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3,496,558

METHANE AND COAL DUST DETECTION

Filed July 3, 1967

3 Sheets-Sheet 1

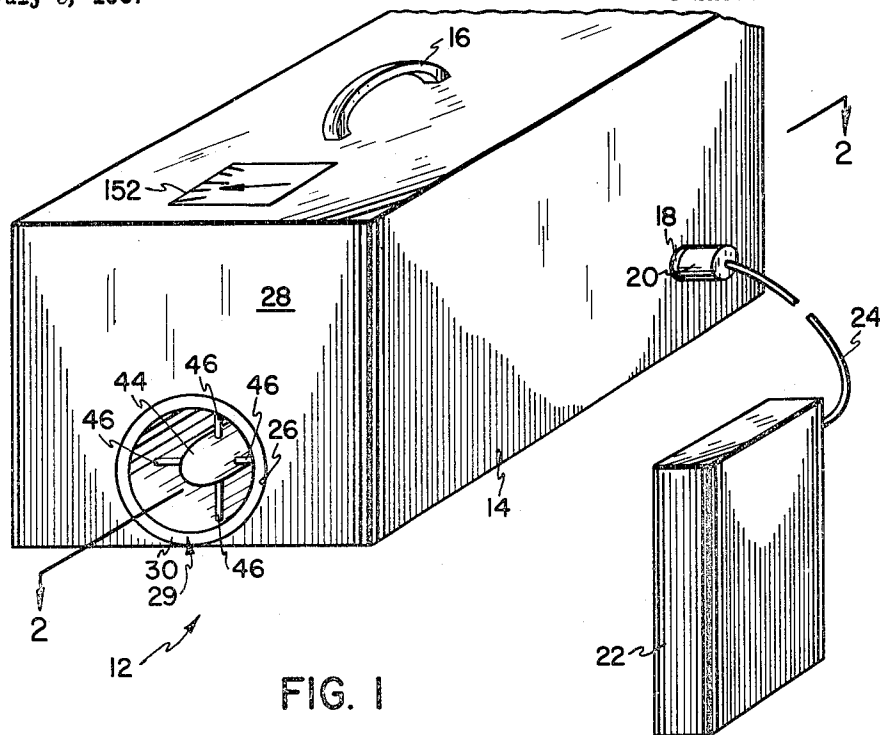


FIG. 1

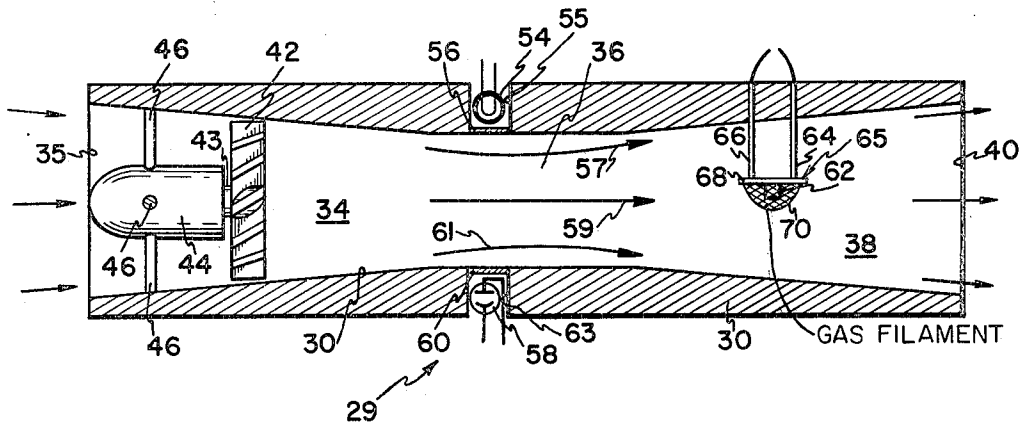


FIG. 2

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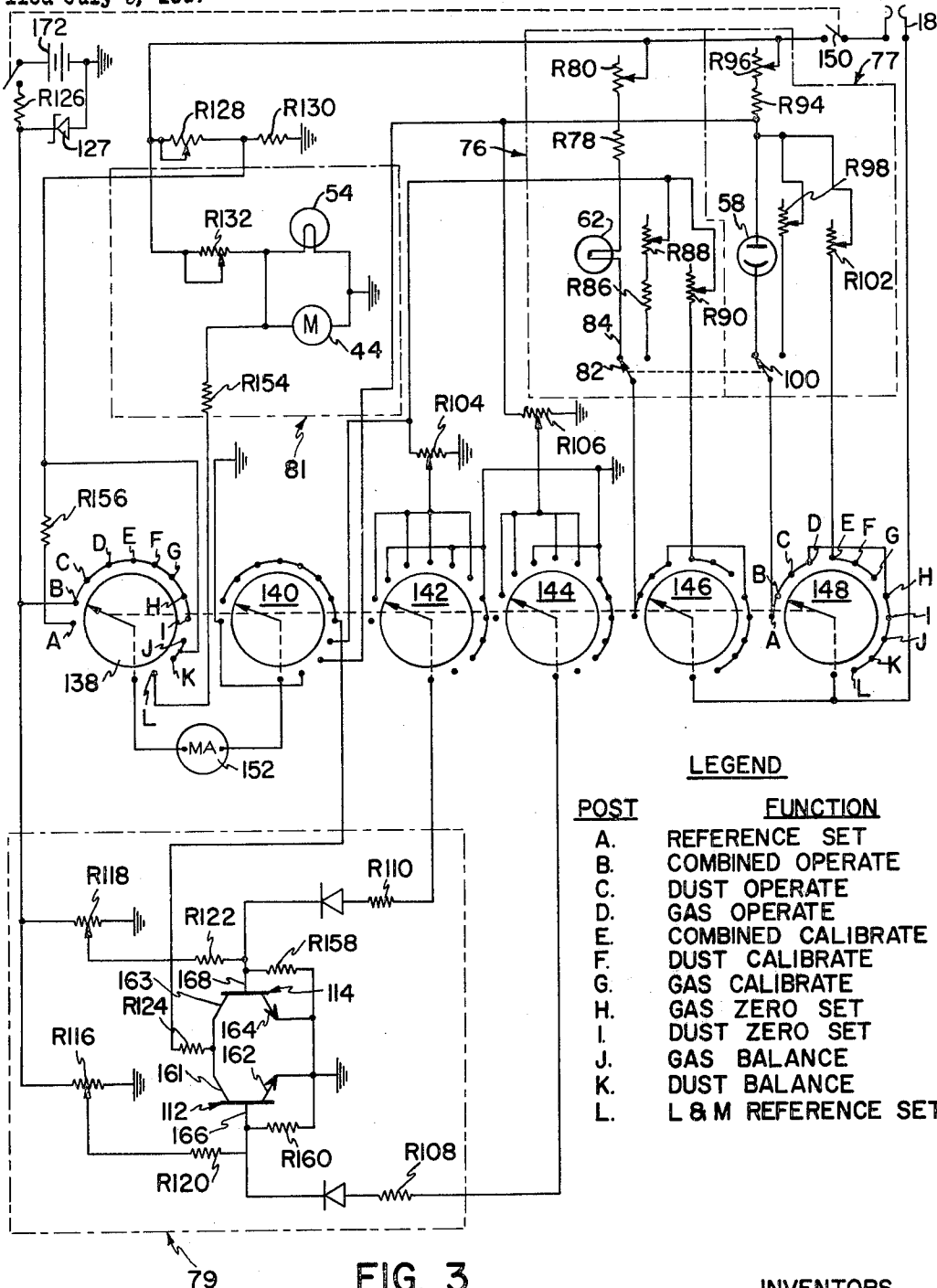
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POST	FUNCTION
A.	REFERENCE SET
B.	COMBINED OPERATE
C.	DUST OPERATE
D.	GAS OPERATE
E.	COMBINED CALIBRATE
F.	DUST CALIBRATE
G.	GAS CALIBRATE
H.	GAS ZERO SET
I.	DUST ZERO SET
J.	GAS BALANCE
K.	DUST BALANCE
L.	L & M REFERENCE SET

