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[54] **TOXIC GAS INDICATOR**

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[52] **U.S. Cl.** ..... **340/237 R;** 340/285

[51] **Int. Cl.** **G08b 17/10**

[58] **Field of Search** ..... 340/237 R, 237 S, 381, 340/285; 23/232 E, 254 E, 255 E; 73/27 R

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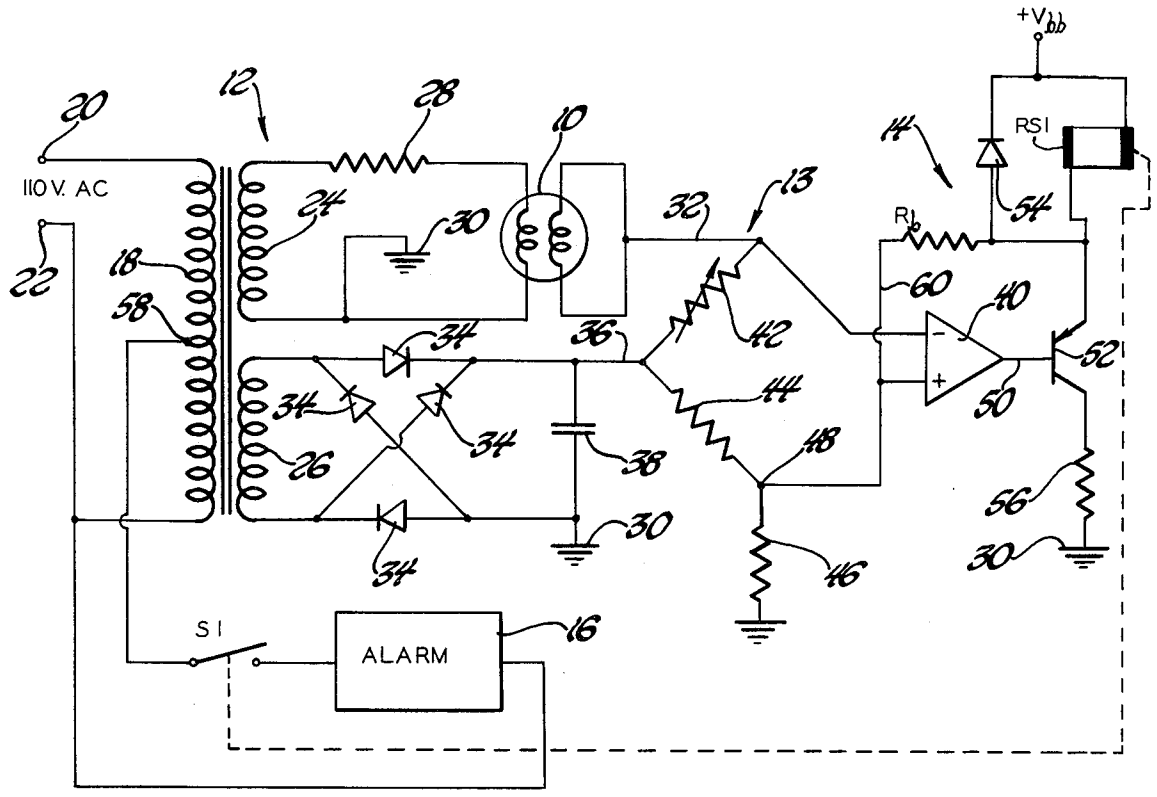
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[57] **ABSTRACT**

A toxic gas detection and alarm system comprising a variable resistance semiconductor type sensor connected in a bridge circuit and compared to a reference voltage to control a relay circuit for an alarm device. The voltage comparison is carried out by means of an amplifier and switch arrangement having a positive feedback circuit for controlling a "hysteresis" effect in the overall detector circuit sensitivity. An autotransformer having a tapped primary and a pair of secondary windings is used to energize the sensor and to provide the bridge reference voltage such that turning the alarm device on results in increased sensor energization current. This increase in energization causes a decrease in sensor sensitivity and an automatic purging of the sensor area.

