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A. S. SIMAKOV, *Associate Professor, Candidate of Engineering Sciences, as.simakov@yandex.ru*
A. A. BYZOVA, *Master*

Saint-Petersburg Mining University, Saint Petersburg, Russia

SELECTING UTILITIES FOR PORTABLE MINE AIR CONTROL

One of the key objectives of mine safety is the continuous control of gas concentrations in mine air.

Chemical composition of mine air depends on geological conditions, mining technology and type of mining equipment. The main sources of chemical contamination of mine air are gas emission from rock mass, oxidation processes, blasting and operation of mining machines.

The presence of personnel in underground tunnels should be allowed with regard to the mine air content of oxygen, hydrogen and harmful gases. A harmful gas is methane that accumulates in closed spaces and is explosive. Methane concentration in the air of operating underground mines can never exceed maximum allowable values. The mine air content of oxygen is to be not less that 20% and hydrogen content cannot be higher than 0.5% (by volume).

Key words: *methane, mine, control, meter, sensor, concentration, UART, ZigBee*

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Introduction

Methane concentration should be controlled in all underground excavations where methane can release and accumulate [1].

Depending on methane hazard category of a mine [2], methane concentrations in mine air can be controlled using fixed and portable meters [3] (**Table**).

Table. Mine air methane concentration meters

Methane hazard category of mine	Meters		
	Portable, casual CH_4 control	Portable, continuous CH_4 control	Fixed, automated CH_4 control
Nonhazardous	—	—	—
Categories I and II: with and without methane presence	+	+	—
Category III, super hazardous and outburst hazardous	+	+	+

Methane concentration meters

Portable meters of methane concentration allow continuous control of mine air in personnel operation areas [4]. Such meters should be small and light, provide sufficient accuracy of measurements and capable to operate for a long time with an independent power supply [5].

The functional chart of a methane concentration meter [6] is shown in **Fig. 1**.

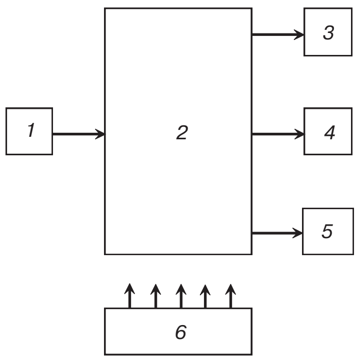

Fig. 1. Functional chart of methane concentration meter: *1* — methane sensor; *2* — electronic circuit diagram; *3* — audible alarm; *4* — digital data display; *5* — interface; *6* — power supply

The most important element of the meters is methane sensor [7]. Operation of methane sensors can be based on different physical principles [8]. Methane sensors possess characteristics that should be taken into account in design of a meter [9], for example:

- Response rate. Inasmuch as a response curve greatly flattens on approach of a terminal value, the time of response is often determined as the time taken for a sensor to reach 90% of the final indication and, accordingly, is known as T90.
- Ensitivity. A sensor should have sensitivity to measure methane concentration accurate to basis points.
- Power input.
- Contamination tolerance.

A few kinds of methane sensors and their serviceability in portable meters are reviewed below in this article.

Catalytic sensor

Catalytic sensors (**Fig. 2**) use thermal effect of catalytic combustion of methane on the surface of low-temperature catalyst.

The sensitive element is an activated alumina cylinder wound with platinum wire to ensure current-induced heating of elements up to a temperature of 360–400°. The surface of the sensitive element is coated with the platinum–palladium catalyst for flameless combustion of methane. Burning methane heats the platinum wire of the element, and its resistance changes as a result in conformity with the change in the methane concentration in the air [10].

Usually, catalytic sensors have T90 from 20 to 30 s and power input from 300 mW to 1.5 W.

The most common defect of catalytic sensors is failure of performance under impact of certain chemical substances. In this connection, it is important to verify sensors during installation and carry out cyclic calibration tests when in service.

