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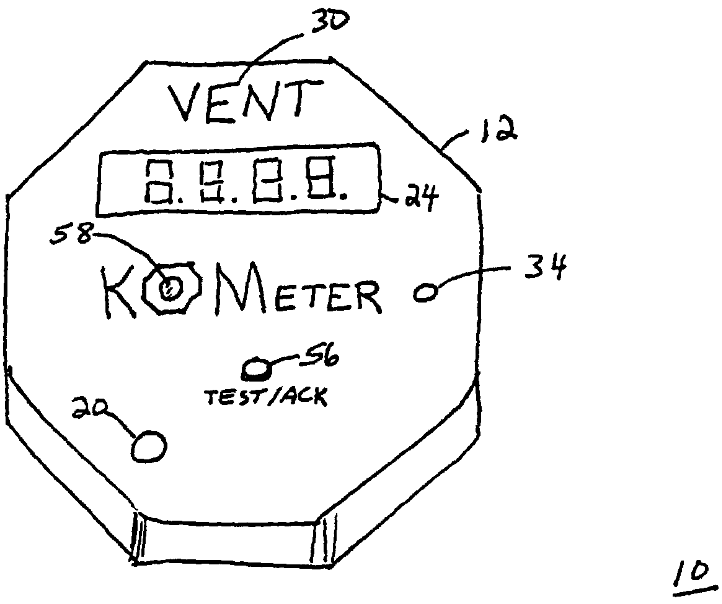
(54) Title: CARBON MONOXIDE DETECTOR FOR AIR VEHICLES



(57) Abstract: A carbon monoxide detector for an air vehicle wherein the indicated and alarmed level of carbon monoxide is compensated to account for the increased susceptibility of a human body to the effects of carbon monoxide as the ambient air pressure is decreased. A pressure sensor provides a signal utilized to adjust a carbon monoxide level signal or a carbon monoxide level alarm set point. A display of the carbon monoxide sensor may be utilized to present both the time and the adjusted level of carbon monoxide to the occupants of the air vehicle.

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CARBON MONOXIDE DETECTOR FOR AIR VEHICLES

This application claims benefit of the November 17, 1999, filing date of United States Provisional Patent Application No. 60/165,969.

BACKGROUND OF THE INVENTION

The present invention relates generally to the field of carbon monoxide detectors, and more particularly to a carbon monoxide detector for use in an air vehicle.

The dangers of carbon monoxide poisoning are well known, and an entire industry has developed around the fabrication of carbon monoxide detectors. The effects of carbon monoxide are particularly dangerous for the operator of a motorized vehicle. The Federal Aviation Administration has recognized the danger of carbon monoxide contamination in aircraft, and issued advisory circular AC 20-32B titled "Carbon Monoxide (CO) Contamination in Aircraft – Detection and Prevention" on November 24, 1972. The Society of Automotive Engineers, Inc. revised its Aerospace Standard AS412A on December 15, 1956, after its original issue on November 1, 1948.

Carbon monoxide is the product of incomplete combustion of carbonaceous fuels. It is a colorless, odorless and tasteless gas which is found in varying amounts in the exhaust of most internal combustion engines. Carbon monoxide will combine with the hemoglobin in the blood of a human being and will reduce the oxygen carrying capability of the blood. The affinity of hemoglobin for carbon monoxide is much greater than its affinity for oxygen, so even small quantities of carbon monoxide may have a deleterious effect on the ability of the blood stream to carry oxygen. A reduced oxygen supply to the brain will reduce a person's ability to reason and to make decisions, and it may make the person dizzy, nauseous and disoriented. Exposure to even very small amounts of carbon monoxide over an extended period of time may reduce a pilot's ability to operate an air vehicle safely. Extended exposure to low concentrations of carbon monoxide may be as hazardous as is short exposure to relatively high concentrations. Accordingly, the Federal Aviation Administration advises pilots to take prompt corrective action in the event that the pilot smells exhaust odors or begins to feel any symptom of carbon monoxide poisoning. Such action may include shutting off the cabin air heater, providing a source of fresh air into the cockpit of the air vehicle, avoiding smoking, using a separate oxygen supply, and landing at the first opportunity.

