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IMPROVING EFFICIENCY OF INFORMATION MEASUREMENT SYSTEM OF COAL MINE AIR GAS PROTECTION

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ПІДВИЩЕННЯ ЕФЕКТИВНОСТІ ІНФОРМАЦІЙНО-ВИМІРЮВАЛЬНОЇ СИСТЕМИ АЕРОГАЗОВОГО ЗАХИСТУ ВУГІЛЬНИХ ШАХТ

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ABSTRACT

Purpose. Development of scientific approaches to creation of high-precision and high-speed optoelectronic measurement systems within the complex of air gas safety of coal mines by means of the developed and implemented methods and means of measurement systems efficiency improvement taking into account compensation of the effect of destabilizing factors.

Methods. Experimental studies have been carried out in mine production conditions and laboratories on the physical models of information measurement systems using metrologically certified measuring instruments.

Findings. It has been proposed to determine the efficiency of the developed information and measurement systems on the basis of the arithmetic mean of n groups and the geometric mean of the information data rate of m meters measuring mine atmosphere parameters in coal mines for each group separately. It has been found that the use of the developed information system measuring methane and dust concentration within the UTSSC increases data rate of mine air gas protection system by 16.5 bits/s.

Originality. For the first time, logical design of information and measurement system of methane and dust concentration has been proposed and implemented, which, in contrast to the existing ones, is based on increasing accuracy and speed of measuring channels response to methane and dust concentration, which allowed to increase probability of detecting explosive situations from 0.90 to 0.98 and provide enhancement of mine air gas protection.

Practical implications. The developed methods and techniques allowed to implement a number of projects for the mining industry: high-speed measurement system evaluating methane concentration in a mine complex of monitoring telephone communication and notification "SAT" (private company "Deyta Express", Ukraine); measurement system of polydisperse dust concentration for unified telecommunication systems of supervisory control and automated management of mining machines and technological complexes "UTSSC" (State Enterprise "Petrovsky Plant of Mining Machinery", Ukraine).

Keywords: *measurement system, concentration, methane, dust, coal mine, accuracy, speed of response*

1. INTRODUCTION

During the development and operation of information measurement systems (IMS) for methane and dust concentration in coal mines, it is necessary to assess the feasibility of using different system options and selecting the most efficient one (Palmius, 2007; Martinsons, Davison, & Tse, 1999). The efficiency of such systems is determined by the ratio between information and the minimum amount of time spent on its processing (Pitt, Watson, & Kavan, 1995), therefore one of the efficiency indicators is speed of the response.

Widespread use of different IMS led to the research into developing generalized performance indicators that can be used in practice for comparing different options (Scott, 1995). However, determining the generalized performance indicator is quite a challenge because it has strict imposed requirements:

– functional connection with the characteristics of IMS;
– providing characteristics of IMS while performing tasks;
– mathematical reasoning and physical nature.

Analysis of the requirements set for the generalized performance indicator showed that they can be quite controversial. Therefore, the more the generic performance indicator reflects properties of the system, the harder it is to be chosen. Known methods of developing the generalized indicator are based on the following postulates (Pitt, Watson, & Kavan, 1995):

– efficiency of the system is determined by comparing it with any other system (an equivalent or a prototype);

– generalized indicator is taken as a sum of partial indicators and certain weighted coefficients;

– while choosing the generalized indicator it is necessary to find interrelationship between a set of technical characteristics of the system and its cost.

Analysis of existing information and measurement systems of methane and dust concentration resulted in finding discrepancies between their specifications, parameters and current requirements for speed, accuracy and measurement reliability. Dust concentration measuring devices used today are not able to work in real-time operation conditions simultaneously with methane concentration measuring devices. This leads to a significant delay in identification and evaluation of the limits of explosive powder-gas mixture and substantially reduces efficiency of the air gas protection system (AGP) of coal mines.

Figure 1 shows the interface of the program for visualizing topology of the subsystem of mine atmosphere measurement parameters in coal mines, which is used in the unified telecommunication system for supervisory control (UTSSC).

