United States Patent [19]

Gruensfelder

[11] **3,879,717**

[45] **Apr. 22, 1975**

[54] **PORTABLE METHANE MONITOR AND ALARM SYSTEM**

[75] Inventor: **Kurt Gruensfelder,** Dresher, Pa.

[73] Assignee: **K-F Industries, Inc.,** Philadelphia, Pa.

[22] Filed: **June 19, 1974**

[21] Appl. No.: **480,730**

[52] **U.S. Cl.**..... **340/237 R;** 340/249; 340/371; 340/409

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

[58] **Field of Search**..... 340/237 R, 237 S, 249, 340/384 E, 371, 409; 23/254 E, 255 E; 73/27 R

[56] **References Cited**

UNITED STATES PATENTS

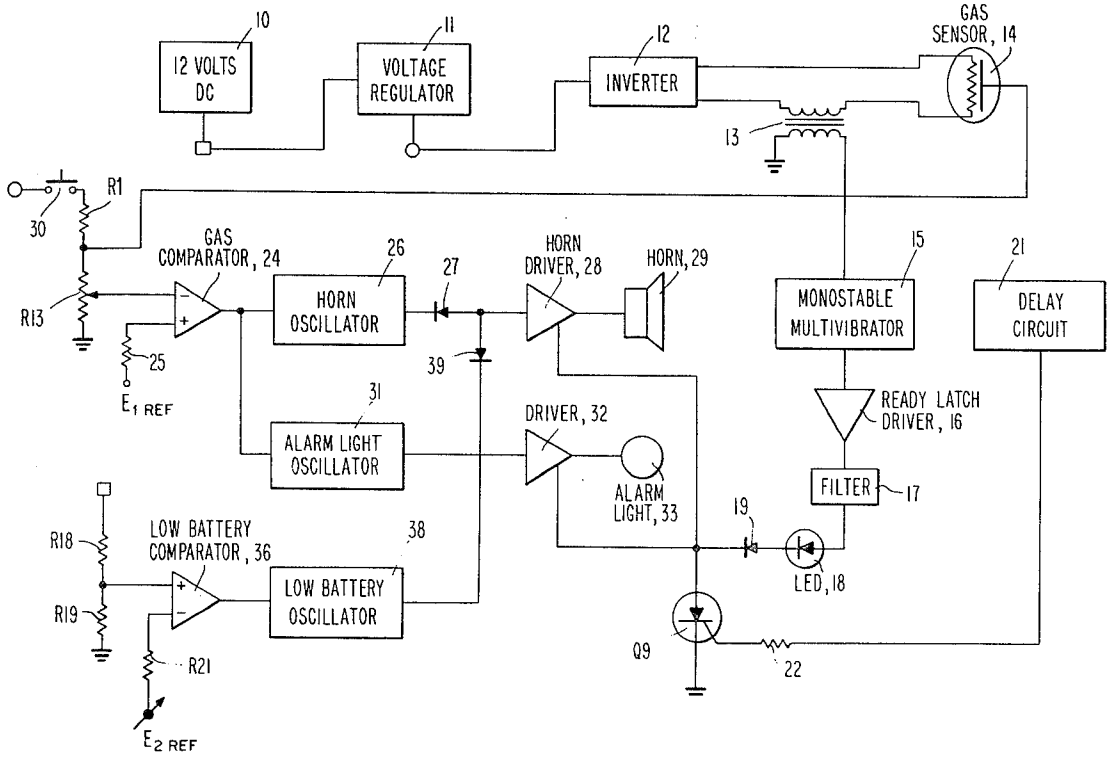
3,392,379	7/1968	Thomason et al.	340/371 X
3,594,751	7/1971	Ogden et al.	340/249 X
3,609,732	9/1971	Kasahara et al.	340/237 R
3,686,655	8/1972	Kasahara	340/237 R
3,733,595	5/1973	Benedict	340/237 R
3,750,123	7/1973	Caillouet, Jr.	340/237 R
3,774,186	11/1973	Enemark	340/409 X
3,801,972	4/1974	Hokim et al.	340/237 R

Primary Examiner—John W. Caldwell
Assistant Examiner—Daniel Myer
Attorney, Agent, or Firm—Paul & Paul

[57] **ABSTRACT**

A portable, battery-operated, continuous methane monitor and alarm instrument includes a semiconductor gas sensor which, in response to an increase in concentration of methane gas, exhibits a lowering of its resistance. A push-pull oscillator provides an alternating current at 3–5 kilohertz to the heater of the gas sensor. This heater current passes through a differentiating pick-off transformer and develops voltage pulses which trigger repeatedly a monostable multivibrator. The output of the multivibrator is inverted, amplified, and filtered to produce a constant DC current which flows through and energizes a light-emitting diode (LED) provided that a silicon-controlled rectifier (SCR) which is in series with the LED has been fired. The illumination of the LED signifies that the instrument is in operative condition. The SCR is not fired, however, following turn-on of the instrument, until after an initial delay of the order of 1–3 minutes to allow the semi-conductor gas sensor to heat up to a temperature sufficient to purge it of absorbed contaminants. If, thereafter, with the SCR in the ON condition, the gas sensor senses methane gas of sufficient concentration (0.8 – 1.2 per cent), the gas sensor produces a voltage which, when compared with a reference voltage, is sufficient to actuate two alarm oscillators, one of which actuates an audible horn circuit and the other of which actuates a visual flashing-light signal circuit. The instrument also includes a low-battery circuit to develop a signal to indicate that the battery voltage has fallen below a selected value.