7 Claims, 3 Drawing Figures



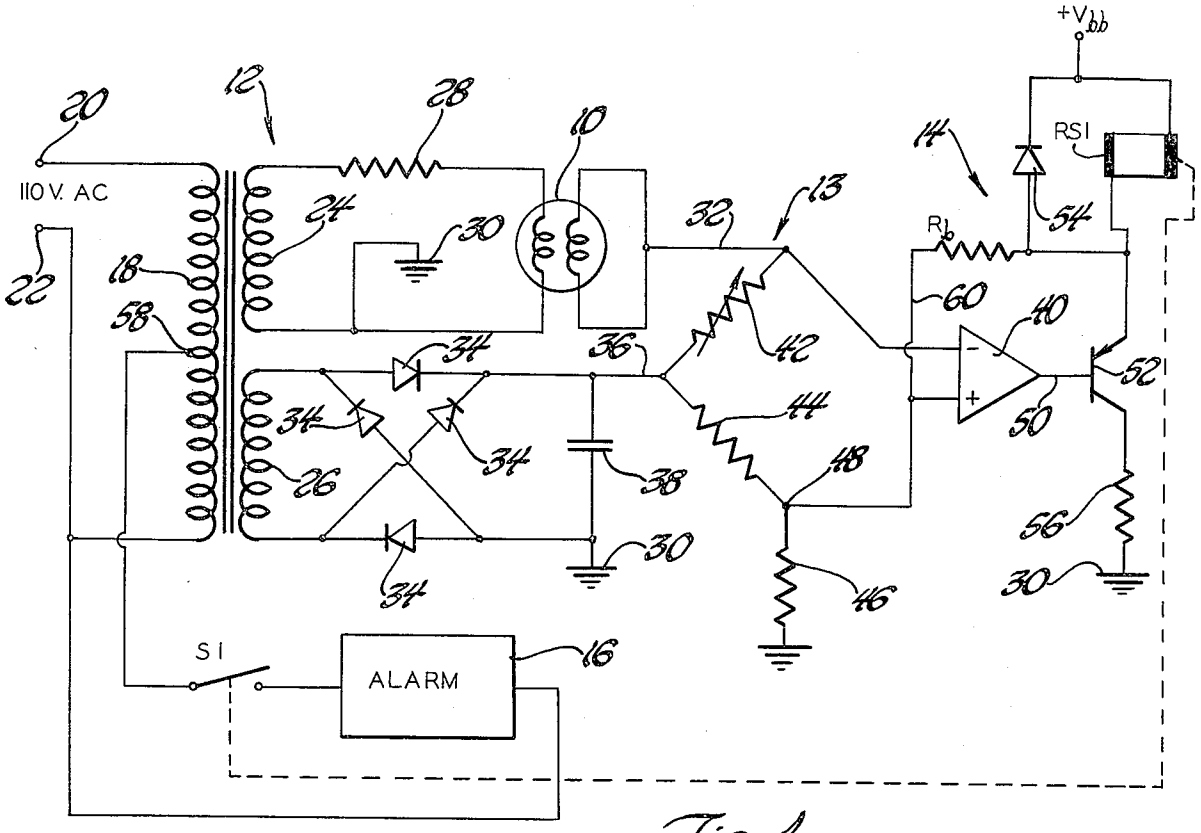


Fig. 1

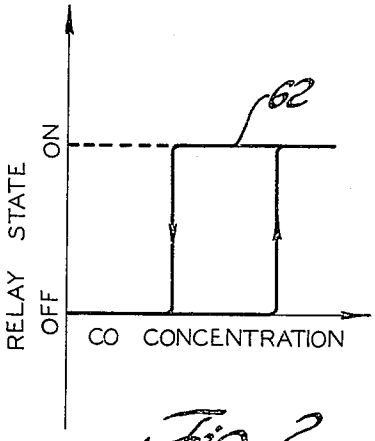


Fig. 2

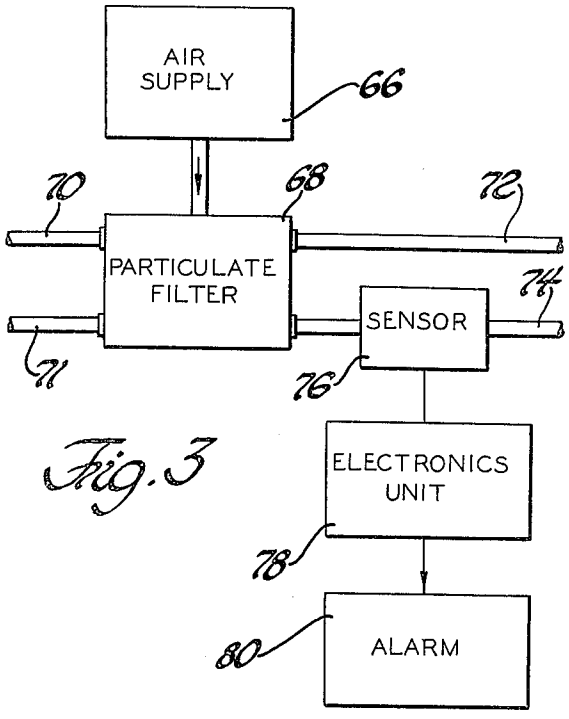


Fig. 3

TOXIC GAS INDICATOR

INTRODUCTION

This invention relates to toxic gas alarms and particularly to an improved detector and alarm system using a solid state sensor device which presents a varying electrical resistance characteristic in response to the presence of a toxic gas such as carbon monoxide, propane, butane, alcohol, gasoline and other hydrocarbons.

BACKGROUND OF THE INVENTION

The growing awareness of the harmful effects of a high toxic gas level in the air has resulted in an increased need for sensitive and reliable devices for detecting the presence of such gases in dangerous quantities and for providing a suitable indication when an alarm condition exists. Some early prior art devices have employed heated platinum wires for burning the gases and suitable detector means for indicating the burning condition. However, such prior art devices consume substantial amounts of power and thus do not lend themselves to situations and applications where a low power portable or semiportable device is required.

Later, improved prior art devices include substantially improved semiconductor type sensors which present a varying electrical resistance characteristic in response to the presence of the toxic gas, but such sensors have heretofore been primarily combined with associated circuitry which produces a relatively low sensitivity as well as other problems such as line voltage sensitivity and instability. One such prior art circuit includes an SCR switch connected to receive the varying voltage which results from the variable resistance characteristic to switch current through a relay which in turn controls an alarm device. It can be readily appreciated that such a detector circuit is sensitive to line voltage variations and in fact may create an instability problem in that the switching of the alarm device to the energized condition inherently results in a line voltage drop across the sensor. In addition, it has been found that the typical metal oxide type solid state sensor exhibits an alternating current component in the output signal which can aggravate the instability problem unless suitable compensation means are employed.

Accordingly there exists a need for a substantially improved toxic gas sensor using semiconductor type sensors so as to provide increased reliability, simplicity and sensitivity to a much greater degree than has heretofore been available.

BRIEF SUMMARY OF THE INVENTION

In accordance with the present invention a toxic gas detector and alarm system is provided wherein the sensitivity to line voltage variations of the prior art devices is effectively eliminated. In general this is accomplished by means of a detector circuit for use in combination with a semiconductor, variable resistance type sensor, the sensor being connected as a component in a bridge circuit such that an electrical signal quantity related to the toxic gas presence is compared to a reference signal. In the preferred embodiment, the electrical signal quantity and the reference signal are generated from the same supply line thereby to maintain a constant amplitude ratio irrespective of line voltage variations.

In accordance with a second feature of the present invention, means are provided to effectively eliminate any cycling effect which might otherwise result from the AC component of the sensor signal and for providing, in addition, a variable "hysteresis" effect to accommodate various sensitivity curves as may be required in various sensor applications. In general this is accomplished by means of a detector circuit for use in combination with a semiconductor sensor of the variable resistance type wherein feedback means are provided between the output and the input of a control circuit thereby to effectively increase the sensitivity of the overall detector system to toxic gas level once an alarm condition has been reached. In accordance with the preferred embodiment of the invention hereinafter described in detail the control circuit includes an operational amplifier functioning as a comparator to control the on and off states of a transistor switch, and a feedback circuit comprising a resistor, which may be variable, between the primary circuit of the transistor switch and one of the inputs of the operational amplifier thereby to facilitate the variable "hysteresis" characteristic in a simple and highly economical fashion.

In accordance with a third feature of the invention an input circuit of novel design is provided to eliminate the inherent droop in line voltage typical of the prior art devices when the alarm condition obtains and, in fact, to provide a slight increase in the energizing signal to the sensor thus to effectively decrease sensor response and purge the sensor area by increasing the temperature and oxidation rate of the sensor device. In the preferred embodiment to the invention hereinafter described in detail, this specific objective is met and accomplished by means of an input circuit in the form of an autotransformer having tapped primary winding and a pair of secondary windings, one of the secondary windings being employed for the purpose of energizing the sensor and the other secondary winding being employed to generate a reference voltage. The tapped primary winding is adapted to be connected to a supply line and is also connected to the alarm device, such as a buzzer or light or combination of such devices, through a relay controlled switch. When the alarm condition obtains and the relay controlled switch closes, the effect of the autotransformer is to increase current through the secondary winding which supplies the energizing signal to the sensor thus to increase the temperature of the sensor and effectively decrease its response to the toxic gas level.

These and other features and advantages of the invention will be best understood by reference to the following specification which describes a specific embodiment of the invention in detail.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic circuit diagram of an illustrative embodiment of the invention and employing a metal oxide semiconductor sensor device;

FIG. 2 is a representation of the "hysteresis" effect which is provided by the circuitry of FIG. 1; and

FIG. 3 is a block diagram of an air supply system for a plurality of users wherein the sensor and associated circuitry of FIG. 1 are employed to indicate and constantly monitor the quality of air being delivered to a plurality of recipients.

DETAILED DESCRIPTION OF THE SPECIFIC EMBODIMENT

Looking now to FIG. 1 the specific and illustrative

embodiment of the invention is shown to comprise a circuit including a metal oxide semiconductor sensor **10** which presents a variable resistance characteristic when exposed to toxic gases such as carbon monoxide, propane, butane, alcohol, gasoline and other hydrocarbons. The sensor **10** is connected to an input or energizing circuit **12** hereinafter described in detail to provide a suitable AC energization of the sensor as well as to provide a DC signal for energization of a bridge circuit **13.** The sensor **10** is further connected to an output or control circuit **14** which responds to the variable resistance characteristics of the sensor to control the condition of an alarm device **16.** As previously described the alarm device **16** may be any of a large number of devices including lights, buzzers, bells, strip chart recorders and other indicating and data collecting devices.

The sensor **10** is preferrably a metal oxide semiconductor device having a resistance characteristic which changes in the presence of a contaminating gas such as those mentioned above. In addition such semiconductor devices are highly responsive to the magnitude of the energizing signal; ie, an increase in the magnitude of the energizing signal quantity results in an increase in the temperature of the sensor and this temperature increase results in a higher rate of oxidation of the toxic gas being sensed thus to appear as a decrease in sensitivity or response. A suitable device is available from Figaro Engineering of Osaka, Japan and is described in the U.S. Pat. to Taguchi, No. 3,631,436. The schematic circuit representation of FIG. **1** is taken from the disclosure of the Taguchi patent. The metal oxide semiconductor device available from Figaro Engineering exhibits a normal resistance on the order of 100,000 ohms in air at room temperature and a resistance of approximately 100 ohms in a heavy alcohol vapor. Accordingly the sensitivity and response range of such devices is particularly suitable for use in the present invention.

Describing the circuit of FIG. **1** in greater detail, the input circuit **12** is shown to comprise an autotransformer having a tapped primary winding **18** adapted to be connected across a 110 volt AC supply by means of terminals **20** and **22.** The autotransformer further comprises separate secondary windings **24** and **26** of which the secondary winding **24** is connected through a current limiting resistor **28** to the input side of the semiconductor sensor **10.** The other side of the secondary winding **24** is connected to ground **30** as shown. The output side of the sensor is represented by line **32** and carries the electrical signal quantity of the illustrative embodiment which represents the toxic gas level being sensed. This signal is applied to the bridge circuit **13** which may be considered as part of output or control circuit **14** as hereinafter described.

Secondary winding **26** is connected through a conventional rectifying bridge made-up of diodes **34** to an output line **36** which is applied to the bridge circuit **13.** A capacitor **38** is connected between line **36** and ground **30** to filter out any AC component which might be present and to provide a relatively uniform constant level DC signal as the bridge energization signal quantity.

The bridge circuit **13** comprises one leg effectively made-up of the variable resistor **42** and the sensor **10,** the supply for the leg of the bridge including resistor **42** coming from the diode rectifier bridge by way of line **36.** The other leg of the bridge circuit comprises fixed and equal value resistors **44** and **46,** the midpoint or junction **48** of which is representative of the point at which the reference signal is obtained.

Output or control circuit **14** comprises as the primary active element thereof an operational amplifier **40** which functions as a voltage comparator and which is provided with a positive input connected to junction point **48** between the resistors **44** and **46** in the reference leg of the bridge circuit previously described. The negative input of operational amplifier **40** is connected to the variable leg of the bridge circuit thus to receive the output of the sensor **10.** The values of the resistors **42, 44,** and **46** are set such that the inputs to the operational amplifier **40** are normally unbalanced; i.e., the negative input voltage is greater than the positive input and, thus, a low voltage signal appears on output **50** of the amplifier.

The signal on output **50** is applied directly to the base or control electrode of the transistor switch **52** shown in FIG. **1** to be of the pnp type. The emitter-collector circuit of transistor switch **52** is connected in series with a supply source *Vbb*, the parallel combination of a relay coil RS1 and diode **54,** and a series resistor **56** which is connected to ground **30.** The low voltage output of the operational amplifier **40** appearing on line **50** is effective to maintain the transistor switch **52** in the conductive condition as long as no toxic gas contamination is detected by the sensor **10.**

As indicated by the reference characters RS1 and S1 on the relay coil and switch, respectively, the flow of current from the source *Vbb* through the relay coil RS1 and the transistor **52** operates to maintain the switch S1 between the center tap **58** of the transformer primary winding **18** and the alarm device **16** in the open condition. Any failure of current to flow through the relay coil RS1 results in the immediate closure of switch S1. When the switch S1 is open, no current flows through the alarm device **16** and, accordingly, no warning or indication of toxic gas presence is given. However, any failure of current to flow through the coil RS1 results in the immediate closure of switch S1 thus causing the current to flow through the alarm device **16** to indicate the exposure of the sensor **10** to a toxic gas. It can be seen that the automatic closure of switch S1 upon failure of current to flow through the relay coil RS1 is a "fail-safe" feature in that any loss of signal or circuit failure in the system of FIG. **1** between the secondary windings of the transformer and the output circuit of transistor **52** will result in the indication of an alarm condition.

As previously mentioned, the bridge circuit comprising resistors **42, 44,** and **46** and the sensor **10** is initially unbalanced; i.e., the resistor **42** is set so that the voltage on line **32** is greater than the voltage appearing at point **48.** Accordingly, the operational amplifier **40** produces a "low" output which is at, or near, ground level potential. A negative base-emitter bias on transistor **52** renders it conductive and causes current to flow through the relay coil RS1. This maintains switch S1 open and holds off the alarm indication. Should any variation in line voltage occur, such variation is reflected equally into the secondary windings **24** and **26** and, accordingly, the bridge remains unbalanced since the sensor signal and the reference signal quantities remain in the same ratio. On the other hand, should sensor **10** be exposed to a toxic gas of sufficient concentration, the

voltage on line **32** is caused to decrease until it equals the voltage at point **48.** At this time the operational amplifier **40** switches to a "high" output condition rendering transistor **52** nonconductive. This terminates the flow of current through the relay coil RS1 and permits switch S1 to close. With switch S1 closed, current flows from terminal **20** to primary winding **18,** center tap **58,** switch S1, and alarm **16** back to terminal **22,** thus, turning on the alarm.

The semiconductor sensor **10** is completely self-recovering and when the toxic gas condition has been cleared the self-purging action hereinafter described in greater detail terminates the alarm condition and restores the circuit of FIG. **1** to the "ready" condition. It may, of course, be advisable in certain instances to include a recording device in alarm **16** to indicate the occurrence of the alarm condition over some period of monitoring. Alternatively it may be desirable to establish a holding feature in the alarm **16** so that it must be reset by some prespecified act.

Looking again to FIG. **1** the operational amplifier **40** is provided with a positive feedback path **60** including a resistor Rb which is connected between the emitter of transistor **52** and the positive input of the amplifier. Accordingly the failure of current to flow through the emitter-collector circuit of transistor **52** results in a voltage increase at the positive input of the amplifier thus giving rise to a hysteresis condition which is illustrated in the curve of FIG. **2.**

Looking to FIG. **2** it can be seen that the curve **62** has a broad hysteresis loop configuration indicating that the alarm condition is given at a high toxic gas concentration (in this case CO) whereas the alarm condition remains in effect until the toxic gas concentration has been reduced to a level which is substantially below the initial triggering level. By varying resistor R*b* in the positive feedback path **50** the width of the loop in curve **62** may be varied between zero hysteresis and infinite hysteresis depending on the desires and objectives of the individual circuit designer and user.

Still referring to FIG. **1** another feature of the invention is the use of the autotransformer in the input circuit **12** having split secondary windings **24** and **26** and the center tapped primary winding **18.** Although the scientific explanation for the phenomenon to be described immediately hereinafter is not fully understood the benefits of the phenomenon are quite clear. It has been found that the closure of switch S1 to establish the alarm condition has the effect of coupling additional flux through the core of secondary winding **24** thus producing increased current flow through the semiconductor sensor **10.** This in turn has the effect of heating up the sensor **10** and decreasing its effective sensitivity to toxic gas concentrations. As will be apparent to those of ordinary skill in the art, the opposite effect which is normally encountered when line voltage droops from alarm turn-on can produce a condition of instability where the alarm tends to be "locked on" until the circuit is broken. In addition the added heating affect of the sensor **10** tends to produce a purging action; ie, the residual gas concentration around the sensor is oxidized at an increased rate. Clearly there are other circuit configurations which might give rise to this increased current flow condition and accordingly while the circuit configuration of FIG. **1** is preferred and represents the best mode of carrying out the invention now known to the inventor it is to be understood that the invention is not limited to the exact structure illustrated in FIG. **1.**

Looking now to FIG. **3** there is shown a system **64** for supplying air to a plurality of users of life support systems; ie, persons who are working in a contaminated air atmosphere and who must wear breathing apparatus. In FIG. **3** the air supply **66** may take the form of a compressor or air pump connected through a manifold type particulate filter **68** having a plurality of output lines or hoses **70, 71, 72** and **74.** A suitable particulate filter is available from the E. D. Bullard Company of Sausalito, California.

As shown in FIG. **3** a semiconductor toxic gas sensor **76** of the type designated by the reference character **10** in FIG. **1** is suitably disposed in the airline **74** so as to constantly monitor the quality of air being supplied through the life support system to the various users thereof. It is necessary to monitor only one of the several life support lines **70, 71, 72** and **74** inasmuch as all receive air from a common supply. Sensor **76** is connected to an electronic unit **78** which in turn is connected to an alarm device **80** to indicate the presence of a toxic gas of predetermined concentration in the air supply of the life support system. The electronic unit **78** may, of course, take the form illustrated in FIG. **1** and accordingly the alarm device **80** may correspond in all essential functional respects to the alarm device **16** of FIG. **1.**

Various other uses of the sensor system of FIG. **1** and equivalence thereof will occur to those skilled in the art.

It is to be understood that the description given above is illustrative in character and is not to be construed as limiting the subject invention to the exact construction and circuit arrangements shown.

Having thus described my invention, I claim:

1. Apparatus for indicating the presence of a toxic gas comprising, a solid state sensor having a relatively large nominal resistance but being responsive to the presence of said toxic gas to present a substantially reduced electrical resistance characteristic, bridge circuit comprising as a first leg the series combination of said sensor and a variable resistor and as a second leg the series combination of two reference resistors, the first and second legs being connected in parallel, input circuit means including first means connected directly to said sensor for energizing said sensor with electrical energy of a predetermined magnitude for producing an electrical signal quantity related to the resistance characteristic of said sensor, said input circuit means further including second means connected across both of the first and second legs for energizing the bridge circuit and for producing a reference quantity, control circuit means including comparator means having separate inputs connected to the mid-points of said first and second legs for comparing said electrical signal quantity to said reference quantity and for producing an output signal quantity when said electrical signal quantity bears a predetermined relationship to said reference quantity, and indicator means for indicating an alarm condition connected to be controlled by said output signal quantity for indicating the presence of said gas, said input circuit means including a transformer having a tapped primary winding and first and second secondary windings, said tapped primary winding being connected to said indicator means for energizing said indicator means under the control of said output signal

quantity, said first secondary winding being connected to energize said sensor, and said second secondary winding being connected by circuit means to said reference resistor to produce said reference quantity, whereby the relative energization of said first and second legs is constant irrespective of variations in the voltage applied to said primary winding.

2. Apparatus as defined in claim **1** wherein said control circuit means further includes switch means having conductive and nonconductive states and being connected to receive said output signal quantity to be controlled thereby and relay means connected in circuit with said switch means and a source of electrical energy, applied to said sensor said relay means being operatively connected with said indicator means for energizing said indicator means whenever said switch means is in one of said conditions.

3. Apparatus as defined in claim **2** wherein said relay means energizes said indicator means whenever said switch means is in the nonconductive condition.

4. Apparatus as defined in claim **1** wherein said sensor is a solid state semiconductor device having a response characteristic to the presence of said toxic gas which is related to the magnitude of the energizing electrical energy applied thereto, said input circuit means including means for increasing the magnitude of said energizing energy applied to said sensor whenever said indicator means indicates an alarm condition.

5. The apparatus as defined in claim **1** further including feedback means connected between the input to said comparator means connected to said second leg and the output of said control circuit means for automatically varying said predetermined level upon activation of said indicator means when the presence of said gas is detected by said sensor whereby the toxic gas level for terminating the alarm condition is less than said predetermined level.

6. Apparatus for indicating the presence of a toxic gas comprising, a solid state sensor having a nominal relatively large resistance but being responsive to the presence of said toxic gas to present a substantially reduced electrical resistance characteristic, input circuit means connected to said sensor for energizing said sensor with electrical energy of a predetermined magnitude, control circuit means having an input and output, said input being connected to said sensor for receiving an electrical signal quantity from said sensor related to the resistance characteristic thereof, said control circuit means producing on said output an output signal quantity when said electrical signal quantity on said input reaches a predetermined level, and alarm means for indicating an alarm condition connected to be controlled by said output signal quantity for indicating the presence of said gas, said input circuit means further including means for increasing the magnitude of said energizing energy applied to said sensor whenever said alarm means indicates an alarm condition.

7. Apparatus as defined in claim **6** wherein said input circuit means comprises a transformer having a primary winding and at least a first secondary winding, said first secondary winding being connected to energize said sensor, and means connected between said primary winding and said alarm means for energizing said alarm means under the control of said output signal.

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