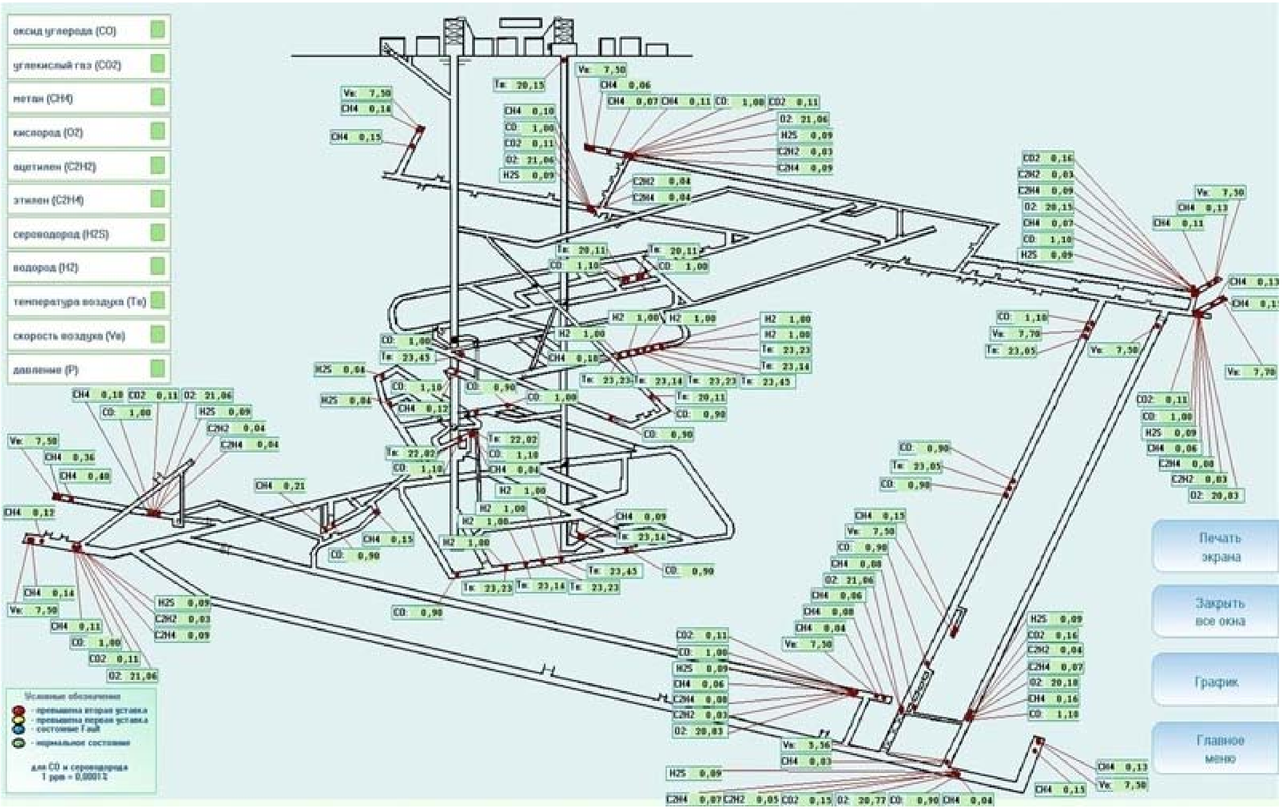

Figure 1. Interface of the program for visualizing topology of the subsystem of mine atmosphere measurement parameters in coal mines UTSSC

Having studied characteristics of the subsystem for measuring parameters of mine atmosphere in the UTSSC, we discovered that it comprises a methane concentration meter of TX3261.01 type (ITRAS, 2016) which performs measurements of methane concentration in the range of 0 to $4^{vol.}$%. This meter has the allowed response time related to the speed of methane concentration increase at less than 2 s ($0.5^{vol.}$%/s), as prescribed by NPAOP 10.0-1.01-10, 2010. Catalytic thermal time constant of the meters used in the UTSSC is not less than 3 – 4 s. To ensure registration of the required speed increase in volume concentration of methane (no more than 2 s), software methods of digital processing of output signals are used in high-speed sensors. According to the requirements for stationary methane meters (DSTU 24032:2009, 2009), generally accepted as fast-responding, these sensors must also ensure that the response time for methane volume concentration is no more than 0.8 s. For sensors which are based on thermocatalytic method, the value is practically not achievable due to physical and technical features of the sensors. Therefore it is necessary to develop new approaches to designing subsystems of measuring methane concentration of mine atmosphere in coal mine conditions in terms of speed increase, accuracy and reliability of metrological measurements.