19 Claims, 2 Drawing Figures



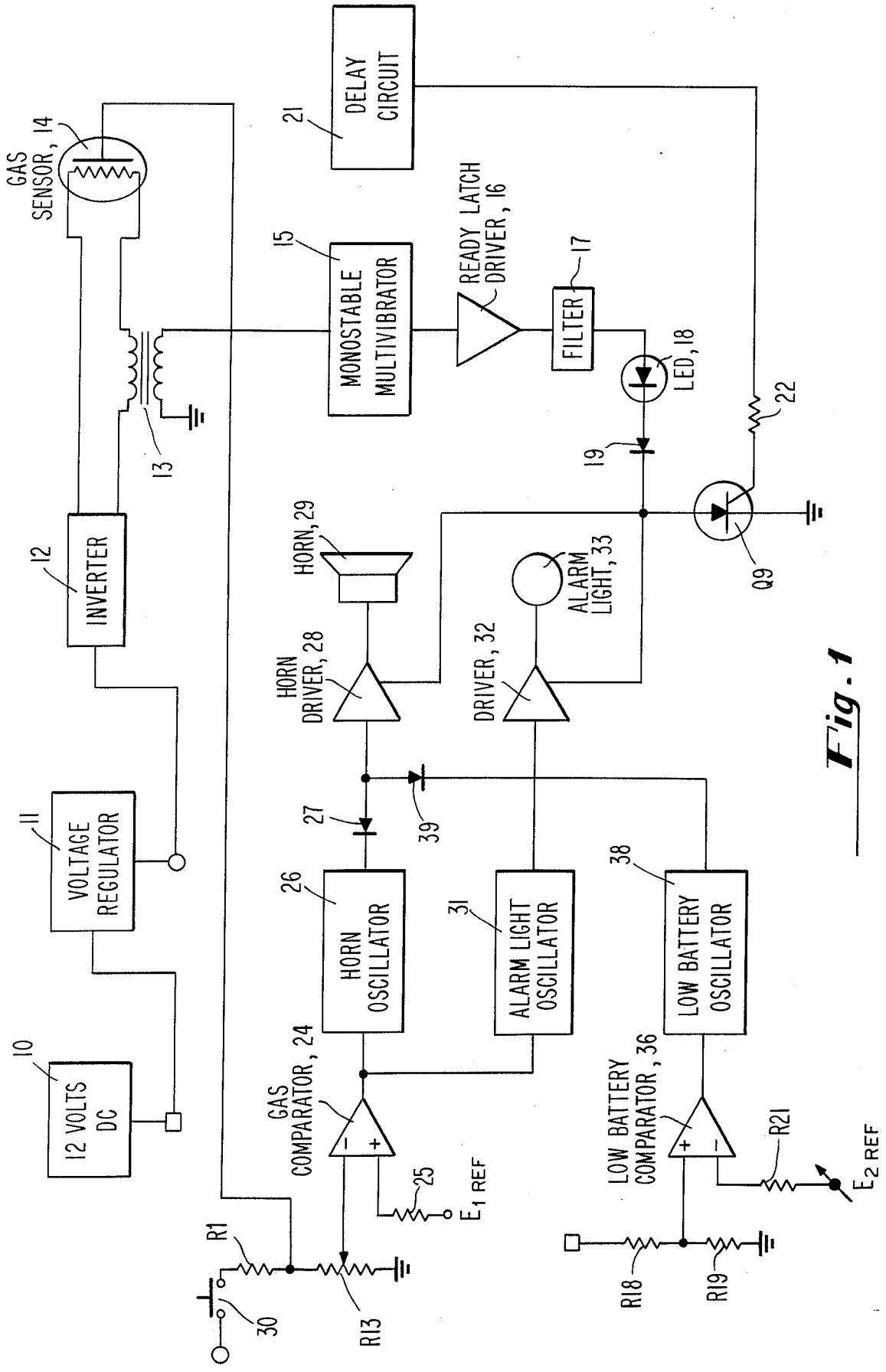

DELAY CIRCUIT
21
GAS SENSOR, 14
MONOSTABLE MULTIVIBRATOR
15
READY LATCH DRIVER, 16
FILTER
17
LED, 18
22
19
13
INVERTER
12
HORN, 29
ALARM LIGHT, 33
Q9
HORN DRIVER, 28
DRIVER, 32
VOLTAGE REGULATOR
11
27
39
38
26
HORN OSCILLATOR
31
ALARM LIGHT OSCILLATOR
LOW BATTERY OSCILLATOR
10
12 VOLTS DC
GAS COMPARATOR, 24
LOW BATTERY COMPARATOR, 36
25
$E_{1\ REF}$
R21
$E_{2\ REF}$
R1
30
R13
R18
R19

