relay 31 to drop out and actuate the trouble indicator in the central station receiver 10.

Turning now to the operation of FIG. 2, it should first be noted that there are several requirements which the operating circuit must meet. A first of these requirements is that the voltage existing across the ionization sensing element 51 between anode and cathode remain constant. It is also a necessary requirement that the circuit be capable of being calibrated for decreasing sensor cell-sensitivity wherein the gain of the amplifier is increased as the circuit is recalibrated.

The ionization chamber-type combustion products detector has a pair of spaced anode and cathode electrodes wherein the anode carries thereon a radioactive source of beta particles such as Ni 63 for rendering the air in the chamber conductive and causing an ionization current in the interelectrode space. The magnitude of the ionization current depends upon whether the ions are formed in pure gases such as air, or in gases that are mixed with products of combustion such as air mixed with smoke and the various gases given off as a result of combustion. The ions are produced in the space between the electrodes by means of the radioactive source. To insure stable operation, an electrostatic shield is provided by means of a third electrode surrounding the first two electrodes.

An overall view of the quiescent operation of the circuit of FIG. 2 shows a constant current flowing through resistor 37 with this current being split between currents flowing through the FET transistor Q1 and transistor Q2. Similarly, a constant current is flowing through the resistor 50 with this current being the sum of the currents flowing through transistors Q3

and Q4. The current flowing in transistor Q5, which controls the discriminator, is a function of the current in transistor Q4. Under normal operating conditions, that is, when there is no smoke being sensed by the sensor 51, neither of the discriminator transistors Q6 nor Q7 is conductive.

Two reference potentials are maintained in the circuit with respect to negative conductor 35, the first reference potential E_1 being at junction 47, that is, the constant voltage across resistor 50 is maintained by the fact that the voltage drop from base to emitter of transistor Q4 is approximately 0.5 of a volt, and the base electrode of transistor Q4 is connected to a fixed point on the voltage divider comprising resistors 40, 41 and 42. Because the transistor Q4 maintains a constant potential at junction 47, the resistor 50 may be thought of as a constant current generator, if desired. The transistors Q3 and Q4 are both normally conductive and it should be apparent that with a constant current flowing through the resistor 50 a change in the conduction of transistor Q3 results in an equal and opposite change in the conduction of transistor Q4.

The second reference potential E_2 at junction 36 is maintained by the transistor Q2 since its base electrode is connected to the adjustable wiper of potentiometer 41 of the voltage divider. The junction 36 is thus clamped to a voltage of about 0.5 volts less than the setting of the wiper on potentiometer 41. The fixed reference voltage E_2 at junction 36 results in a constant current flowing through the resistor 37 which may be thought of as a constant current generator, if desired. Thus the differential amplifier comprising transistors Q1 and Q2, both of which are normally conductive, divide up the current flowing through resistor 37 and an increase in the current through transistor Q1 results in an equal and opposite decrease in the current flowing through transistor Q2.

In a typical operating circuit as shown in FIG. 2, the resistive feedback means 49 may be of a value in the order of 10,000 megohms and the clean air impedance of sensor 51 may be in the order of 27,500 megohms so that about 180×10^{-12} amperes flows through the sensor 51 from anode to cathode, and a voltage of 5 volts is maintained at the gate electrode of the transistor Q1. Approximately 0.8 of a volt bias exists between gate and drain of transistor Q1 and therefore the reference E_2 is maintained at 5.8 volts by adjusting the wiper on potentiometer 41 to a setting of approximately 6.3 volts. Since the voltage at the gate of transistor Q1 is 5 volts, the guard ring surrounding the anode of the cell 51 and the feedback resistor is also maintained at 5 volts, this reference E_1 being maintained by having the base electrode of Q4 tied to a voltage of approximately 5.5 volts on the voltage divider.

The guard ring is necessary because of the extremely high impedance circuit to the gate of FET transistor Q1 to prevent leakage currents from disturbing the balance of the system.