A notable drawback of the UTSSC is that concentration of air-borne coal dust is not measured in the system. The presence of a sufficiently large amount of dust in mine atmosphere increases the probability of explosive situations in coal mines. This drawback is related to the fact that using existing aspiration sampling apparatuses, it is impossible to perform a continuous control measurement of dust concentration and dispersion. There is no coherent algorithm for determining the probability characteristics of powder-gas mixture explosiveness depending on speed and humidity of mine atmosphere, as well as on air-borne dust dispersion. Now industrial plants in Ukraine do not produce automatic dust concentration measuring devices, while overseas products are not designed for conditions of mine atmosphere.

Having analyzed characteristics of the air gas protection system UTSSC of mines, we can conclude that it is necessary to extend its functionality. Development and implementation of new methane and dust concentration meters for the system of coal mines air gas protection in the UTSSC will make it possible to identify and predict emergency situations with burst releases of methane and dust in coal mine atmosphere.

The conducted research enabled us to identify a scientific and applied problem of creating and technological implementation of new evidence-based approaches to information and measurement technology that will help to develop high-speed and high-precision optoelectronic measurement systems in the complex of air gas safety provisions of coal mines and industrial plants. The problem cannot be solved with the help of measuring methods and parameters of mine atmosphere control used today. To solve it, we need to develop new methods, models and solutions, which constitute the very core of this paper.

Our preliminary considerations after analysis of the problems concerned with coal mine air gas safety were the following:

1. Methods of optical control of dust and gas component concentration allow to ensure the necessary processing speed with the regulated measurement control precision. This breaks new ground for assessing the probability of sudden methane and dust explosions in coal mine atmosphere.
2. Prospects of further use of these methods are limited by decrease in accuracy and reliability of metrological meters due to complicated conditions of coal mines.
3. It was established that at present stage of theoretical and practical research, the most promising trend of solving the problem associated with air gas safety of coal mines is developing new approaches, methods and technical means of obtaining measurement information concerning changes in characteristics and parameters of coal mine atmosphere, contemporary ideas and techniques for digital processing of measurement data by means of information and measurement systems.

The aim of our research is to develop scientific approaches to creating high-speed optoelectronic measurement systems in the complex of providing air gas mine safety through the use of the proposed and implemented methods and means of improving the efficiency of measurement systems based on accounting and compensating destabilizing factors.

2. MAIN PART

While designing information measurement system of methane and dust concentration in coal mine atmosphere, it is necessary to assess the feasibility of using a certain system configuration. The amount of the obtained information is equal to the value of entropy set in the measurement process. Ideally, during the measurement, when there is no uncertainty about the number of methane molecules or dust particles, the maximum value of the obtained information is numerically equal to the initial entropy of the powder-gas mixture under analysis.

As a quantitative measure to compare the capacity of different measurement systems to obtain information about the content of the measured component in the analyzed gas mixture, a binary logarithm of the number of specified concentrations can be used. According to the Nyquist and Harley criterion (Sedalishhev, 2008), the number of signal levels cannot increase indefinitely, as it is limited to the reduced error of measurement. That occurs due to the impossibility to accurately measure the change of dust and gas component concentration in the analyzed gas mixture which is twice less than the absolute error ($2\Delta_C$) of the meter.

The entire measurement range can be replaced by a sequence of values of the determined concentrations of dust and gas components in the mixture. Thus, neighbouring values differ by twice the value of the absolute measurement error. If the concentration of dust and gas components varies from 0 to C_{max}, you can obtain $C_{max}\,(2\Delta_C)^{-1}$ of discrete levels of concentration. If the values of concentration within the measurement range have the same occurrence probability, the amount of information J, which is obtained during one measurement with absolute error Δ_C, is determined according to the following formula (Sedalishhev, 2008):

$$J = \log_2\left(\frac{C_{\max}}{2\Delta_C}\right). \qquad (1)$$

According to the formula (1), the data rate of information measurement system of methane and dust concentration in mine atmosphere is defined as the speed of obtaining measurement data, i.e. the maximum possible amount of information obtained per unit of time. If a time interval spent on conducting one measurement is Δt, then for $C_{max} >> \Delta_C$ and data rate G considering formula (1), we obtain (Sedalishhev, 2008):

$$G = \frac{J}{\Delta t} = \frac{1}{\Delta t}\log_2\left(\frac{C_{\max}}{2\Delta_C}\right). \qquad (2)$$

The results of calculating the data rate of the information and measurement system of methane concentration based on formula (2) by changing the absolute error Δ_{CH_4} from 0.01 to $0.20^{\text{vol.}}\%$ ($C_{max} = 4^{\text{vol.}}\%$) and processing speed of the meter Δt from 0.1 to 10 s, are shown in Figure 2.

Response time of methane concentration meters, which are designed as a means to control gas and power outages as required by DSTU 24032:2009, is less than 0.8 s with absolute error of measurement not more than $\Delta_{CH_4} = \pm 0.20^{\text{ vol.}}\%$ within the range from 0 to $4^{\text{vol.}}\%$ (DSTU 24032:2009, 2009). The value of the data rate of methane concentration meters has to be 4.15 bit/s, according to (2) (Fig. 2).

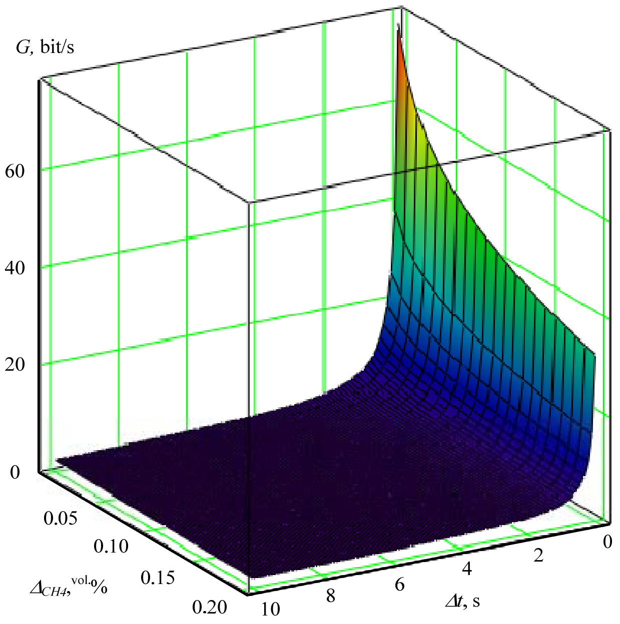

Figure 2. Data rate of the methane concentration meter at $\varDelta_{CH_4}$ from 0.01 to 0.20 vol.% and $\varDelta t$ from 0.1 to 10 s

The existing methane concentration meters, which are used today in the UTSSC system of AGP, have speed of response not less than 15 s (ITRAS, 2016). The value of information data rate of industrial sample meters of methane concentration is 0.22 bit/s. Departing from the analysis of the data, we can conclude that currently used meters have 19 times less value than regulated requirements to the information data rate (DSTU 24032:2009, 2009).

Having analyzed the data rate of methane concentration meters, we made a conclusion that the most significant impact on the information data rate (2) has speed of response of the meter ($\varDelta t$). Therefore, while measuring methane concentration using optical absorption method of control, it is necessary to eliminate the system of gas mixture sample preparation and provide natural circulation of mine atmosphere through the measuring sensor. Thus the expected value of the meter response speed according to preliminary theoretical and experimental studies will amount to no more than 0.15 s at the value of absolute error not exceeding ±0.10 vol.%. The value of the data rate of the developed measuring channel of methane concentration in mine atmosphere will constitute not less than 28.81 bit/s.

The obtained value of the information data rate of the developed meter for measuring methane concentration is 130 times higher than the value in existing meters and 7 times higher than the standard requirements (DSTU 24032:2009, 2009) for stationary fast-speed meters. Therefore, for the design of the measuring channel of methane concentration in mine atmosphere it is necessary to use optical absorption method of control with open optical channel.

A similar analysis was done for the designed measuring meter of dust concentration. Thus, the value of the data rate of the aspiration meter of PKA-01 type is 0.016 bit/s at $\varDelta_C = \pm 200$ mg/m^3 $C_{max} = 3000$ mg/m^3 and $\varDelta t = 180$ s. The results of our preliminary studies have shown that the expected value of the response speed of the meter measuring dust concentration will amount to less than 0.8 s at $\varDelta_C = \pm 50$ mg/m^3 and $C_{max} = 3000$ mg/m^3. Accordingly, the value of data rate of the developed measuring meter of dust concentration is at least 6.134 bit/s, which is 380 times more than that of the certified aspiration meter of PKA-01 type. The obtained results fully justify the development of information measurement system for dust concentration in the conditions of mine atmosphere.

Incorporating the results of the previous research (Palmius, 2007; Martinsons, Davison, & Tse, 1999), we proposed to use the arithmetic mean of the data rate of different meters groups for assessing the efficiency of information measurement systems. Thus, while implementing the system using groups of meters distributed in regulated (NPAOP 10.0-1.01-10, 2010) points of mine openings, its efficiency is assessed according to the following formula:

$$\overline{G_a} = \frac{1}{n}\sum_{i=1}^{n} GS_i\ , \tag{3}$$

where:

$\overline{G_a}$ – the arithmetic mean assessment of data rate of the system with spatial distribution of meter groups;

GS_i – data rate of the i-th group of meters;

n – number of groups.

While implementing the system using groups of meters of mine atmosphere parameters to assess the efficiency of each j-th group within IMS, we proposed to use the geometric mean value to estimate the data rate of the meters within the same group with the following formula:

$$\overline{G_g} = \sqrt[m]{\prod_{j=1}^{m} GD_j}\ , \tag{4}$$

where:

$\overline{G_g}$ – geometric mean assessment of information data rate of a group of meters at one point of mine atmosphere;

GD_j – data rate of each meter in the analyzed group;

m – number of meters of coal mine atmosphere parameters in the j-th group.

The physical nature of the geometric assessment of system data rate (4) is the growth of this indicator by changing alarm capacities of each measurement channel of the systems separately. And (4) helps evaluate the increase of this indicator during the introduction of a new measurement channel to the structure of IMS that is not available or was controlled at a qualitative level in the basic version of the system. Evaluation of the efficiency increase of the measurement system is based on the information data rate of n distributed groups in different parts of mining openings in coal mines. Each n group can contain in its structure from 1 to m measurement channels of mine atmosphere parameters. Therefore, with (3) and (4) the efficiency of the developed system is proposed to be determined on the basis of the arithmetic mean of n groups of geometric mean values of information data rate sec of m meters of mine atmosphere parameters for each group separately (Ashrafi, Jaafar, Bakar, & Lee, 2011):

$$\overline{G_{ag}} = \frac{1}{n}\sum_{i=1}^{n}\overline{G_{g_i}} \,. \quad (5)$$

For comparison of the developed measurement system with the existing one in formula (5), we highlighted the value of data rate of the existing system of the UTSSC for air gas protection (G_{ES}) without using meters of methane and dust concentration in mine atmosphere:

$$\overline{G_{ag}} = G_{ES} + \frac{1}{n}\sum_{i=1}^{n}\sqrt{GD_{CH4\,g_i}\cdot GD_{C\,g_i}}\,, \quad (6)$$

where:

G_{ES} – UTSSC; data rate of the existing system UTSSC;

GD_{CH4} and GD_C – data rate of meters of methane and dust concentration.

The value of data rate of the UTSSC system, the value of which is determined by the formula (6), when it is used in the system of 32 methane concentration meters and 16 dust concentration meters, is (Fig. 1):

– for the existing system of mine air gas protection UTSSC:

$$\overline{G_{ag}}_{\,exist} = G_{ES} + \frac{1}{32}\left(16\sqrt{GD_{CH_4}\cdot GD_C} + 16GD_{CH_4}\right) =$$
$$= G_{ES} + \frac{1}{32}\left(16\sqrt{0.221\cdot 0.016} + 16\cdot 0.221\right) = G_{ES} + 0.14 \text{ bit/s};$$

– for the UTSSC system with regulated requirements (DSTU 24032:2009, 2009):

$$\overline{G_{ag}}_{\,requir} = G_{ES} + \frac{1}{32}\left(16\sqrt{GD_{CH_4}\cdot GD_C} + 16GD_{CH_4}\right) =$$
$$= G_{ES} + \frac{1}{32}\left(16\sqrt{4.152\cdot 6.13} + 16\cdot 4.152\right) = G_{ES} + 4.60 \text{ bit/s};$$

– for the developed measurement system of methane and dust concentration in coal mine atmosphere, which is a part of the UTSSC:

$$\overline{G_{ag}}_{\,develop} = G_{ES} + \frac{1}{32}\left(16\sqrt{GD_{CH_4}\cdot GD_C} + 16GD_{CH_4}\right) =$$
$$= G_{ES} + \frac{1}{32}\left(16\sqrt{28.81\cdot 6.13} + 16\cdot 28.81\right) = G_{ES} + 21.05 \text{ bit/s}.$$

The results of the assessments of information data rate of the existing measurement systems and those developed allowed us to conclude that the developed system (21.05 bit/s) has 4.6 times the value of information data rate compared to the requirements (DSTU 24032: 2009, 2009) 4.6 bit/s and 149 times more compared to the existing system of mine air gas protection UTSSC (0.14 bit/s).

Provided that the emergence of an explosive situation in mine atmosphere varies according to the normal distribution of probabilities, and meeting the requirements (DSTU 24032:2009, 2009) at UTSSC, the probability of detection of explosive situations is 0.90 (Lovkin, 2003). With this probability and data rate of the UTSSC and compliance with the regulated requirements, the value of mean square deviation distribution of a random variable on condition that the normal distribution of probabilities of detecting explosive situations will constitute $\sigma \pm 33.8$ bit/s, with its distribution in the range $\pm 1.64\sigma$ with zero mean.

Comparison of the distribution of a random variable of detecting explosive situations and information data rate of the developed measurement system which a part of the UTSSC enabled us to determine the width (α) of this distribution interval:

$$\begin{cases} \overline{G_{ag}}_{\,requir} = G_{ES} + 4.60 = \pm 1.64\sigma; \\ \overline{G_{ag}}_{\,develop} = G_{ES} + 21.05 = \pm\alpha\sigma. \end{cases} \quad (7)$$

While solving the system of equations (7), we defined the distribution interval of the random variable α while detecting and identifying explosive situations in coal mines using the developed information measurement system of methane and dust concentration within the UTSSC: $\alpha = \pm\left(1.64 + \frac{21.05 - 4.60}{33.8}\right) = \pm 2.13$, thus it was found that the occurrence of these events is randomly distributed in the interval $\pm 2.13\sigma$, which corresponds to 0.98 probability of detecting explosive situations in mine atmosphere of coal mine openings.

Based on the analysis, we can conclude that the data rate of the UTSSC system can be increased by 16.5 bit/s while developing new types of optoelectronic meters of methane and dust concentration in mine atmosphere. This will increase the probability of detecting explosive situations from 0.90 to 0.98 and provide improvement of AGP.

Scientists of Electronic Technology Department of DonNTU designed, created and experimentally tested the prototype and experimental samples of meters measuring dust and gas concentration in coal mine atmosphere (Vovna & Zori, 2016), namely:

1. Test sample meters of methane concentration from 0 to $4^{vol.}\%$ with basic absolute error of less than $\pm 0.1^{vol.}\%$. In this case, the obtained value is 2 times lower than regulated by the Industrial Safety Standards (NPAOP 10.0-1.01-10, 2010) and State Standard (DSTU 24032:2009, 2009).

The speed of the developed meter response is less than 84 ms, which is 1.8 times less than the required amount (150 ms). This value is obtained during the research (Vovna, 2016) and is proposed to be included as an amendment to the Industrial Safety Standards and State Standard (DSTU 24032:2009, 2009) to decrease its value to 0.15 s compared to the existing value of 0.8 s.

The value of additional measurement errors of methane concentration depends on changes of the following destabilizing factors:

– temperature change in the range from +5 to +35°C is $\Delta_{CH4}(T) = \pm 0.09^{vol.}\%$, which is 2.2 times less than the regulated value ($\pm 0.2^{vol.}\%$);

– dust concentration from 0 to 5 g/m^3, which is five times the margin, compared with the requirements of state standard (DSTU 24032:2009, 2009) during the operation of meters (1 g/m^3), $\Delta_{CH4}(C_C) = \pm 0.10^{vol.}\%$, which is 2 times less than the value of the regulated error (up $\pm 0.2^{vol.}\%$).

The most probable ($P = 0.95$) value of the additional error of methane concentration measurement with temperature changes and dusting of mine atmosphere was no more $\pm 0.15^{vol.}\%$, which is 2.5 times less than twice the value of the main acceptable error (max $\pm 0.4^{vol.}\%$).

2. Model sample meters of coal dust concentration in the measurement range from 0 to 3000 mg/m^3 with the

basic absolute error of less than ±14 mg/m^3, which is 3.5 times less than the required value (max ±50 mg/m^3) and 14 times less than that of the prototype. The prototype is the certified aspiration meter ПКА-01, which has a measurement error ±200 mg/m^3.

The speed of the meter response does not exceed 0.15 s the value of which is three orders of magnitude less than that of the certified aspiration meter PKA-01 (180 s), which allows to measure dust concentration in real-time and synchronized with the methane concentration meter.

The absolute value of additional error of measurement of dust concentration with changes of a destabilizing factors – temperature ranging from +15 to +40°C is less than ±4 mg/m^3, which is 3.5 times less than the value of the basic error of measurement (±14 mg/m^3) and fully meets the requirements for this meter.

The developed meters of methane and coal air-borne dust concentration were tested in the research laboratory of Electronic Technology Department of Donetsk National Technical University and in industrial conditions:

– laboratories of air gas protection of the Mine named after M.I. Kalinin under the agreement No 752/10-294 from 30.04.2010 to implement the scientific research and experimental design work “Development of measurement meter using infrared optical absorption method of methane concentration monitoring in coal mine atmosphere” together with a private company “Deyta Express” and JSC “Colliery Group Pokrovske” and a production company “Mine 1/3 Novohrodivska”;

– laboratories of the State Enterprise “Petrovsky Plant of Mining Machinery” under the agreement No 230/2907 from 29.08.2008 on cooperation between Donetsk National Technical University and the State Enterprise “Petrovsky Plant of Mining Machinery”.

3. CONCLUSIONS

Solutions to the scientific and applied problem of technologycreation and implementation of new evidence-based approaches to information measurement equipment presented in the paper, allowed developing high-speed and high-precision optoelectronic measurement system in the complex of providing mine air gas safety.

Analysis of ways for improving information and measurement systems of methane and dust concentration in coal mine atmosphere helped to solve the following problems:

– to develop test sample meters of dust concentration for the system of air gas protection of coal mines the UTSSC during the implementation of the scientific research and experimental design work by Donetsk National Technical University in cooperation with the State Enterprise “Petrovsky Plant of Mining Machinery” on the topic “Development of optical meter of dust concentration in coal mine atmosphere”;

– to conduct complex testing of sample meters of methane and coal dust concentration in the laboratory of the Research Institute of Mine-Rescue and Fire Safety “Respirator” (Donetsk);

– to coordinate scheme and design solutions on the developed sample meters of methane and coal dust concentration with Makiivka State Scientific Research Institute of safety in the mining industry “MakSRI” (Makiivka);

– to develop the design documentation for the meters of methane and coal dust concentration for mine atmosphere conditions;

– to carry out certification in “MakSRI” of a pilot batch of meters of dust and gas concentration on intrinsic safety parameter for obtaining permission to install them at coal mines within the UTSSC and SAT of AGP;

– to install three sample meters of methane and dust concentration in the mine and conduct preliminary industrial trials;

– to analyze the results of industrial trials and develop the design documentation for manufacturing meters of methane and dust concentration for the UTSSC and SAT of air-gas safety in coal mines.

One of prospective trends of further research is developing a hardware-methodological complex for determination of methane yield from wells of man-made reservoirs of coal-rock mass under the agreement No 340/4108 from 28.08.2012 on cooperation between Donetsk National Technical University and Institute of Geophysics named after S.I. Subbotin of the National Academy of Sciences of Ukraine. The implementation of this complex will develop the scientific basis of new technologies to intensify extracting energy resources.

Another quite important trend of future research is developing scientific foundations of control measuring dust and gas concentration for systems of environmental monitoring. The proposed scientific and practical results of the work will allow to create complexes and systems that will carry out real-time monitoring of measuring gas concentration in the atmosphere of industrial plants and control technological process based on the measurement results. During the computerized processing of measurement data, measurement results are accumulated with the design of adaptive extrapolation models to track deviations from the technological process according to the results of gas analytical measurements.

The results of our work can be used in the development of compact infrared analytical gas measuring meters for control of concentration of the most common pollutants (oxides and carbon dioxide, methane, nitrogen oxides, etc.) which occur in exhaust gases of vehicles, atmosphere of industrial plants and systems for environmental monitoring.

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research sample meters of methane and dust concentration for coal mine conditions, as well as support in conducting research in industrial conditions.

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ABSTRACT (IN UKRAINIAN)

Мета. Розробка наукових підходів до створення високоточних швидкодіючих оптоелектронних вимірювальних систем у складі комплексу забезпечення аерогазової безпеки шахт за рахунок використання запропонованих і реалізованих методів та засобів підвищення ефективності вимірювальних систем на основі обліку й компенсації впливу дестабілізуючих факторів.

Методика. Експериментальні дослідження виконано у виробничих умовах шахт і в лабораторіях на фізичних моделях інформаційно-вимірювальних систем з використанням метрологічно-атестованих засобів вимірювань.

Результати. Запропоновано визначати ефективність досліджуваної інформаційно-вимірювальної системи на основі середнього арифметичного n груп від середнього геометричних значень інформаційних пропускних спроможностей m вимірювачів параметрів рудничної атмосфери вугільних шахт за кожною групою окремо. Встановлено, що використання розробленої інформаційно-вимірювальної системи концентрації метану та пилу у складі УТАС підвищує пропускну спроможність системи аерогазового захисту шахт на 16.5 біт/с.

Наукова новизна. Вперше запропоновано і реалізовано логічну побудову інформаційно-вимірювальної системи концентрації метану та пилу, яка, на відміну від існуючих, заснована на підвищенні точності та швидкодії вимірювальних каналів концентрації метану і пилу, що дозволило збільшити вірогідність виявлення вибухонебезпечних ситуацій з 0.90 до 0.98 та забезпечити зростання рівня аерогазового захисту шахт.

Практична значимість. Розроблені методи і засоби дозволили реалізувати низку проектів для підприємств гірничої промисловості: швидкодіюча вимірювальна система концентрації метану для комплексу шахтного диспетчерського телефонного зв'язку та оповіщення "САТ" (Приватна компанія "Дейта Експрес", Україна); вимірювальна система концентрації полідисперсного пилу для уніфікованої телекомунікаційної системи диспетчерського контролю та автоматизованого управління гірничими машинами і технологічними комплексами "УТАС" (Державне підприємство "Петровський завод вугільного машинобудування", Україна).

Ключові слова: *вимірювальна система, концентрація, метан, пил, вугільна шахта, точність, швидкодія*

ABSTRACT (IN RUSSIAN)

Цель. Разработка научных подходов к созданию высокоточных быстродействующих оптоэлектронных измерительных систем в составе комплекса обеспечения аэрогазовой безопасности шахт за счет использования предложенных и реализованных методов и средств повышения эффективности измерительных систем на основе учета и компенсации влияния дестабилизирующих факторов.

Методика. Экспериментальные исследования выполнены в производственных условиях шахт и в лабораториях на физических моделях информационно-измерительных систем с использованием метрологически-аттестованных средств измерений.

Результаты. Предложено определять эффективность исследуемой информационно-измерительной системы на основе среднего арифметического n групп среднего геометрических значений информационных пропускных способностей m измерителей параметров рудничной атмосферы угольных шахт по каждой группе отдельно. Установлено, что использование разработанной информационно-измерительной системы концентрации метана и пыли в составе УТАС повышает пропускную способность системы аэрогазового защиты шахт на 16.5 бит/с.

Научная новизна. Впервые предложено и реализовано логическое построение информационно-измерительной системы концентрации метана и пыли, которая, в отличие от существующих, основана на повышении точности и быстродействия измерительных каналов концентрации метана и пыли, что позволило увеличить вероятность обнаружения взрывоопасных ситуаций с 0.90 до 0.98 и обеспечить рост уровня аэрогазовой защиты шахт.

Практическая значимость. Разработанные методы и средства позволили реализовать ряд проектов для предприятий горной промышленности: быстродействующая измерительная система концентрации метана для комплекса шахтной диспетчерской телефонной связи и оповещения "САТ" (Частная компания "Дейта Экспресс", Украина); измерительная система концентрации полидисперсной пыли для унифицированной телекоммуникационной системы диспетчерского контроля и автоматизированного управления горными машинами и технологическими комплексами "УТАС" (Государственное предприятие "Петровский завод угольного машиностроения", Украина).

Ключевые слова: *измерительная система, концентрация, метан, пыль, угольная шахта, точность, быстродействие*

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