Fig. 1

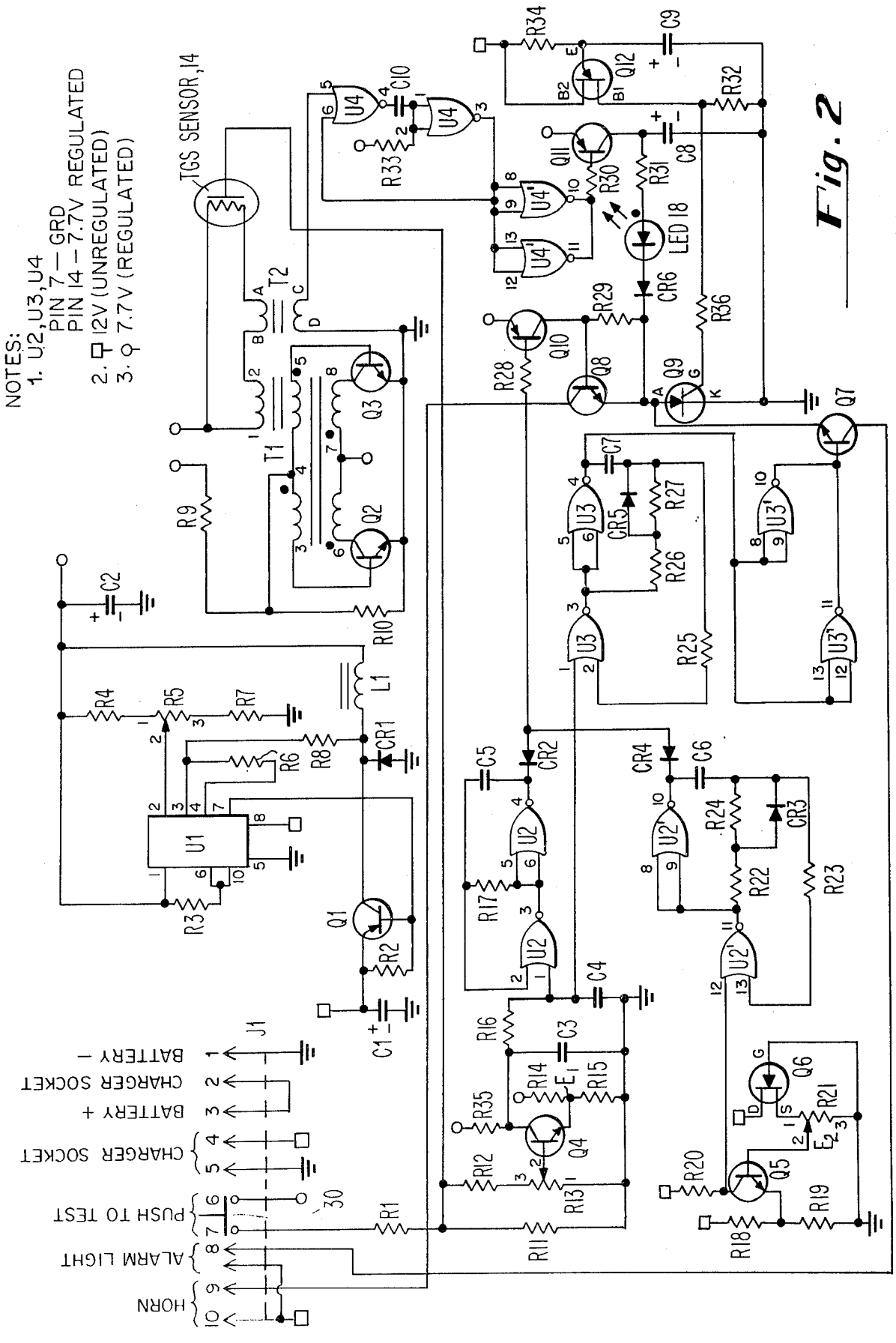

NOTES:
1. U2,U3,U4
PIN 7 — GRD
PIN 14 — 7.7V REGULATED
2. □ 12V (UNREGULATED)
3. ○ 7.7V (REGULATED)
TGS SENSOR,14
T1
T2
L1
U1
U2
U3
U4
Q1
Q2
Q3
Q4
Q5
Q6
Q7
Q8
Q9
Q10
Q11
Q12
LED 18
CR1
CR2
CR3
CR4
CR5
CR6
J1
BATTERY −
CHARGER SOCKET
BATTERY +
CHARGER SOCKET
PUSH TO TEST
ALARM LIGHT
HORN
30