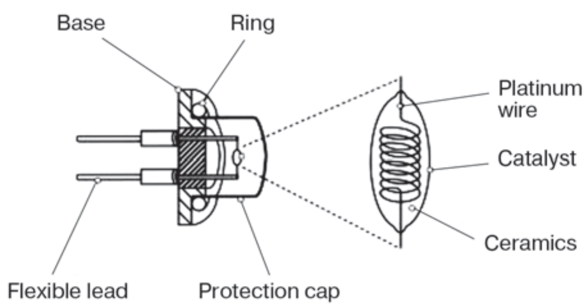

Fig. 2. Catalytic sensor

Semiconductor sensor

Semiconductor sensors are made as tin oxide films. These sensors use the principle of operation based on the change in conduction of a semiconductor material when molecules of detectable gases are adsorbed at its surface. The process of gas adsorption at the surface of a semiconductor depends on temperature. For any gas, there is a range of temperatures within which the sensitivity toward the gas is maximal.

For different semiconductor materials and detectable gases, the temperature ranges from 100° to 500°. In order to enhance selectivity of a sensitive element, the latter can be added with catalysts — platinum, palladium, etc.

Series-production semiconductor methane sensors require supply from 100 to 800 mW and have T90 from 10 to 30 s.

The typical features of semiconductor sensors are limited rate of response, short life, high sensitivity toward contaminating substances and substantial error of measurements. In this connection, semiconductor sensors are mostly used in signaling devices and leak detectors [11].

Electrochemical sensor

The operation of an electrochemical sensor is based on the principle that a component under detection enters reaction with a sensitive layer directly on electrode or in the solution nearby the electrode [12]. Electrochemical sensors are divided into:

— potentiometric;
— amperometric and
— conductometric.

Electrochemical sensors are small in size and have an almost linear characteristic. The response time T90 is 30–60 s. The power intake may reach 500 mW.

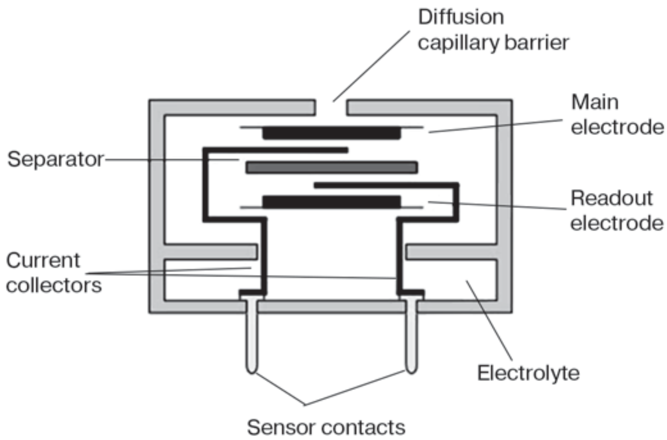

Fig. 3. Electrochemical conductometric sensor

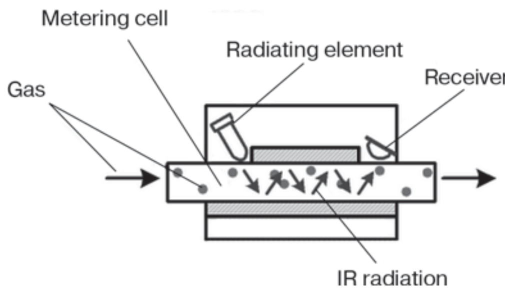

Fig. 4. Infrared optical sensor

Electrochemical sensors can detect super-low concentrations of gases.

Electrochemical sensors are subjected to contamination by associated gases. Some electrochemical sensors require cyclic replenishment of electrolytic solution (**Fig. 3**).

Infrared optical sensor

The operating principle of optical sensors (**Fig. 4**) is based on the capacity of gases to absorb infrared light. Each gas to be detected has its maximum IR absorption, and concentration of gas is determined by means of measuring the degree of IR absorption.

IR absorption by gases is independent of oxygen and tolerates vibration and noise [13]. Such sensors are highly sensitive and accurate, well selective and reliable, and have short time of response — T90 is less than 10 s (up to 30 s if a filter is used).

Moreover, these sensors endure impact of high concentrations of test and associated gases.

The power consumed by these sensors ranges from 3.5 to 5 mW.

Conclusions

Sum up, the IR optical methane sensors can be assumed the best and most efficient for the use in portable gas detectors. These sensors feature sufficiently high sensitivity, short-time response, low power input, contamination insensitivity and long service life.

Out of a variety of optical methane sensors, an emphasis should be laid on Optosense products, namely MIPEX 02 and MIPEX 03 sensors. Their specification is given below [14]:

Meter range (depending on the model)	0–2.5 % (by volume) 0–5 % (by volume) 0–100 % (by volume)
Error	±0.1 % (by volume)
Response time (T90)	
sensor without filter	≤ 15 s
sensor with filter	≤ 30 s
Voltage	from 3 to 5 V
Power input	≤ 5 mW
Signal output	UART or UART + analog signal

The universal asynchronous receiver–transmitter UART facilitates communication between the sensors and microcontrollers and, thus, simplifies measurement data processing. MIPEX03 UART has an analogue output, which makes the sensors universal in terms of measurement data displaying.

Regarding the operation of the sensors in portable independent power supply facilities, it is necessary to select microcontrollers with UART and low power consumption.

To this effect, it is convenient to use MSP430 manufactured by Texas Instruments, with extra lower energy intake, in particular, microcontroller MSP430x2xxx [15].

At the clock frequency of 1 MHz and with the operating hardware peripherals, the specified microcontroller takes supply current of 300 μA [16].

The indication of the measurement data is convenient with LCD. There is no need to continuously display data. The information can only be displayed when the control value exceeds a threshold, with the accompanying audible signal of a certain frequency and duration.

The inclusion of MIPEX IR sensors, MSP430G2553 microcontroller and LCD in a portable meter of methane concentrations will provide a packaged unit with the independent power supply, capable to operate for a long period of time without replacement or recharging of the feed element.

The equipment can be added with wireless transfer of data on methane concentration to an operator's board.

The system of real-time data collection and control needs no high rate of exchange as a rule. For this reason, the wireless data communication between the methane concentration meter and the operator's board can use IEEE802.15.4 (ZigBee) supporting standard [17].

This standard sets the maximum data rate of 250 Kbps and the communication range of the order of a few tens meters within line of sight. A feature of the nets based on IEEE802.15.4 standard is the capacity to implement any topology, including cellular [18].

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S. G. GENDLER *[1], Professor, Doctor of Technical Science, sgendler@mail.ru*
A. M. GRISHINA *[1], Postgraduate*
E. A. KOCHETKOVA *[2], Labour Protection Specialist of Occupational Safety and Health Division*

[1]Saint-Petersburg Mining University, Saint Petersburg, Russia
[2]Almazov National Medical Research Centre, Saint Petersburg, Russia

OPTIMIZATION OF EXPENDITURES FOR LABOR PROTECTION AT DEEP MINING

The analysis of the state of the labor protection and industrial safety system of Russia's coal mining industry demonstrates that the rise in the investment into the measures directed at improving does not lead to a sufficient fall in the risk of occupational injuries and occupational diseases. Moreover, it has been found that at a number of the industry's enterprises the risk of occupational traumatism and occupational diseases follows either an upward trend or a wavelike trend with minimum and maximum values. One of the ways of achieving an increase in the effectiveness of the HSE system is determining the amount of expenditures that leads to the minimum values of the risk of occupational injuries and occupational diseases, which can be considered 'economically justifiable risks'. In the article the procedure of calculating investment into industrial security and labor protection for coal mining companies is proposed. The method for calculating optimal expenses on preventing occupational injuries and economically justifiable risk is elaborated.

Key words: *coal mine, labor protection, accident rate, coal mining industry, industrial security, cost optimization, economically viable risk*
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Introduction

The possibility of ensuring the admissible values of the risk of occupational diseases, injuries and accidents is determined by the expenses on industrial safety and labor protection [1, 2]. The correlation between these expenses for OOO Prokopyevskugol Corporation for 2010–2013 is presented in **Fig. 1**.