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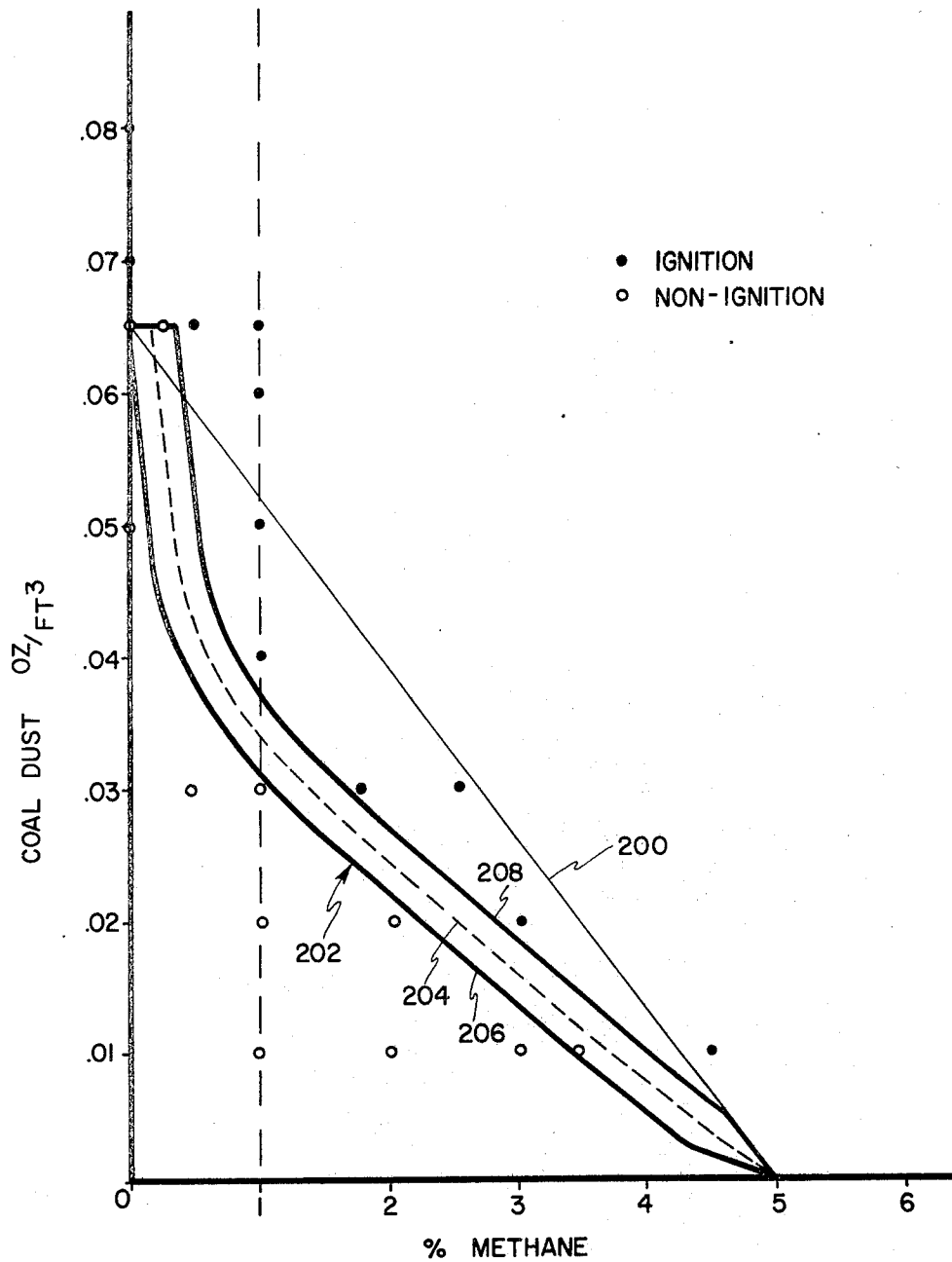


FIG. 4

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METHANE AND COAL DUST DETECTION

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5 Claims

ABSTRACT OF THE DISCLOSURE

An easily transported mine safety device comprising a combination coal dust-methane detector for individually and collectively determining the relative concentrations of dust and gas in the air so that the likelihood of an explosion in a mine can be accurately ascertained at any instant in time.