Carbon monoxide may be especially dangerous in an air vehicle because a human's susceptibility to the effects of carbon monoxide poisoning will increase with increased altitude. As altitude increases, the ambient air pressure decreases and the human body has difficulty in obtaining enough oxygen. Accordingly, the oxygen starvation effect of carbon monoxide may become magnified at reduced air pressures.

There are a large number and many types of carbon monoxide detectors known in art. Unfortunately, existing carbon monoxide detectors are not specifically designed for use in aircraft. Chemical spot detectors provide an indication of the presence of carbon monoxide by a change in color on the indicator material. Such detectors have a very short useful life, and they are generally incapable of detecting low levels of carbon monoxide. Electronic carbon monoxide detectors have become increasingly popular for use in homes and other structures.

However, such detectors are not generally for use in air vehicles due to the vibrations, temperature and altitude extremes often experienced in an air vehicle environment. Accordingly, the use of such detectors in private air craft has been minimal.

BRIEF SUMMARY OF THE INVENTION

Thus, there is a particular need for a carbon monoxide detector that is especially suited for general aviation aircraft. Accordingly, a carbon monoxide detector for an air vehicle is described herein as including: a carbon monoxide sensor, a pressure sensor and a signal processor for producing an alarm signal responsive to both the carbon monoxide level and the atmospheric pressure within the air vehicle cabin. A display unit is provided for presenting both a visual and an audible alarm when the carbon monoxide level exceeds a predetermined value. The display may present both the time and the ambient carbon monoxide level during those periods when the carbon monoxide is below the alarm set point level. A signal processor contained within the carbon monoxide detector may be programmed with an algorithm for decreasing the carbon monoxide level alarm set point in response to a decreasing atmospheric pressure. The carbon monoxide detector may further include a temperature sensor and a relative humidity sensor for providing appropriate calibration of the carbon monoxide signal.

BRIEF DESCRIPTION OF THE DRAWINGS

The features and advantages of the present invention will become apparent from the following detailed description of the invention when read with the accompanying drawings in which:

Figure 1 is a schematic illustration of the circuitry within a carbon monoxide detector adapted for use in an air vehicle.

Figure 2 illustrates a carbon monoxide detector adapted for use in an air vehicle to include the circuitry illustrated in Figure 1.

DETAILED DESCRIPTION OF THE INVENTION

A new carbon monoxide detection system is described herein as having particular benefits when used in an air vehicle. The term air vehicle is used herein to include airplanes, helicopters, and the like. Carbon monoxide detector 10 is illustrated in Figure 2 as being contained within a housing 12 that may be affixed to a portion of an air vehicle interior (not shown). The circuitry contained within the carbon monoxide detector 10, as schematically illustrated in Figure 1, is preferably constructed from solid state and/or discreet components in order to minimize the size and power requirements for the unit, as well as to improve the shock and vibrational load carrying capabilities of the circuitry. The unit illustrated in Figure 2 is currently being sold under the trademark "KOMeter" by the assignee of the present invention at Internet web page http://www.simsysinc.com/asd/kometer.htm.

The carbon monoxide detector 10 includes a signal processor 14 adapted to receive a plurality of input signals and to produce a plurality of output signals in response thereto, as will be described more fully below. Signal processor 14 may be any sort of analog or digital signal processing device, and in one embodiment is a PIC 16C77 8-bit microcontroller by Microchip.

Carbon monoxide detector 10 includes a carbon monoxide sensor 16 operable to sense the level of carbon monoxide present in an ambient environment and to produce a carbon monoxide level signal 18 responsive to the level of carbon monoxide. In one embodiment, the carbon monoxide sensor 16 may be a model TGS2440 CO detector available from Figaro USA Inc. The carbon monoxide sensor 16 may be mounted within housing 12 but exposed to the ambient environment through an opening 20 formed in housing 12. Carbon monoxide level signal 18 is provided as an input to signal processor 14. Signal processor 14 includes logic for producing a plurality of output signals in response to carbon monoxide level signal 18. In one embodiment, logic within signal processor 14 is utilized to generate an output signal 22 for driving an alpha-numeric display unit 24. In one embodiment, the alpha-numeric display unit 24 is a four-digit display device such as model HDSP-A153 available from Ligitek. Alpha-numeric display unit 24 is mounted to housing 12 so as to be visible to an occupant of the air vehicle in which the carbon monoxide detector 10 is installed. Signal processor 14 may further contain logic for generating output signals 26, 28 for driving visual signal indicator 30 and audio signal indicator 32 respectively. In the embodiment illustrated in Figure 2, visual signal indicator 30 takes the form of the word "VENT" which is selectively illuminated from within housing 12 by a lamp (not illustrated) which is energized upon the receipt of output signal 26. Audible signal device 32 may be a buzzer or whistle, such as model KBS-20DB-3A available from AVX Kyocera. In the embodiment of Figure 2, audible signal device 32 is mounted within housing 12 near an opening 34 formed in housing 12 to allow sound to emanate freely from within the housing 12.