Fig. 2

PORTABLE METHANE MONITOR AND ALARM SYSTEM

BACKGROUND OF THE INVENTION

It is well known that, in the mining of coal, methane gas may be liberated which, if the concentration becomes high enough, produces a highly explosive methane-air mixture which is liable to be ignited by a spark. Since the mining of coal necessitates the use of power equipments which are driven by electric motors which may be subject to sparking, safety regulations have been adopted which specify motor construction and motor design intended to prevent arcing or sparking. Nonetheless, there exists the possibility that a spark may be developed, and, if the concentration of methane gas is sufficiently high, a violent explosion may be produced with disastrous results.

SUMMARY OF THE INVENTION

An important object of the present invention is to provide a battery-operated, hand-carry type of monitor and alarm device for sounding an alarm, both audible and visual, when the concentration of methane gas reaches a predetermined concentration.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a continuous monitoring and alarm device according to the present invention.

FIG. 2 is a detailed circuit diagram which corresponds to the block diagram of FIG. 1.

DESCRIPTION OF A PREFERRED EMBODIMENT

One specific form of device according to the present invention is illustrated in FIGS. 1 and 2 and will now be described. While specific values and components will be indicated, it is to be understood that these are merely representative and that other values and components may be used, within the scope of the claims appended hereto.

Referring now to the drawings, the gas sensor **14** is a transistor-like device which depends upon the surface effect of a gas on the semi-conductor making available more free electrons for conduction and thus lowering its resistance. When ON, and in the absence of absorbed gas, such as methane, the semi-conductor exhibits a high resistance, but when subjected to methane (or like) gas, the sensor exhibits a progressive lowering of its resistance which is related to the concentration of the gas and the time of exposure. One such suitable gas-sensor device is a Taguchi Gas Sensor, type 308, which may be procured from Figaro Engineering, Inc., 3-1-5-6 Higashitoyonaka, Toyonaka City, Osaka 560, Japan.

A regulated power supply is used which comprises the components identified by blocks **10** and **11** in FIG. **1.** As there indicated, the unregulated supply is a 12-volt battery. Voltage regulator **11** is a switching type regulator having high efficiency. This permits the output-regulating transistor (transistor Q1 of FIG. 2) to be either fully ON or OFF, When transistor Q1 is off, energy stored in inductor L1, filtered by capacitor C2, is supplied to the circuit. In the particular circuit being described, the switching duty cycle may be automatically adjusted by potentiometer R5, so that a voltage of 7.7 volts DC is delivered to the instrument at the regulated voltage terminals. The duty-cycle function is performed, as seen in FIG. 2, by an integrated circuit U1 (which may be Type 723) in combination with the output transistor Q1 (which may be Type 2N4403).

As indicated by the notes in FIG. 2, the regulated 7.7 volts DC, wherever it appears in the circuit, is represented by a medium sized circle, while the regulated 12 volts DC is represented by a small square. The medium sized circles are not to be confused with the small circles of the various NOR gates.

As seen in the block diagram of FIG. 1, the output of voltage regulator 11 is delivered to a push-pull inverter-oscillator 12 which, as seen in FIG. 2, includes the transistors Q2 and Q3. This circuit oscillates between 3 and 5 kilohertz (khz). The output from inverter-oscillator 12 is delivered to the heater of gas sensor 14 by means of transformer T1. The output, at 500 milliamperes (ma), is 1.45 volts.

As seen in FIG. 2, in series with the output lead to the heater of gas sensor 14, is a small toroidal pick-off transformer T2 which is designed to differentiate the output waveform. This pick-off transformer T2 produces a pair of positive and negative voltage pulses or spikes for each cycle. These spikes are, of course, only present when current flows through the gas sensor 14. If, for any reason, no current is flowing in the gas-sensor, no spikes are produced by the transformer T2. Also, if, for any reason, the current through the gas-sensor device 14 is severely reduced, such as by a malfunction, the amplitude of the pulses produced by T2 will likewise be substantially reduced, and these may be insufficient for their intended purpose. The voltage pulses or spikes produced by the pick-off transformer T2, in response to current flow through the gas-sensor, are used to trigger repeatedly a monostable multivibrator designated 15 in the block diagram of FIG. 1. The monostable multivibrator 15 (FIG. 1) includes the NOR gate component U4 and associated circuitry of FIG. 2. All NOR gates used in the instrument are quad 2-input metal-oxide semi-conductor (MOS) integrated circuits in 14-pin dual in-line package (DIP) form.