Let it now be assumed that products of combustion become present in the area of ion sensor 51. The presence of products of combustion in the chamber of the sensor reduces the ionization current flow through the sensor and in effect, increases the interelectrode impedance. Turning momentarily to a consideration of FIG. 3, it may be seen that curve *a* shows the current versus voltage curve for clean air of sensor 51 while curve *b* shows the current versus voltage curve for air which includes a given quantity of combustion products. This reduction in current through the sensor will tend to increase the potential at gate G of transistor Q1 with the result that the current flowing through the output circuit of transistor Q1 tends to increase. As has been explained above, any incremental increase in the current flowing through Q1 results in an incremental decrease of the same amount in the collector current of transistor Q2. Direct coupled amplifier Q3 amplifies this incremental reduction in current of Q2 so that less current flows through Q3 and resistors 45 and 46. The potential at the wiper of potentiometer 45 moves in a less positive direction, that is, the potential E_4 is reduced. The voltage E_3 across feedback impedance 49 is also reduced to restore the potential at gate G towards its steady state value.

A consideration of FIG. 2 reveals that the voltage E3 across feedback resistor 49 is equal to the voltage E4 which exists between the wiper of potentiometer 45 and the reference potential E1 at junction 47. This results because the voltage at the gate of Q1 and the reference voltage E1 at junction 47 are initially set to be identical, the upper terminal at which E3 and E4 are measured (the wiper of potentiometer 45) is common, and the voltages E3 and E4 increase and decrease together and remain equal. As a result, the current I_{out} flowing at the output of the primary portion of the amplifier, that is, through impedance or resistors 45 and 46, is directly proportional to the current through sensor 51, which is also the current through feedback resistor 49. It is recognized that the current I_{out} is of much larger magnitude than the current in the sensing circuit.

The reduction in current I_{out} through transistor Q3, and resistors 45 and 46 results in an increase in collector current of output conditioning amplifier transistor Q4 by an amount equal to the decrease through Q3, since a constant current flows through resistor 50. As a result, transistor Q5 conducts more, its collector potential changes in a positive going direction and discriminator transistor Q6 becomes conductive. Current then flows from the positive conductor 20 through the resistor 64 and transistor Q6 to the conductor 22. This has the effect of increasing the value of I_{sig} to pull in the marginal relay 30 and actuate the alarm.

After several years of operation, depending upon the half-life of radioactive material in the sensor 51, the sensitivity of the sensor 51 will be decreasing, i.e., its interelectrode impedance increases, and the curves showing current versus voltage for clean air and for air containing products of combustion may now be represented by curves a' and b' of FIG. 3. It will be understood that there is a very gradual shift downward in the slope of these curves as the radioactive element becomes less active. It will further be noted from FIG. 3 that the curves a' and b' are not separated by as large a current difference as are the original curves a and b so that it may be said that the sensitivity of the sensor 51 is decreased. The circuit is designed so that a recalibration of the input to correspond to the new quiescent clean air operating point of the sensor will also increase the gain of the amplifier. When a recalibration becomes necessary, the wiper of voltage divider 45 is moved in a downward direction to a less positive setting so that the original voltage of the gate (in the example, 5 volts) is again obtained. It will be noted that the signal developed at the output of transistor Q3 appears across resistors 45 and 46 but that as the wiper of potentiometer 45 is moved downwardly, a lesser portion of the signal developed across these resistors is applied as negative feedback through the resistor 49. With less negative or degenerative feedback applied, the gain of the amplifier is increased to compensate for the reduction in sensitivity of the element 51.

If during operation, the sensor 51 should somehow become shorted or if various elements of the circuit should fail, so that the conduction of transistor Q5 is reduced below its normal value the potential at junction 69 will be less positive and transistor Q7 will receive a forward bias through resistor 68 whereby it becomes conductive. This provides a resistive path between conductors 22 and 21 through the transistor Q7 and resistor 65 which has the effect of reducing toward zero the current I_{sig} , which flows through conductor 16 to the terminal 13. The normally energized relay 31 then drops out to give a trouble indication.

Resistor 65 is chosen so that the current through Q7 can cancel the E.O.L. current flowing to terminal 13 of the central station without excessive current through Q7. Resistor 64 is chosen so that when transistor Q6 is switched on, it produces sufficient additional current to terminal 13 to cause the marginal relay to operate for alarm even if another sensor had already produced a trouble indication. This allows alarm operation of the system even while waiting repair of a trouble condition in one of the sensors.