The carbon monoxide detector 10 further includes a pressure sensor 36 adapted to measure the ambient atmospheric pressure and to produce a pressure signal 38 in response thereto. In one embodiment, pressure sensor 36 may be a model MPX4100A series or PPXA4100A series pressure sensor supplied by Motorola, Inc. Pressure signal 38 is provided as an input to signal processor 14. Signal processor 14 includes logic for making output signals 22, 26, 28 responsive to both the carbon monoxide level signal 18 and the pressure signal 38. In this manner, carbon monoxide detector 10 may be utilized as a display apparatus to provide carbon monoxide level warnings that are responsive to the altitude of the air vehicle within which the detector 10 is installed. Unlike prior art devices, warning information provided by displays 24, 30, 32 may be controlled to compensate for the change in sensitivity to carbon monoxide that is experienced by a human passenger as the altitude of an air vehicle increases.

Carbon monoxide detector 10 may further include a relative humidity sensor 40 adapted to produce a relative humidity signal 42 in response to the level of the relative humidity in the ambient environment. Detector 10 may also include temperature sensor 44 adapted to produce temperature signal 46 in response to the ambient temperature. In one embodiment, the relative humidity sensor 40 is a model NH-02 provided by Figaro and the temperature sensor is model AD22100 provided by Analog Devices. The relative humidity signal 42 and temperature signal 46 are provided as inputs to signal processor 14 for calibrating the carbon monoxide level signal 18 for variations induced by changes in the ambient humidity and temperature. Such calibration may include logic within signal processor 14 for disabling the alarm output of carbon monoxide detector 10 at temperatures above and below its useful operating temperature range. Both relative humidity sensor 40 and temperature sensor 42 may be mounted within housing 12.

Carbon monoxide detector 10 also includes a timer such as a clock 48 operable to produce a time signal 50 as an input to signal processor 14. Clock 48 may be provided as a separate device or be made integral to a microcomputer chip utilized as signal processor 14.

Carbon monoxide detector 10 may also include a user input signal device 52 adapted to provide a user input signal 54 to microprocessor 14. In the embodiment of Figure 2, the user input signal device 52 is shown as a test/acknowledge button 56 mounted to housing 12. As will be described more fully below, the test/acknowledge button allows an occupant of an air vehicle to provide various input signals to the logic contained within signal processor 14.

The use of carbon monoxide detector 10 for protecting the occupants of an air vehicle will now be described. Carbon monoxide detector 10 may be installed within the cabin or other interior space of an air vehicle by mounting housing 12 to an appropriate surface. Power may be supplied to the carbon monoxide detector 10 from the electrical system of the air vehicle, with an auxiliary battery provided within housing 12 to maintain microprocessor memory information during periods when the main power is off. A power-on indicator light 58 may be provided on the face of housing 12 to indicate when main electrical power is being supplied to the unit. After appropriate warm-up and calibration periods, carbon monoxide sensor 16 will provide a carbon monoxide level signal 18 indicative of the level of carbon monoxide in the vehicle cabin. Information provided to the occupant regarding the level of carbon monoxide in the cabin is derived from carbon monoxide level signal 18, with appropriate adjustment in response to the pressure signal 38, relative humidity signal 42, and temperature signal 46. The relative humidity signal 42 and temperature signal 46 provide a calibration to account for the change in responsiveness of the carbon monoxide sensor 16 over varying levels of relative humidity and temperature. Pressure signal 38 is utilized to account for the change in the sensitivity of the human body to carbon monoxide at various ambient pressure levels. In one embodiment, the indicated level of carbon monoxide is varied linearly with a change in the ambient atmospheric pressure. For example, the adjustment for pressure may be a simple inverse function, given that at one-half a given atmospheric pressure, a given level of carbon monoxide will have twice the impact on a human being. Logic within signal processor 14 may utilize a simple look-up table to calibrate for changes in pressure. For example, a nominal level of carbon monoxide may be indicated at a pressure of 1000 millibars. At 900 millibars, the same level of carbon monoxide may be displayed as being the nominal level divided by 0.9. Similarly, the same level of carbon monoxide may be indicated as the nominal measured level of carbon monoxide divided by 0.8 at a pressure of 800 millibars, and so forth. Thus, at one-half the nominal pressure, i.e. 500 millibars, the indicated level of carbon monoxide will be twice the actual measured level. The simple look-up table described above represents one possible algorithm for determining an adjusted carbon monoxide level as a function of the carbon monoxide level signal 18 and the pressure signal 38.