As stated above, the monostable multivibrator circuit 15 is triggered repeatedly by voltage pulses of proper amplitude developed in the toroidal pick-off transformer T2 in response to the flow of current through the gas sensor 14. The output of the multivibrator 15 is inverted by the inverter designated U4' in FIG. 2, is then amplified by driver circuit Q11, and filtered by circuit C8, R31, to provide, upon proper conditions, a constant DC current flow of about 5 milliamperes (ma) to energize and illuminate the light-emitting diode (LED) designated 18 in FIGS. 1 and 2 and to hold SCR Q9 in the ON condition provided it has been properly triggered.

Two conditions must be met in order for a current flow of approximately 5 milliamperes to flow through LED 18 to illuminate the same. First, current must be flowing through the gas sensor 14 having approximately the proper amplitude and wave shape to provide the proper pulses at the input to multivibrator 15. Secondly, a so-called "ready" latch silicon-controlled rectifier (SCR), designated Q9 in FIGS. 1 and 2, must have been fired.

The function of the so-called "ready" latch circuit, an important component of which is the SCR identified as Q9, is to provide an initial delay. It is to be understood that during the time that the instrument is being recharged by the battery charger (approximately 13

hours are required for recharging), the gas sensor becomes contaminated by absorption from the atmosphere so that when the instrument is removed from the charger and first turned on, the gas-sensor is in an alarm condition. A short time (approximately 1 to 3 minutes) is required to heat the gas sensor to a temperature sufficient to purge it. During this purge period, an "alarm" condition exists, so far as the device is concerned, and unless provision be made to take care of this situation, the instrument will sound an alarm when it is first turned on. To take care of this situation, and to prevent the device from sounding an unwanted or false alarm, a time delay of about 1–3 minutes is provided. This delay is controlled by the oscillator circuit identified as **21** in the block diagram of FIG. **1.** A principal component of the delay circuit **21** (FIG. **1**) is the unijunction transistor Q12 of FIG. **2** which, in combination with capacitor C9 and resistor R34, operates as a long period oscillator. As indicated above, after a delay of the order of 1–3 minutes, controlled by resistor R34 and capacitor C9, the oscillator **21** applies a trigger pulse to the gate terminal G of the SCR Q9 sufficient to turn on the SCR.

After the trigger pulse has disappeared, the SCR Q9 will stay ON provided that the LED **18** circuit is delivered the desired constant DC current flow of 5 milliamperes. Whether or not such a desired current is flowing through the LED circuit depends upon the current flow at the gas sensor **14.** Normally, there will be current flowing in the gas sensor and the SCR Q9 will therefore be held ON. If, for any reason, no heater current is flowing through the gas sensor **14,** no voltage pulses are produced by the differentiating pick-off transformer T2, and the monostable vibrator **15** is not driven. In such case, transistor Q11 is OFF, and the desired 5 milliamperes of current is not being delivered through the LED circuit. In this situation, the SCR Q9 will not remain ON and LED **18** will not be ON.

It will be understood that the visual indication provided by the turning on of LED **18,** after the 1 to 3 minutes delay, confirms proper operation of the following elements comprising the combination of the present invention:

1. Battery **10**
2. Voltage Regulator **11**
3. Inverter **12**
4. Delay Oscillator **21**
5. SCR Q9
6. Gas Sensor **14** (neither shorted nor open)
7. Multivibrator **15**

This leaves for testing only comparator **24,** horn oscillator **26,** horn driver **28,** horn **29,** alarm light oscillator **31,** light driver **32** and alarm light **33.** These tests are carried out by depressing switch **30** at a time when LED **18** is on. This has the effect of putting resistance R1 across the gas sensor **14** thus simulating an alarm voltage at the input to comparator **24.** Thus, all components of the system, except low battery comparator **36** and low battery oscillator **38,** are tested through operation of LED **18** and test switch **30.** Reliability for continuous monitor use in the mine may thus be confirmed before descending into the mine proper.

Failure of the SCR Q9 to remain ON after having been triggered by the output of delay oscillator **21** will turn off LED **18** and will prevent horn driver **28** and alarm driver **32** (FIG. **1**) from operating, if, at this stage, the alarm test button **30** is depressed since a second trigger pulse from oscillator **21** will not arrive at the gate of SCR until 1 to 3 minutes have elapsed.