This invention pertains to a mine safety device and more particularly to a combination methane and coal dust detector which instantaneously detects and registers the individual or composite concentrations of methane and coal dust present in air.

One of the most significant hazards of underground mining results from the presence in the air environment of mines of relatively high concentrations of methane or coal dust or both. At respective critical concentrations, methane in air or coal dust in air will comprise an explosive mixture, dangerous to the well-being of the miners if inadvertently ignited. Moreover, methane together with coal dust will, in combination, comprise an explosive mixture where neither the methane nor the coal dust concentration is individually explosive.

In an effort to combat such hazardous environmental conditions, a number of methane detectors have been proposed by the prior art for the purpose of detecting the concentration of methane in ambient air within a mine. Likewise, a number of detectors have been proposed for the purpose of determining relative dust concentrations. Lack of an instrument capable of measuring the explosive characteristics of the combined concentrations of methane and coal dust has made it impossible to accurately predict the likelihood of a mine explosion. Thus, mine explosions continue to periodically occur resulting in destruction of human life as well as equipment.

It is therefore a primary object of the present invention to provide a portable detector capable of easily and speedily detecting the explosive characteristics of ambient air as measured by both the individual and the collective relative concentrations of two explosive ingredients in the air.

For purposes of illustration only, the presently preferred embodiment of this invention includes a methane and coal dust detector assembly which comprises a venturi sampling chamber through which samples of air are forcibly displaced.

A light source and an oppositely disposed photoelectric cell are located adjacent the throat of the venturi and are used to determine the quantity of coal dust present in the sampled air as measured by the quantity of light reaching the photocell. A gas detector located within the venturi accommodates measurement of the amount of methane in the air passing through the venturi as measured by the change in resistance of the detector filament as methane contacts the filament surface within a shielded region of the gas detector. A suitable meter or indicator, electrically connected to the dust and gas detectors, accommodates selective display of the methane concentration, the coal dust concentration, and the integrated concentration of methane and coal dust, taken together.

The coal dust-methane detector of this invention is preferably operated on a low-voltage battery of the type

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used to power miners' lanterns so that both the detector and the battery may be conveniently hand carried underground.

It is another significant object of the present invention to provide a device for improving mine safety by providing instantaneous and accurate detection of the potential explosive environment of a mine as measured by the individual or collective presence of methane and coal dust in the ambient air of a mine.

These and other objects and features of the present invention will become more fully apparent from the following description and appended claims taken in conjunction with the accompanying drawings wherein:

FIGURE 1 is a schematic perspective representation of the presently preferred detector embodiment of this invention;

FIGURE 2 is a longitudinal cross section taken along line 2—2 of FIGURE 1;

FIGURE 3 is a circuit diagram schematically depicting circuitry that may be used with the embodiment of FIGURE 1; and

FIGURE 4 graphically depicts curves representing coal dust and methane concentrations which illustrate the general limits between potentially explosive mixtures and non-explosive mixtures.

Reference is now made to FIGURE 1 which in perspective schematically depicts one embodiment of the methane and coal dust detector of the present invention, the detector being generally designated 12. The detector 12 is conveniently housed in a suitable casing 14, preferably constructed of aluminum or other light material according to known method. A handle 16, fixed to the top of the casing 14, is provided to accommodate convenient portability from place to place. An electrical fitting 18, situated at one side of the casing 14, is adapted to receive an electrical plug 20 which transmits the electrical power from the portable power source 22 to the detector 12 through an electrical cable 24.

The power source 22 is preferably a portable battery such as commonly used in the mining industry at the present time. One such suitable power source is manufactured by Mine Safety Appliances of Pittsburgh, Pa., namely catalog No. 71746.

An aperture 26 in the front face 28 of the casing 14 and a corresponding aperture (not shown) in the back face of the casing 14 accommodates passage of ambient air through a sampling chamber, generally designated 29 (see FIGURE 2).

The sampling chamber 29 may be formed of black Plexiglas, although other suitable materials could be used, and has an internal venturi passageway 30. The venturi 30 comprises (a) a front frusto conical passageway 34 extending from intake opening 35 to the throat 36, (b) the throat 36 of the venturi, which preferably is a cylindrical passageway of substantial length, and (c) a rear oppositely disposed frusto conical passageway 38 which extends from the throat 36 to the outlet opening 40.