The adjusted carbon monoxide level may be indicated as a numeric value on display device 24. In addition to displaying a numeric value representing the adjusted carbon monoxide level within the cabin of an air vehicle, carbon monoxide detector 10 may further display one or more alarms when the adjusted carbon monoxide level reaches various predetermined set points. For example, it is known to provide a warning when the carbon monoxide level has reached or exceeded 75 ppm for a time duration of 10 minutes. Similarly, it is known to provide a warning when the carbon monoxide level reaches or exceeds 150 ppm for 5 minutes, and to provide an immediate alarm when the carbon monoxide level reaches or exceeds 400 ppm. Logic within signal processor 14 may be programmed to contain such set points for comparison to the adjusted carbon monoxide level. The increased sensitivity of the human body to carbon monoxide poisoning as the pressure is reduced is accounted for by utilizing the adjusted carbon monoxide level, rather than the actual measured valve, in comparison to standard alarm level set points. Alternatively, an actual level of carbon monoxide may be compared to one or more alarm set points that are made responsive to pressure signal 38. In lieu of calculating an adjusted carbon monoxide level, logic within signal processor 14 may be utilized to calculate adjusted alarm set points which are reduced from nominal set points in response to a decreasing ambient atmospheric pressure signal 38. Both of the above described techniques provide improved protection for the occupant of an air vehicle against the adverse effects of carbon monoxide by providing an alarm at a progressively lower level of carbon monoxide as the altitude of the air vehicle increases. One may envision another embodiment where the duration of exposure to a given level of carbon monoxide is reduced before an alarm is sounded as the altitude is increased. In such an embodiment, the length of time before an alarm is provided during which an occupant is exposed to a given exposure of carbon monoxide will be decreased as the altitude of the air vehicle increases.

In addition to providing a numeric display of the level of carbon monoxide or an adjusted level of carbon monoxide, carbon monoxide detector 10 may provide a visual instruction to ventilate the cabin atmosphere by the illumination of visual signal device 30 in response to output signal 26. Such visual alarm information may be provided when the carbon monoxide level or adjusted carbon monoxide level reaches an immediate or timed set point value. At the same time, an audible alarm may be provided by audible alarm device 32. The occupant of the air vehicle has the option of silencing the audible alarm by pressing the test/acknowledge button 56. Preferably, even after the acknowledgement of an alarm, the carbon monoxide level detector 10 will continue to provide visual alarm 30 and a numeric display of the carbon monoxide level on display 24 until a safe level of carbon monoxide is regained.

The clock 48 may be utilized to generate a visual display of time on display device 24. In one embodiment, carbon monoxide detector 10 is utilized to provide an alternating visual display of time and adjusted carbon monoxide value on display device 24. By combining these two types of information onto a single display unit, carbon monoxide detector 10 advantageously reduces the amount of space within the air vehicle cabin that is necessary to provide both types of information. In one embodiment, the display 24 is normally used to indicate the time, but approximately once or twice a minute, the adjusted level of carbon monoxide is displayed. This may be accomplished by displaying the letters -CO- for approximately two seconds followed by a number indicative of the adjusted carbon monoxide level for approximately two seconds. This type of display allows the occupant of the air vehicle to become accustomed to the normal levels of carbon monoxide, so that when a small increase in the carbon monoxide level occurs that is below the alarm level set point, the occupant may be alerted to the need for a higher level of awareness. Furthermore, consistent levels of carbon monoxide that are greater than zero but less than a first alarm set point may be indicative of the need for maintenance on the air vehicle. In this embodiment, when an alarm level is reached, the time display is terminated and a continuous indication of the carbon monoxide level may be displayed along with the audible signal warning 32 and visual alarm instructions 30.