Assuming that SCR Q9 stays ON after the initial purge and delay period, as will normally be the case, the instrument now awaits the sensing of a concentration of methane gas approaching values which have been predetermined as being critical. In the specific device being described, an alarm will sound when the methane concentration at the gas sensor approaches a value between 0.8 per cent and 1.2 per cent. When a concentration of methane gas in this range is encountered by the gas sensor **14,** the so-called "gas" voltage which is developed at sensor **14,** when applied across resistor R12 and potentiometer R13 of gas comparator circuit **24,** causes the output of gas comparator **24** to drop to a low value sufficient to turn on oscillators **26** and **31.** The concentration at which this occurs is set by adjustment of R13. Referring to FIG. **2,** if the so-called "gas" voltage applied by R13 to the base of transistor Q4 exceeds the reference voltage E1 applied to the emitter by way of voltage divider R14, R15, the transistor Q4 turns ON and the output of the comparator drops to a low value. This has the effect of turning on the horn oscillator **26** and the alarm-light oscillator **31** of FIG. **1.** These oscillators preferably operate at different frequencies. R16 and C3 operate as an RC filter to eliminate any residual high frequency components originating at inverter-oscillator **12.**

As seen in FIG. **2,** the horn oscillator **26** includes the NOR gates U2 interconnected to provide a free-running oscillator whose output is applied through diode CR2 to the base of transistor Q10 to turn ON the transistor. This, in turn, turns ON transistor Q8. Transistors Q10 and Q8 are the amplifiers or driver components for the horn **29.**

The flashing light oscillator **31** includes the NOR gates U3, and the inverter comprising NOR gates U3' connected in parallel. Turning ON oscillator **31** has the effect of turning ON transistor Q7. Transistor Q7 is the amplifier or driver for the flashing alarm light **33.** Oscillators **26** and **31** are isolated from each other by diodes CR2 and CR4.

It will be noted that two separate oscillators are provided for horn **29** and light **33.** This is necessary because the horn **29** requires about 60 hertz with a 50 per cent duty factor, while the flashing alarm light **33** requires about 1 to 10 hertz at a duty factor of about 10 per cent.

It is to be understood from FIG. **2,** that for the alarm horn and the flashing light to be driven by their driver amplifiers Q10, Q8 and Q7, respectively, the SCR Q9 must be ON. If the SCR Q9 is not ON, neither of the driver amplifiers will be operative and neither of the alarms will be given since the path to circuit ground is through SCR Q9.

The device of the present invention also makes provision for sensing a low-battery condition. A portion of the unregulated battery voltage (12-volts) from source **10** (FIG. **1**) is supplied through a voltage divider R18, R19 to transistor Q5 of a low-battery comparator circuit identified **36** in FIG. **1.** If this voltage drops below a reference value E2, which may for example be set at 10.5 volts, the output of comparator **36** goes low and the low-battery oscillator **38** is turned on. This is a free-running oscillator embodying the NOR gates U2' of FIG. **2** and the associated resistors R22 and R24 and capacitor C6. Referring to FIG. **2,** it will be seen that

the reference voltage for the low-battery comparator is obtained by using a field effect transistor (FET) identified Q6 in FIG. 2. This FET is connected in a source follower configuration. This results in a constant current generator. By picking off a voltage from the source resister R21, a very stable voltage is obtained which is quite independent of the supply voltage. The output of the low-battery oscillator 38 is an asymmetrical waveform which will modulate the horn oscillator signal when the unit is in an alarm condition, thus producing an interrupted signal (a 60 hertz signal interrupted at approximately ½ second intervals).

As previously indicated, all oscillators in the device illustrated and described consist of two interconnected NOR gates forming one oscillator. The NOR gates are metal oxide semi-conductor integrated circuit (MOS) devices in a 14 pin DIP configuration. These MOS devices require extremely low power for their operation and this low power characteristic makes it possible to carry out continuous operation of the monitor of the present invention for a full day before the battery requires recharging.

As indicated in the notes on FIG. 2, at the integrated circuit packages containing U2, U3, and U4 (and their primes), the regulated voltage (7.7 volts) is connected to pin 14, and circuit ground is connected to pin 7. These pins 14 and 7 are not, however, shown in the drawing.

OPERATION

When the instrument is unplugged from the battery charger socket, the unit is automatically turned on. To prevent foreign particles from entering the charging socket, a plug is inserted into the socket.

After a short period of time (about two minutes), a small red indicator light, which is visible behind a hole on the side of the casing of the unit, will become illuminated. This red indicator light is the light emitting diode 18 (LED) of the block diagram of FIG. 1 and the circuit diagram of FIG. 2. The presence of light from the LED indicates that the sensor and most of the internal circuits are working properly as previously described. Absence of the red indicator light indicates that the unit is not working properly and should not be put into service.

After the indicator light has become illuminated, the alarm test button 30 on the front of the unit should be pressed to test the operation of the horn and the flashing light. If the horn does not sound, or if the light does not flash, when the button is depressed, the unit should not be put into service.

Assume that the unit after initial test which indicated the instrument to be in good working conditon is placed at its selected location in the mine. If the concentration of methane at the location of the unit increases to 0.8 – 1.2 percent, the horn will sound and the alarm light will flash. This will continue until the concentration falls below these limits. If the battery is low, i.e., if only about 30 per cent of the charge remains the sound will be interrupted at approximately one half second intervals since the horn oscillator signal will be modulated by the low battery oscillator signal under these conditions. This will give notice of a low battery condition. If a low battery condition arises when there is not an alarm condition, a clicking sound will emanate from the horn, similar to the sound made when smacking the tongue against the roof of the mouth. This signifies that the battery is too low for reliable operation of the unit.