A constant speed, multi-vane fan 42 is located just past the inlet 35 inside the venturi 30. The fan 42 is driven through shaft 43 by a conventional electric motor 44 enclosed in a contoured motor housing shaped to provide good aero-dynamic characteristics. The motor 44 and fan 42 are supported in a stationary position essentially coaxial with the venturi 30 by radially disposed braces 46. Wiring for carrying electric current from the battery 22 to the electric motor 44 may be located in one or more of the radially disposed braces 46 to prevent unnecessary obstruction of the intake passageway 34 and to eliminate fouling of the wiring in the rotating fan 42.

With the constant speed fan 42 so located, air will be drawn into the venturi 30 through the intake 35 in re-

sponse to rotation of the fan 42. As air is forced through the sampling chamber, its instantaneous velocity changes in proportion to the cross sectional area of the venturi. Thus, air being displaced through the venturi throat 36 will be moving at a faster rate than air being displaced through the intake 35 and the exhaust opening 40.

A light source 54 is located within a recess 55 at the throat 36 of the venturi 30, somewhat closer to the front passageway 34 than to the rear passageway 38. The light source 54 may be a common flashlight lamp which generates illumination that travels through a transparent window 56, formed of Plexiglas or the like, and across the venturi throat 36. The illumination thereafter passes through another window 60 and is sensed by a photo-detector 58 located within a recess 63 diametrically opposite the light source 54. One suitable photo-detector is RCA 4425 cadmium sulphide photoelectric tube, manufactured by Radio Corporation of America.

The location of the light source and photodetector in the throat 36 of the venturi 30 reduces the need for recalibration of the detector. Air that is forced through the passageway 30 by rotation of the fan 40 is caused to converge toward the center of the venturi throat 36 at an accelerated speed. Thus, air containing coal dust is displaced toward the center of the venturi throat and away from the peripheral edges as indicated by arrows 57, 59 and 61 (FIGURE 2). After an initial buildup or coating of coal dust particles on the exposed surface of windows 56 and 60, equilibrium or near equilibrium in the buildup is apparently reached and, following calibration, the resistance to the passage of light afforded by the coated windows 56 and 60 will remain nearly constant for a long period of time.

A methane detector 65, such as the catalog No. MSA 11355 produced by Mine Safety Appliance Company of Pittsburgh, Pa., is located somewhere within the venturi, as, for example, in the rear passageway 38. Electric current is passed through the filament 62 of the gas detector 65 such that it is maintained at or above a minimum predetermined temperature. The filament 62 is situated near the center of the passageway 38 of the venturi 30 and fixed to the venturi wall in that position by a bracket comprising support members 64 and 66 and base 68.

The filament 62 is enclosed in a wire mesh or screen 70, which functions to break up long chains of methane molecules and thereby prevent chain reaction ignition or explosion of the methane as it comes in contact with the filament within the screen 70 by the filament 62. The relatively low specific heat of the methane causes a change in resistance of the filament wire 62. This change in resistance is detected and measured by the circuitry of FIGURE 3 as directly indicative of the concentration of methane in the ambient air passing through the sampling chamber 29.

Location of the gas filament 62 in the exhaust portion 38 of venturi 30 accomplishes two significant purposes: (a) the velocity of the air passing through the venturi 30 is somewhat reduced in the exhaust portion 38 and thus has a much reduced tendency to cool the filament 62, and (b) the dust in the air is dispersed in the exhaust portion 38 which substantially reduces accumulation of dust on the filament 62 and the screen 70. Thus, this invention accommodates a prolonged expected useful life of the detecting elements and provides surprisingly consistent long-term accuracy.

Reference is now made to FIGURE 3 which depicts suitable circuitry for use as part of the detector 12 of FIGURE 1. Since a number of equivalent circuits could be easily devised and used, the circuitry of FIGURE 3 is only one suitable circuitry embodiment and is presented only as being illustrated and not to restrict the scope of the invention.

The circuitry of this embodiment comprises a gas detector segment 76, coal dust detector segments 77, amplification circuitry 79 and light and motor segment 81.

A Wheatstone bridge which comprises elements of some of the preceding segments forms another basic component of the circuitry.

The Wheatstone bridge includes resistors R78, R80, R96, R94, R128, and R130. The 1000 ohm potentiometer R128 and the 100 ohm fixed resistor R130 provide reference resistance on the bridge. The resistors R80, R78, and R96, R94 in series with the filament 62 and the photocell 58 respectively are adjusted to balance with the bridge reference resistance. Changes in resistance in either the filament 62 or photocell 58 or both will result in a signal representing the amount of gas or dust that causes the resistance change.

The gas detector segment 76 comprises a filament 62 which is energized for use when the switch 82 provides electrical communication through the line 84. The filament 62 is maintained at a proper operating temperature by adjusting the current through the filament 62 using fixed resistor R78 and variable resistor R80 having resistances 7 ohms and 3 ohms respectively. The filament 62 is calibrated by positioning the switch 82 to complete the circuit through resistor R86 and variable resistor R88. Resistor R86 preferably has a 0.5 ohm fixed resistance and variable resistor R88 is preferred to have a 1 ohm variable resistance.

Since the resistance level of the circuit through R86 may be accurately determined, the instrument 12 may be calibrated to a predetermined reference position without regard to the gas concentration in the atmosphere. The calibration procedure will be more fully discussed hereafter. Variable resistor R90 is approximately 3 ohms and is adjustable to represent a known offset of the Wheatstone bridge. Therefore current may be directed through the variable resistor R90 to verify that the elements of the gas detecting component 76 are functioning correctly and thus the variable resistor R90 serves as a check for malfunction.

Referring now to the coal dust detector segment 77, the phototube 58 is depicted in series with resistor R94 and variable resistor R96. Resistor R94 has a fixed resistance of about 1000 ohms and R96 has a 500 ohm variable resistance. R96 is adjusted to place a potential of about 0.65 volt on the photocell 58. This photocell potential approximately equals the potential in the filament 62 in this embodiment of the invention. Switch 100 and switch 82 are schematically shown as being joined together so that they are conjointly actuated. When the switch 82 is located to complete a circuit through resistor R86, switch 100 will provide electrical communication through variable resistor R98. Resistor R98 is preferably a 100 ohm variable resistor and it is adjusted to function as a known offset of the photocell 58. The resistor R98 therefore accommodates calibration of the photocell 58 to a known resistance value representative of a reference coal dust concentration. The 100 ohm variable resistor R102 is adjustable to function as a known bridge offset resistance. Therefore, the variable resistor R102 is used to check for malfunction of the photocell circuitry 77 in essentially the same manner that the variable resistor R90 (previously described) is used to check for malfunction in the filament circuitry 76.

The amplifier circuitry generally designated 79 comprises two essentially identical transistors 112 and 114 such as are manufactured by General Electric (Catalog No. 2N337). The transistors 112 and 114 amplify the signal which appears through the resistors R108 and R110. Resistors R108 and R110 preferably have a fixed value of about 4700 ohms and function with 100,000 ohm potentiometers R104 and R106 to control the sensitivity of the amplifiers 112 and 114.

In order for the amplifiers to function properly, a constant reference voltage must be provided at the transistor bases 166 and 168. The reference voltage to the transistors is provided by a power source 172 through a 1000 ohm resistor R126 and a 7.5 volt Zener 127 such as is manufactured by Motorola (Catalog No. 1N1768). The power

source 172 may be any common 9 volt power source. A reference condition is imposed on the amplifiers 112 and 114 and is maintained at a zero reading by two fixed 27,000 ohm resistors R120 and R122 and two adjustable 100,000 ohm potentiometers 116 and 118. A single 6200 ohm resistor R124 is connected to both of the amplifier collectors 161 and 163 and thus accommodates combination of the signal representing the gas and dust concentrations. The potential between the transistor bases 166 and 168 and their respective emitters to ground 162 and 164 is controlled by resistors R158 and R160.

The light and motor circuitry segment 81 includes a light source 54 such as a General Electric Lamp No. 222 and a conventional electric motor 44. A 50 ohm potentiometer R132 provides a current range which corresponds to the proper operating ranges of the lamp 54 and motor 44. The 18,000 ohm resistor R154 cooperates with the potentiometer R132 to control the operating current for the motor 44 and the lamp 54.

The operation and calibration of the instrument is facilitated by fixed function switches 138, 140, 142, 144, 146 and 148 that are simultaneously controlled by a single dial (not shown). Although only the post positions on switches 138 and 148 are designated, post positions on all of the function switches are considered to have identical designations. To initially calibrate the instrument the switches 82 and 100 are placed in an operating position completing the circuit through the filament 62 and the photocell 58 respectively. The on-off switch 150 is placed on "on" position. With the function switch set to reference position A (see legend) the meter 152 is adjusted to read 29 micro amps with the 1000 ohm potentiometer R128. This sets 0.65 volt across the 100 ohm resistor R130.

The function switch is moved to L and M (light and motor) reference position L and the meter is adjusted to read 29 microamps with the 50 ohm potentiometer R132.

The function switch is positioned at K, the dust balance position, and the operate-calibrate switches 82 and 100 are located in the operate position. This balances the Wheatstone bridge and induces a potential of 0.65 volt across the photocell 58. With the switches 82 and 100 in the calibrate position the meter 152 is adjusted to read zero, using the dust calibration resistor R98. This matches the calibrate resistor to the resistance in the photocell 58. The switch is then moved to location J, the gas balance position, and the operate-calibrate switch is placed in operate position, and the meter 152 is set to read zero using the 3 ohm potentiometer R80. This balances the Wheatstone bridge and sets 0.65 volt across the gas filament 62.

With the function switch in gas balance position (position J) the operate-calibrate switches 82 and 100 are located in calibrate position and the meter 152 is adjusted to read zero using the gas calibrate 1 ohm resistor R88. This matches the calibrate resistor R88 to the resistance in the filament 62.

The function switch is located at position I, the dust zero set, and the operate-calibrate switches 82 and 100 are moved to operate position so that the meter 152 may be adjusted to read 2 microamps using the 100,000 ohm potentiometer R116. This adjusts the reference current for dust amplifier 112 and grounds the input to the gas amplifier 114. The switch is then moved to gas zero set (position H) and the meter 152 is adjusted to read 2 microamps using the potentiometer R118. This adjusts the reference current for gas amplifier 114 and grounds the input to the dust amplifier 112.

The switch is then located at position G which is the dust-calibrate position, and the meter 152 is adjusted to a predetermined level using the potentiometers R102 and R106 which control the gain to the transistors. The function switch is then located at position F which is the gas-calibrate location and using the potentiometers R90 and R104 gain control the meter 152 may be adjusted to a predetermined reference position for purposes of calibration.

The potentiometer R90 and the gain control R104 function in the same manner as the potentiometer R102 and the potentiometer R106 described above.

With the switch located in position E the reading on meter 152 indicates the calibration of the combined dust and gas detectors.

With the instrument calibrated according to the method above it is ready to measure the ambient atmosphere. The switch is located at position D and the meter 152 directly indicates the concentration of coal dust. When the switch is located at position C the meter 152 directly indicates the concentration of methane. And finally with the switch located at position B the combined concentrations of coal dust and gas may be read directly on the meter 152.

It is presently preferred that most of the calibration procedure described above be carried out at the manufacturing site of the instrument. Subsequent to initial calibration, the instrument may be easily operated by calibrating the instrument to a predetermined coal dust reference reading and a predetermined gas reference reading. It is then a simple matter to check the zero position and directly read the concentrations of gas and dust or, significantly, the combined concentrations of gas and dust by simply locating the function switch at position B, C, or D.

Reference is now made to FIGURE 4 which shows a line 200 representing the theoretical combinations of methane and coal dust which comprise an explosive mixture. Theoretically, all concentrations above the line 200 will ignite and all concentrations below the line 200 will not ignite.

Experimentally, however, it has been demonstrated that ignition takes place at significantly lower concentrations. Curve 202 represents the methane and coal dust concentrations which experimentally comprise an explosive mixture for one particular coal dust type.

The data was obtained by selectively introducing mixtures of methane and coal dust into an explosion gallery. The explosion gallery is formed of a one foot length of tubular Plexiglas having a diameter of about 2½ inches. The explosion gallery is provided with two spaced electrodes that will generate a spark at the command of an operator. The explosion gallery also is provided with a pressure transducer which measures the changes in pressure as a result of an explosion. The explosion gallery does not comprise a part of this invention.

Mixtures of various compositions were introduced into the explosion gallery and a spark was introduced. Explosions, as indicated by a significant change in pressure, were recorded and the curve 202 was obtained. The curve 202 includes a line 204 representing the mean concentrations of coal dust and methane and the variance represented by lines 206 and 208 resulting from expected error in measuring the concentrations of methane and coal dust introduced into the explosion gallery.

From FIGURE 4 it is evident that combinations of methane and coal dust form explosive mixtures with air at concentrations below the explosive concentration for each individually. Therefore it is significant that the presently preferred embodiment of this invention is capable of accurately measuring the combined concentrations of methane and coal dust within the limits of 0% to 5% methane and 0.00 to 0.07 ounce per cubic foot of coal dust.

Therefore, the potential hazard of explosion in a mine may be detected by simply hand-carrying the precalibrated instrument into the mine and at any subsequent point in time locating the function switch at positions B, C or D to determine the respective concentrations of explosive elements in the ambient mine atmosphere.

The above-identified embodiment of the present invention uniquely provides a mine safety device contributing significantly to the safety of underground mining by making it possible to detect explosive conditions in the mine

air. Moreover, the above-described embodiment of the present invention accommodates repeated measurement of gas and dust concentrations with improved precision because of the unique sampling chamber configuration. Thus, the present invention as represented by the above-described embodiment provides a portable mine-safety device which will significantly contribute to the safety of the mining industry.

What is claimed and desired to be secured by United States Letters Patent is:

1. In a portable safety detector for measuring amounts of suspended dust and gas such as may exist in a mine, comprising a channel including a venturi section through which samples of ambient air are passed, power means for so displacing the ambient air, dust detecting means comprising oppositely disposed radiation source means and radiation detection means situated adjacent the throat of the venturi in generally transverse relation to the flow of air to ascertain the concentration of dust as measured by the resistance to passage of radiation across the venturi caused by the presence of the dust in the sampled air, gas detecting means disposed in the flow path of the sampled air to measure the concentration of the gas in the sampled air, circuitry means to detect signals originating at the dust detecting means and the gas detecting means and to provide indicia as to the actual concentrations of dust and gas individually and collectively as compared with critical concentrations at which an explosion may occur.

2. In a device as defined in claim 1 further comprising a portable low-voltage electrical power source for actuating the power means, the dust detecting means and the gas detecting means and wherein said venturi throat comprises a cylindrical configuration of substantial length whereby the increased speed of air at the throat will restrict accumulation of dust particles along the throat to substantially reduce the need to recalibrate the detector.

3. In a safety device for detecting an explosive environment comprising in combination separate means for independently determining the respective concentrations of at least two explosive substances present in an environment and means for combining the concentration information detected by the said means and means for collectively determining the composite explosive characteristics of the at least two detected explosive substances.

4. In a battery-powered methane and coal dust detector adapted to be hand-carried,

a venturi that internally comprises opposed conical passageways oppositely converging toward a central relatively narrow throat portion, said venturi passageways respectively having opposed entrance and exit openings in communication with ambient air;

a motor-driven fan located within the venturi near one opening to force ambient air through the venturi;

a light source disposed adjacent the throat of the venturi, said light source being separated from the displaced air by a window which accommodates passage of a light beam transversely across the venturi throat to a light sensor recessed in the opposed surface of the venturi throat and likewise separated from the displaced air by a transparent window;

a methane detecting filament disposed within and extending inwardly toward the center of the venturi, said filament supporting a constant voltage which induces an elevated temperature in the filament such that methane gas is selectively ignited within a screen region as it comes in contact with the filament, which increases the temperature of the filament and changes the resistance thereof without exploding or igniting the surrounding air;

circuitry to selectively record the individual and collective responses of the detector filament and light sensor.

5. In a detector as defined in claim 2 further comprising means for developing a detectable warning signal when the critical concentrations of the individual and collective substances are detected.

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U.S. Cl. X.R.

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