Carbon monoxide detector 10 may be utilized to display other types of information, such as the barometric pressure, relative humidity, timers and/or temperature. The user may select from a variety of such displays by providing an input signal 54 to signal processor 14 to enable appropriate logic for providing the desired output display signal 22. In each such mode of operation, the primary display selection may be aborted and an appropriate alarm display provided when any one of several alarm set points is reached for the adjusted carbon monoxide level. Display 24 may further be utilized to present an end-of-life signal for indicating when the design lifetime of carbon monoxide sensor 16 or any other of the sensors 36, 40, 44 is exceeded, or when a recommended maintenance interval is achieved. A lithium storage battery may be provided within housing 12 to maintain power to clock 48 and/or signal processor 14 to ensure that such logic remains accurate in spite of the main power to the unit being turned off.

While the invention has been described in a currently preferred embodiment, many variations and modifications will become apparent to those skilled in the art. Accordingly, it is intended that the invention not be limited to the specific illustrative embodiment, but be interpreted within the full spirit and scope of the appended claims.

CLAIMS

I claim as my invention:

1. A detector comprising:

a carbon monoxide sensor for producing a carbon monoxide level signal responsive to a level of carbon monoxide present in an ambient environment;

a pressure sensor for producing a pressure signal responsive to an atmospheric pressure in the ambient environment;

a signal processor having the carbon monoxide level signal and the pressure signal as inputs and including logic for producing a first alarm signal responsive to the carbon monoxide signal and the pressure signal.

2. The detector of claim 1, further comprising:

a timer for producing a time signal; and wherein

the signal processor has the time signal as an input and includes logic for producing a second alarm signal responsive to the carbon monoxide level signal, the pressure signal and the time signal.

3. The detector of claim 1, wherein the logic comprises an algorithm for decreasing a carbon monoxide level alarm set point in response to a decreasing atmospheric pressure.

4. The detector of claim 2, wherein the logic comprises a first algorithm for determining an adjusted carbon monoxide level as a function of the carbon monoxide level signal and the pressure signal, and a second algorithm for determining a carbon monoxide level alarm set point as a function of the adjusted carbon monoxide level.

5. The detector of claim 2, wherein the signal processor includes logic for producing a third alarm signal responsive to the time signal for indicating a sensor lifetime.

6. A carbon monoxide detector for an air vehicle comprising:

a first sensor for producing a carbon monoxide signal responsive to a level of carbon monoxide present within an air vehicle interior;

a second sensor for producing a pressure signal responsive to an atmospheric pressure in the air vehicle interior;

a signal processor connected to the first and second sensors for producing an output signal responsive to the carbon monoxide and pressure signals; and

a display connected to the signal processor for presenting a visual display to an occupant of the air vehicle in response to the output signal.

7. The detector of claim 6, wherein the signal processor further comprises an algorithm for converting the carbon monoxide signal to an adjusted carbon monoxide signal as a function of the value of the pressure signal; and

the display comprising a numeric display for presenting the visual display as a numeral responsive to the adjusted carbon monoxide signal.

8. The detector of claim 7, further comprising:

a timer for providing a time signal;

the signal processor connected to the timer for producing the output signal alternatively responsive to the adjusted carbon monoxide signal and to the time signal.

9. The detector of claim 8, further comprising logic within the signal processor for producing the output signal that is alternately responsive to an alarm message and to the adjusted carbon monoxide signal when the adjusted carbon monoxide level signal exceeds a predetermined value.

10. The detector of claim 7, wherein the signal processor includes logic for producing a sensor lifetime alarm signal responsive to the time signal.

11. A display apparatus for an air vehicle comprising:

a carbon monoxide sensor for producing a carbon monoxide level signal responsive to the level of carbon monoxide in the interior of an air vehicle;

a clock for producing a time signal;

a display member adapted to produce a visible display;

a signal processor having the carbon monoxide level signal and the time signal as inputs and having an output connected to the display unit for alternately showing on the display member a display corresponding to the time signal and a display corresponding to the carbon monoxide level signal.

12. The display apparatus of claim 11, further comprising:

a pressure sensor for producing a pressure signal responsive to the atmospheric pressure in the interior of the air vehicle, the signal processor having the pressure signal as an input;

logic within the signal processor for generating an adjusted carbon monoxide level signal as a function of the carbon monoxide level signal and the pressure signal;

wherein the signal processor has an output for alternately showing on the display member a visible display corresponding to the time signal and a visible display corresponding to the adjusted carbon monoxide level signal.

13. The display unit of claim 12, further comprising logic within the signal processor for displaying a visible report corresponding to an alarm message with the visible displays corresponding to the time signal and the adjusted carbon monoxide level signal when the adjusted carbon monoxide level signal exceeds a predetermined value.

14. The display unit of claim 11, wherein the signal processor includes logic for producing a sensor lifetime alarm signal responsive to the time signal.

15. A method for protecting an occupant of an air vehicle, the method comprising the steps of:

providing a carbon monoxide detector for measuring the level of carbon monoxide within a cabin of the air vehicle;

providing a pressure sensor for measuring the atmospheric pressure within the cabin of the air vehicle;

providing an alarm to an occupant of the air vehicle when the level of carbon monoxide within the cabin exceeds a first set point value; and

determining the first set point value as a function of the atmospheric pressure within the cabin.

16. The method of claim 15, further comprising the steps of:

providing a timer for measuring time;

providing a second alarm to an occupant of the air vehicle when the level of carbon monoxide within the cabin exceeds a second set point value for a predetermined period of time; and

determining the second set point value as a function of the atmospheric pressure within the cabin.

17. The method of claim 16, further comprising the steps of:

providing a display for visually displaying the first and the second alarms;

using the display to provide a visual display of time when not displaying either the first or the second alarm.

18. The method of claim 17, further comprising the steps of:

calculating an adjusted carbon monoxide value as a function of the measured level of carbon monoxide within the cabin and the measured value of atmospheric pressure within the cabin; and

using the display to provide an alternating visual display of time and adjusted carbon monoxide value when not displaying either the first or the second alarm.

19. A method for protecting an occupant of an air vehicle, the method comprising the steps of:

providing a carbon monoxide detector for measuring the level of carbon monoxide within a cabin of the air vehicle;

providing a pressure sensor for measuring the atmospheric pressure within the cabin of the air vehicle;

calculating an adjusted carbon monoxide value as a function of a measured level of carbon monoxide within the cabin and a measured atmospheric pressure within the cabin; and

providing a first alarm to an occupant of the air vehicle when the adjusted carbon monoxide value exceeds a first set point value.

20. The method of claim 19, further comprising calculating the adjusted carbon monoxide value as the measured level of carbon monoxide times the measured atmospheric pressure within the cabin divided by a nominal atmospheric pressure.

21. The method of claim 19, further comprising the steps of:

providing a timer for measuring time;

providing a second alarm to an occupant of the air vehicle when the adjusted carbon monoxide value exceeds a second set point value for a predetermined period of time.

22. The method of claim 21, further comprising the step of providing the second alarm as a numeric presentation of the adjusted carbon monoxide value.

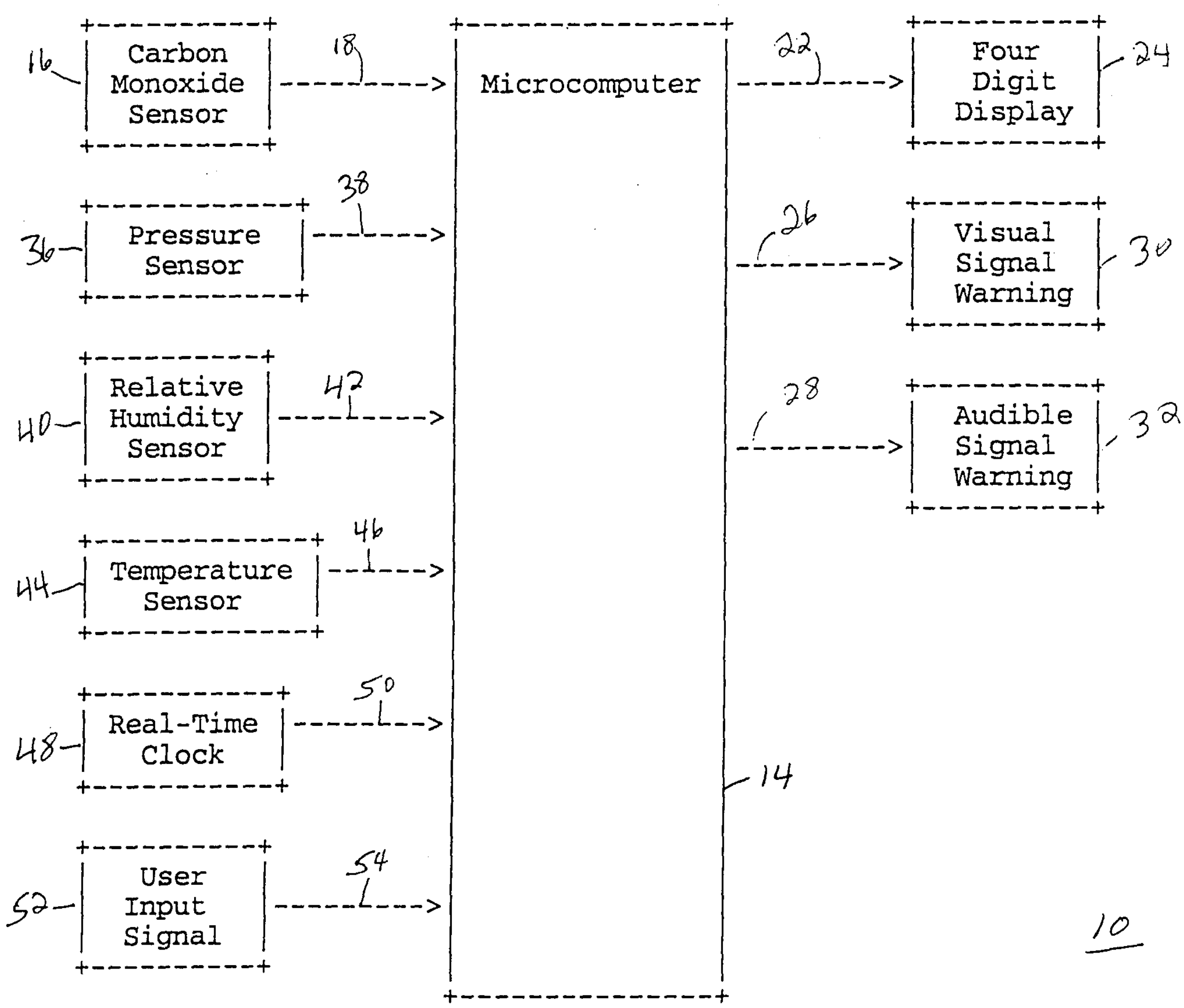
16
Carbon Monoxide Sensor
18
Microcomputer
22
Four Digit Display
24
36
Pressure Sensor
38
26
Visual Signal Warning
30
40
Relative Humidity Sensor
42
28
Audible Signal Warning
32
44
Temperature Sensor
46
48
Real-Time Clock
50
14
52
User Input Signal
54
10

FIG. 1

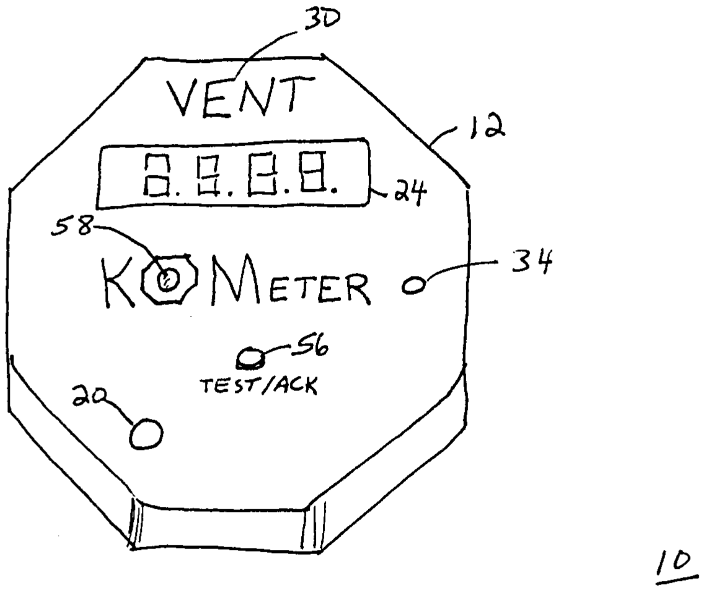

FIGURE 2