SUMMARY

It will be seen from the foregoing description that the present invention provides a portable methane gas monitor and alarm device which comprises: a methane gas sensor of the semi-conductor type which in response to the presence of methane or like gas exhibits a change in its electrical conductivity; battery means for passing current through said gas sensor; a gas voltage comparator; means applying the output of said gas sensor to said gas voltage comparator; first and second oscillators; means for applying the output of said gas voltage comparator to said first and second oscillators; first and second amplifier driver means coupled respectively to the outputs of said first and second oscillators; a silicon controlled rectifier (SCR) gate; a horn alarm; a flashing-lamp alarm; means effectively coupling said first and second driver means to said horn alarm and to said flashing-lamp alarm respectively through said SCR gate, said gate being closed unless opened by a trigger signal applied to its gate terminal and held open by a suitable current, said horn alarm and said flashing lamp alarm thus being disabled unless said SCR gate is open; a monostable multivibrator; means responsive to current flow through said gas-sensor heater for developing trigger pulses to trigger repeatedly said monostable multivibrator; means for filtering the output of said multivibrator for developing a DC voltage; means applying said DC voltage across said SCR gate through an indicating light; initial delay means responsive to turn-on of said instrument for developing, after a delay of 1 to 3 minutes, a trigger signal; and means applying said delayed trigger signal to the gate terminal of said SCR gate to open said SCR gate to allow said DC voltage to drive current therethrough and thereby to latch said SCR gate in open condition. By the means described, the horn alarm and the flashing-lamp alarm are disabled for a period of 1–3 minutes after turn-on of the instrument to allow the gas sensor to heat up and to be purged of absorbed contaminants. Thereafter, the horn alarm and flashing-lamp alarm will be actuated whenever the gas sensor detects the presence of methane gas in concentrations of 0.8 to 1.2 percent.

The device disclosed also includes a circuit which gives notice that the battery voltage has fallen to a low value, as for example, from 12 volts to 10.5 volts.

Without intending to be limited to the types and values indicated below, the following is a specification of types and values of components which may be used to construct an instrument according to the present invention and disclosure:

Battery	12-V, 1.5 AH sealed lead-acid storage battery with gelled electrolyte (Globe Gel-Cel GC 1215-1 with integral current-limiting resistor).
Gas Sensor	Taguchi Gas Sensor Type 308
Transformer T1	Collector — 40 turns No. 32, both sides of center tap Base — 10 turns No. 32, both sides of center tap Tertiary — 8 turns No. 24 Core — Ferrox Cube Corp. Saugerties, N.Y., Series 1811, Grade 3B7
Transformer T2	Primary — 3 turns No. 29 Secondary — 16 turns No. 35 Core — Ferrox 891TD50

-Continued

	Grade 3B7
Transistors Q1, Q10, Q11	2N4403
Transistors Q2, Q3, Q8	MJE181
Transistors Q4, Q5, Q7	2N4401
Transistor Q6	MPF102 (FET)
Transistor Q9	MCR-106-3 (SCR)
Transistor Q12	2N4871 (UJT)
Integrated Cct U-1	Type 723
Dual Gates U2, U3, U4	Type CD-4001
Capacitors C1, C9	250 μf (electrolytic)
Capacitor C2	50 μf
Capacitors C3, C4, C5, C10	.01 μf
Capacitors C6, C7	.2 μf
Capacitor C8	10μf (electrolytic)
Resistor R12	3.9 k
Resistor R13	5 k
Resistors R14, R32, R7	22 k
Resistors R15, R31	820 ohms
Resistor R18	8.2 k
Resistors R19, R1, R4	1 k
Resistor R21, R5	2 k
Resistor R34	100 k

What is claimed is:

1. A methane or like gas monitor and alarm device comprising:

a. gas-sensing means which, in response to the presence of methane or like gas, exhibits a change in its electrical conductivity;

b. means for passing current through said gas-sensing means;

c. comparison means;

d. means applying the output of said gas-sensing means to said comparison means;

e. first and second oscillators;

f. means for applying the output of said comparison means to said first and second oscillators in parallel;

g. first and second amplifier means coupled respectively to the outputs of said first and second oscillators;

h. gate means;

i. horn alarm means;

j. flashing-lamp alarm means;

k. means, including said gate means, coupling the outputs of said first and second amplifier means to said horn alarm means and to said flashing light alarm means respectively;

l. said gate means being closed unless opened by a gate signal, whereby said horn alarm and said flashing-lamp alarm are inoperative unless said gate means is open;

m. means responsive to change in current through said gas-sensing means for developing trigger pulses;

n. means responsive to said trigger pulses for developing a DC voltage;

o. means for applying said DC voltage across said gate means;

p. initial delay means responsive to turn-on of said device for developing a delayed signal; and

q. means applying said delayed signal to said gate means to open said gate to allow said DC voltage to drive current therethrough, thereby to latch said gate in open position.