I claim:

1. Control apparatus for a products-of-combustion detector comprising:

a source of potential having a first terminal and a common terminal;

means for developing a first reference potential with respect to said common terminal;

means for developing a second reference potential with respect to said common terminal;

differential amplifier means having an input stage comprising a field effect transistor, said amplifier means including said means for developing a first reference potential;

further amplifier means comprising second transistor means which has a plurality of electrodes including a control electrode and a first and second current carrying electrode, said first electrode being conductively connected to said first terminal and said second electrode being connected by junction means and impedance means to said second reference potential;

a sensing circuit connected in controlling relation to said field effect transistor signal electrode including products-of-combustion sensing means and resistive feedback means, said feedback means being connected to said junction means and normally biasing said field effect transistor signal electrode to a potential equal to said second reference potential whereby the potential existing across said feedback means remains of essentially the same magnitude as the potential existing across said impedance means so that the current flowing through said impedance means is proportional to the current flowing in said high impedance sensing circuit.

2. The apparatus of claim 1 in which said amplifier means, junction means and impedance means further comprises a potentiometer, one terminal of which is conductively connected to said second transistor means, the other terminal of which is conductively connected to said second reference potential and the adjustable wiper of which is connected to said resistive feedback means, so that when over a period of time said products-of-combustion sensing means loses its original degree of sensitivity, its effective impedance increases and said normal biasing potential tends to change, a readjustment of said adjustable wiper to restore said normal biasing potential simultaneously changes the gain of said amplifier means to compensate for the decreasing sensitivity of said products-of-combustion sensing means.

3. Control apparatus for use with a high impedance condition sensor comprising:

direct coupled amplifier means having a first and a second terminal to be energized from a source of potential and further including;

a field effect transistor having a pair of current carrying electrodes and a signal electrode, the signal electrode providing a potential sensitive input stage;

a reference voltage of a predetermined magnitude with respect to one of said terminals;

an output transistor having current carrying electrodes and a control electrode;

resistive means having first and second extremities and an intermediate tap;

a series circuit connected from said first terminal to said reference voltage, said circuit comprising the current carrying electrodes of said output transistor in series with said tapped resistive means, one of said electrodes being connected to said first terminal and one of said extremities being connected to said reference voltage, the other electrode and second extremity being connected together;

a sensing circuit having a current flow therethrough and connected in a controlling relation to said amplifying means input stage, said circuit including a products-of-combustion sensor of the ionization chamber-type connected between said input stage and said second terminal, and resistor feedback means connected to said input stage, said current flowing through said resistor feedback

means and ionization chamber biasing said signal electrode to a voltage which is equal to said predetermined potential magnitude; and

conductive connecting means connecting said resistor feedback means to said intermediate tap of said resistive means so that the potential existing across said resistor feedback means changes with and remains of substantially the same magnitude as the potential existing across said resistive means portion between said tap and said reference voltage whereby the amplified current flowing through said resistive means is proportional to the current flowing in said sensing circuit.

4. The apparatus of claim 3 in which said resistive means comprises a potentiometer, one terminal of which is connected to said output transistor, the other terminal of which is conductively connected to said reference potential and the adjustable wiper of which is connected to said resistor feedback means, so that if the sensitivity of said condition sensor decreases whereby its effective impedance increases, and the biasing of said signal electrode tends to change from said predetermined potential magnitude, a readjustment of said ad-

justable wiper to restore said signal electrode to said predetermined potential magnitude simultaneously increases the gain of said amplifier means to compensate the control apparatus for the decreasing sensitivity of said condition sensor.

5. The apparatus of claim 3 wherein said sensing circuit is subject to undesired leakage currents to surrounding structure, the apparatus further comprising: guard ring means energized from said reference voltage and positioned to effectively isolate said sensing circuit from the surrounding structure to eliminate said leakage currents.

6. The apparatus of claim 3 in which said reference voltage comprises:

a tapped voltage divider network energized from said first and second terminal; and

further transistor means having its input electrodes connected between a tap on said voltage divider network and one terminal of impedance means the other terminal of which is connected to said second terminal whereby said reference potential is maintained across said impedance means.

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