2. Apparatus according to claim **1** wherein said gas-sensing means is a semi-conductor device which depends on the surface effect of the gas on the semiconductor for available free electrons of conduction.

3. Apparatus according to claim **1** wherein said gate means is a silicon controlled rectifier and wherein said delayed signal developed by said initial delay means is applied to the gate terminal of said silicon controlled rectifier and light means responsive to said DC voltage in series with said silicon controlled rectifier.

4. Apparatus according to claim **1** wherein said means responsive to change in current through said gas-sensing means for developing trigger pulses includes a pick-off transformer having a winding in the filament circuit of said gas-sensing means.

5. Apparatus according to claim **1** wherein said means responsive to said trigger pulses for developing a DC voltage comprises a monostable multivibrator circuit adapted to be repeatedly triggered by said trigger pulses, and a filter circuit for filtering the output of said multivibrator circuit.

6. Apparatus according to claim **2** wherein said gate means is a silicon controlled rectifier and wherein said delayed signal developed by said initial delay means is applied to the gate terminal of said silicon controlled rectifier.

7. Apparatus according to claim **2** wherein said means responsive to change in current through said gas-sensing means for developing trigger pulses includes a pick-off transformer having a winding in the filament circuit of said gas-sensing means.

8. Apparatus according to claim **2** wherein said means responsive to said trigger pulses for developing a DC voltage comprises a monostable multivibrator circuit adapted to be repeatedly triggered by said trigger pulses, and a filter circuit for filtering the output of said multivibrator circuit.

9. Apparatus according to claim **3** wherein said means responsive to change in current through said gas sensing means for developing trigger pulses includes a pick-off transformer having a winding in the filament circuit of said gas-sensing means.

10. Apparatus according to claim **3** wherein said means responsive to said trigger pulses for developing a DC voltage comprises a monostable multivibrator circuit adapted to be repeatedly triggered by said trigger pulses, and a filter circuit for filtering the output of said multivibrator circuit.

11. Apparatus according to claim **3** wherein said gate means is a silicon controlled rectifier and wherein said delayed signal developd by said initial means is applied to the gate terminal of said silicon controlled rectifier.

12. Apparatus according to claim **3** wherein said means responsive to change in current through said gas-sensing means for developing trigger pulses includes a pick-off transformer having a winding in the filament circuit of said gas-sensing means.

13. Apparatus according to claim **3** wherein said means responsive to said trigger pulses for developing a DC voltage comprises a monostable multivibrator circuit adapted to be repeatedly triggered by said trigger pulses, and a filter circuit for filtering the output of said multivibrator circuit.

14. Apparatus according to claim **4** wherein said means responsive to said trigger pulses for developing a DC voltage comprises a monostable multivibrator circuit adapted to be repeatedly triggered by said trigger pulses, and a filter circuit for filtering the output of said multivibrator circuit.

15. Apparatus according to claim **4** wherein said gate means is a silicon controlled rectifier and wherein said delayed signal developed by said initial delay means is applied to the gate terminal of said silicon controlled rectifier.

16. Apparatus according to claim 4 wherein said means responsive to change in current through said gas-sensing means for developing trigger pulses includes a pick-off transformer having a winding in the filament of said gas-sensing means.

17. Apparatus according to claim 4 wherein said means responsive to said trigger pulses for developing a DC voltage comprises a monostable multivibrator circuit adapted to be repeatedly triggered by said trigger pulses, and a filter circuit for filtering the output of said multivibrator circuit.

18. Apparatus according to claim 4 wherein a detecting circuit is provided for detecting that the battery voltage has dropped below a selected reference voltage.

19. Apparatus according to claim 18 wherein said low-battery detecting circuit includes:

a. a voltage comparator for comparing the battery voltage with a reference voltage and for producing an output signal when the battery voltage drops below said reference voltage;

b. a low-battery oscillator;

c. means coupling the output of said comparator circuit to said low-battery oscillator to drive the oscillator;

d. means coupling the output of said low-battery oscillator to the input of said first amplifier for modulating at a low frequency said first oscillator signal when said first oscillator is operating, and for producing a low frequency signal when said first oscillator is not operating.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,879,717 Dated April 22, 1975

Inventor(s) Kurt Gruensfelder

It is certified that error appears in the above-identified patent ard that said Letters Patent are hereby corrected as shown below:

35 U.S.C. 254

Column 1, lines 52-53, change "3-1-5-6" to --3-15-6--.

Column 2, line 6, change "regulated" to --unregulated--.

Signed and Sealed this

nineteenth Day of *August 1975*

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks