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AERODYNAMIC ENVIRONMENT IN MINE ATMOSPHERE DURING GAS-DYNAMIC PHENOMENON

Abstract. The aim of the researches was to study the formation of the aerodynamic environment in mine workings during coal and gas outbursts. In this paper, main parameters are considered, including the velocity of the gas-air medium, gas pressure and the influence of local obstacles with features of overcoming them. The methane concentration is determined in return air stream during methane outbursts in zones of fault dislocations and flexures during mining operations. The relative change in methane concentration along the length of the mine working during the gas-dynamic phenomenon associated with coal micro-outbursts is specified, and the interrelations between the amount of methane released into the mine atmosphere and the change in the pressure of the shock and reflected wave front in the mine atmosphere is also determined depending on the mass of ejected coal during the gas-dynamic phenomenon. Methods and means of explosion localization including barriers and vacuum traps are considered.

On the example of coal-gas outbursts at the O. F. Zasyadko Mine, the main factors that affect the aerodynamic environment in the mine atmosphere during gas-dynamic phenomena were studied. The analysis of the dynamics of gas release and changes in methane concentration in return ventilation streams made it possible to establish the nature of the airflow propagation in mine workings and to assess their impact on the mine ventilation regime. The features of the formation of a two-phase flow consisting of solid and gas phases were determined, and their impact on technological equipment, support systems and the condition of mine workings was also assessed. Some means for localization and devices for reducing the damaging factors of a gas-dynamic phenomenon were considered, which ensure flame suppression, reduction of shock wave pressure, capture of flying fragments and objects, as well as a reduction of methane content in the mine atmosphere.

Approaches to controlling the parameters of shock waves and methane concentration in the mine atmosphere are proposed, which makes it possible to reduce the negative impact of gas-dynamic phenomena on the condition of mine workings and to improve the safety level of mining operations in outburst-prone seams. The obtained results can be used to improve mine ventilation systems and emergency protection measures.

Keywords: gas-dynamic phenomena, control, gas flows, barriers, localization means.

1. Introduction

The low efficiency of the combined use of ventilation and integrated gas-drainage systems at modern high-capacity coal mines does not allow for timely eliminating the danger of local methane accumulations at junction of the mine workings, as well as in certain sections of the mine ventilation system [1]. Emergency situations arise with sudden methane outbursts, the occurrence of local fire sources and their development [2]. Analysis of the causes of their occurrence indicates an inadequate efficiency of operational mine ventilation control and an extremely low level of application of methods for monitoring the state of gas-bearing coal-rock massifs [3]. The solution of this problem is of great scientific and practical importance for ensuring labor protection and occupational safety in coal mines [4, 5].

The aim of this work is to study the patterns of the propagation of gas-dynamic phenomena through the network of mine workings [6]. To achieve the goal, it is necessary to solve the following tasks: to substantiate the methodology for studying the impact of gas-dynamic phenomena on the network of mine workings, and to investigate the patterns of their propagation through the network of mine workings. The de-

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velopment, based on the obtained results, of parameters describing the process of outburst propagation in networks of mine workings, including those that take into account the possible occurrence of an outburst of methane-dust-air mixtures and the development of a fire, is an urgent scientific task.

2. Methods

The research methodology was comprehensive and consisted of assessing the formation of the aerodynamic environment in mine workings during outbursts. Studies of the dynamics of methane concentration changes were conducted according to data from automatic methane control (AMC) in terms of methane content in the mine atmosphere. The gas factor was studied based on the dynamics of background methane concentrations during the shearer operation, coal extraction and stripping according to KAGI data. It was proposed to determine the volume of methane released during a gas-dynamic phenomenon (GDP) based on measurements of methane concentration and air flow in the return ventilation streams in dead-end mine workings where the GDP occurred. Methane concentration was determined using chart records from AMC equipment. Shift and daily printouts were also used. The background methane concentration was determined according to the minimum values. The methane volume released during an outburst (m^3) was calculated taking into account finished cross-section of the mine working.

Models of air shock wave formation and propagation in mine workings were developed on the basis of classical equations of gas flow with shock wave formation [7]. Experimental studies included modeling of physical processes during the generation and propagation of air shock waves under conditions close to those in mine workings, as well as their interaction with various obstacles and means for explosion protection. To enter the initial data, it is necessary to set boundary conditions for each mine working.

Methane explosion can be modeled in two ways: in the form of a chain reaction of combustion, which is taken into account by the heat release parameter, and by specifying a constant pressure in the explosion zone [7]. Conducting such studies is difficult; therefore, a method has been developed for assessing the GDP formation and progression in mine workings based on the parameters of the relative velocities of elastic vibrations in the rock mass that arise during the propagation of a shock wave with flying fragments and objects [2, 8].

Devices for mitigating the GDP damaging factors provide flame suppression, reduction of shock wave pressure, capture of flying fragments and objects, and a decrease in the content of GDP products in the mine atmosphere.

When designing devices for reducing the damaging factors of the GDP, it is necessary to take into account the regime of the GDP propagation, which can vary from deflagration to detonation. Depending on various factors, its parameters vary in a wide range (shock wave velocity from 340 m/s to 1800 m/s, flame propagation velocity from 0.4 m/s to 1800 m/s) [9].

Depending on the applied method for GDP localization, passive (shale and water barriers) or automatic means of localization (AML) are installed in the mine work-

ings, which include localizing barriers, spline stoppings, labyrinth barriers, rapidly deployable explosion-proof units and other structures.

Localization is understood as prevention of flame propagation and high-temperature GDP products by using special technical devices.

In mines extracting both outburst-prone and non-outburst-prone seams, barriers are installed in roadways driven from a safe seam into a hazardous one. Barriers are installed on straight sections of the roadway with a constant cross-section. Cavities formed during roadway advancing behind the support elements in zone, where the barrier is installed, are filled with non-combustible materials. The barrier in the mine working is installed in such a way that it does not create obstacles for mine transport and for personnel moving along the workings.

Gas-dynamic phenomena (GDP) are localized by means of barriers in development workings driven through the coal or coal-rock mass; in longwall faces; in conveyor roadways; in the wings of the mine field for each seam; and in fire areas.

To ensure the correct binding of spatiotemporal factor to the geometry of events occurring in mine workings during the gas-dynamic phenomena, it is advisable to use seismic methods for determining the velocity of longitudinal wave propagation in the rock mass. Determining the medium velocity characteristics makes it possible to improve the accuracy of localization of acoustic signal sources and to reconstruct the parameters of dynamic processes.

Seismoacoustic methods provide registration of impulses that arise as a result of impacts of rock fragments against the walls of the mine roadways, as well as during the sudden release of energy in the rock mass. Based on the analysis of time delays and signal amplitudes, the coordinates of the event origin points, intensity of events and nature of their development are determined.

Atmospheric pressure in the mine working is determined using pressure sensors evenly distributed along the length of the mine roadway. This approach makes it possible to obtain a spatial distribution of pressure and to relate it to the geometry of the mine roadway and seismoacoustic events. Correlation of pressure data with the results of seismoacoustic measurements creates an integrated information base for analyzing dynamic processes.

If there are time intervals between the recorded signals, hodographs of wave propagation along the walls of the mine workings are constructed, which makes it possible to determine the velocity parameters of the wave field, as well as the coordinates and characteristics of events occurring in the rock mass.

A comprehensive analysis of seismic and seismoacoustic monitoring data and aerodynamic environment parameters enables to create an integral picture of the development of gas-dynamic phenomena in mine workings. This, in turn, allows assessment of the impact of the mine atmosphere on the dynamics of these processes, in particular, changes in airflow parameters, distribution of gas components and local turbulent disturbances.

The obtained results can be used for predicting dangerous situations, improving the efficiency of ventilation systems and developing measures to ensure the safety of mining operations.

3. Results and discussion

The main volume of gas emissions from the rock mass begins in the area adjacent to the face of the preparatory roadways. In zones prone to gas-dynamic phenomena, the increase of methane concentration in the return stream exhibits a constantly increasing trend or occurs in the form of spikes. The spikes are observed in the return streams. Turbulence of the return air stream smooths the sources of gas emissions. Therefore, the formation of the aerodynamic environment should be considered in the relation of different regimes of manifestations. Fig. 1a and 1b show the dynamics of gas flow formation during micro-outbursts in zones of disjunctive disturbances at the O.F. Zasyadko Mine.

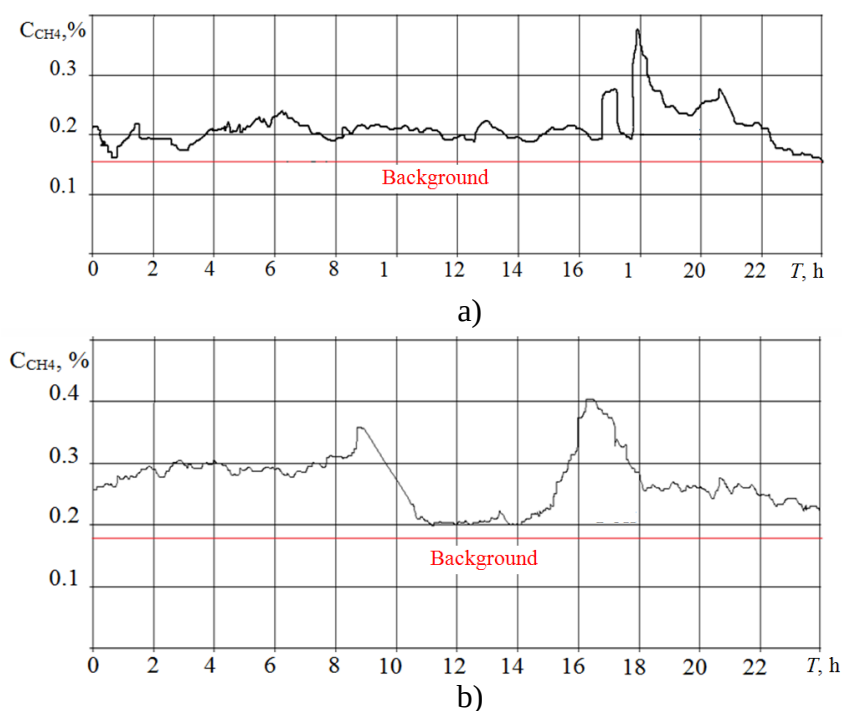


Figure 1 – Methane concentration in return air stream during roadway advancing in the Vitkovska flexure of the 17th western longwall of the seam m_3

In Fig. 1a, the background values of the methane concentration are 0.18%, and, under the threat of the GDP occurrence, they increased to 0.38% and then decreased to the background levels over a period of 4 hours. A similar situation was observed in the 17th western longwall during roadway advancing in the influence zone of the Vitkovska flexure.

In Fig. 1b, the background values were practically the same, at 0.18%, while the anomalous values reached 0.41%. The decrease to background levels lasted for more than 4 hours. Methane release was significant and occurred in the process of micro-outbursts.

Dynamics of the micro-outburst development is shown in Fig. 2 and indicates background values of methane concentration of 0.22–0.26%, and prior to outburst – of about 0.2%. The outbursts occurred at concentrations of 0.44% and 0.40%, respectively. The presented dynamics of methane concentration in the atmosphere of mine

workings prior to gas-dynamic phenomena makes it possible to trace changes in background and peak methane concentration during the formation of aerodynamic environment in dead-end workings. To clarify the fluctuations of background values and methane concentration in the return air stream, experimental studies were performed to determine the relationship between gas-dynamic phenomena and the structure and conditions of the rock mass. For this purpose, seismicity of the Vitkovska flexure was studied. The rock mass destruction was monitored using seismoacoustic measurements [4].

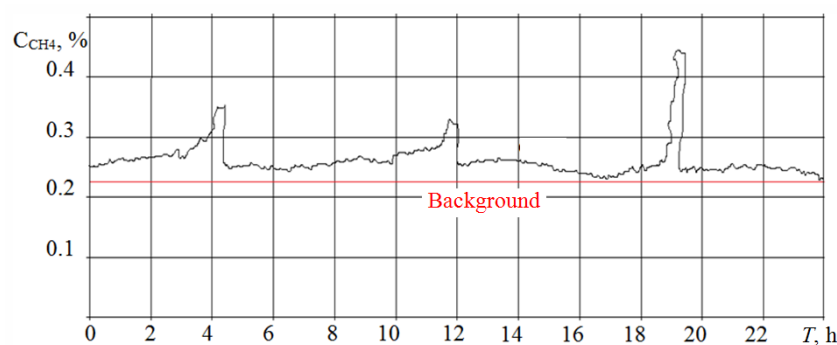


Figure 2 – Methane concentration in return air stream during roadway advancing in the dislocation zone of the 18th western longwall of seam m_3

The force parameters reach their maximum values when fragments of the destroyed rock mass are ejected with the outburst. As a first approximation, they are within the range of $(0.4\text{--}4)\times 10^5$ Pa. Under certain conditions, excess gas pressure can reach values of the same order of magnitude, $(0.1\text{--}3)\times 10^5$ Pa. And, finally, the minimum values correspond to the dynamic pressure of the gas flow, which is less than 0.05×10^5 Pa. Similar data are given in the works [6, 10]. Such dynamic loads affect the technical equipment located within zone of propagation of the two-phase outburst flow, as well as protective devices installed to control this process.

The process of the roadway gas contamination propagates at high speed. The dynamics of pressure distribution in the mine atmosphere is shown in Fig. 2. The gas contamination level remains unchanged for a long time, up to 4.5 hours.

Generalization of the gas contamination process in the mine working showed that, starting from the dead end face, nearly 500 m of the roadway feature high methane content, after which the remaining section of the working begins to fill. As a result, the amount of air in the working decreases due to the rock and coal, which partially close its cross-section [11]. Calculations of the dispersion parameters during outburst of rock, coal and gas makes it possible to establish the dependence between the amount of methane released and the mass of ejected coal in the dead end working, based on the experimental research results and data processing.

Considering the initial velocity on the order of tens of meters per second, the destructive action receives significant kinetic energy (about 0.5×10^3 kJ/t), which ensures its movement through the mine working and has a significant dynamic impact on technological equipment and various types of obstacles.

According to the methane control data by the AGC system, Fig. 3 shows the dynamics of relative gas monitoring.

An intensive decrease in the relative methane concentration is observed in the first section of the roadway (up to 1000 m). At an air flow velocity of 2.2 m/s, active dilution of the gas mixture with a fresh air stream occurs.

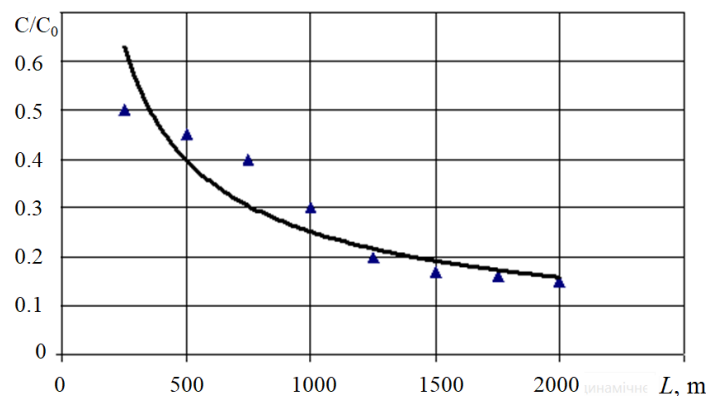


Figure 3 – Relative change in methane concentration along the length of the roadway during the GDP (at an air flow velocity of 2.2 m/s) at coal micro-outbursts

At a distance of 500 m from the location of the micro-outburst, the relative concentration decreases to a level of 0.4–0.45. With further air flow movement (from 1000 m to 2000 m), the rate of concentration decrease slows down, which indicates a gradual equalization of the gas-air mixture and its stabilization. At a distance of 2000 m from the gas emission source, the relative methane concentration is approximately 0.15–0.18 of the initial value, which indicates the efficiency of gas removal by the ventilation airflow at a velocity of 2.2 m/s.

Experimental data on gas pressure according to the results of gas survey at the O.F. Zasyadko Mine are shown in Fig. 4.

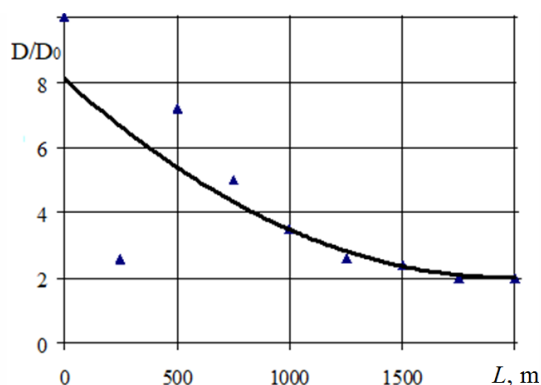


Figure 4 – Relative change in pressure in the mine atmosphere along the roadway length during a gas-dynamic phenomenon

The graph demonstrates a gradual decrease in relative pressure with increasing distance from the source of energy and gas release. The highest values of relative

pressure D/D_0 are recorded directly in the outburst zone (section 0–500 m), where D/D_0 reaches maximum values (over 8 units).

A characteristic exponential decrease in pressure is observed. In the section from 500 m to 1500 m, the most intensive stabilization of air environment parameters occurs, which is associated with the expansion of the compressed gas and its movement along the mine working.

At a distance of more than 1750 m, values of the relative pressure approach the asymptotic minimum (about 2 units), which indicates a gradual pressure equalization in the mine working network and the transition of the wave to the damping stage.

After data preparation, the parameters of air shock waves in the network of mine workings are calculated [10]. The calculated pressure of the front of shock and reflected waves in the mine atmosphere are given in Table 1.

Table 1 – Pressure variations in the shock and reflected wave front in the mine atmosphere depending on the mass of coal ejected during the GDP

Mass of coal ejected during the GDP P , t	Pressure of the shock wave front D , MPa	Pressure of the reflected wave front D_0 , MPa	Shock wave velocity V_p , km/s
5	1.20	0.542	0.59
10	1.05	0.75	0.90
25	2.80	1.500	1.56
40	3.33	2.530	1.80

It was established that the pressure of the fronts of the normal shock wave and wave reflected from the face of the dead-end working differ by the amount of dissipative losses. The dynamics of pressure changes and relative methane concentration over time indicates that within 3–4 minutes after the outburst, the methane concentration reaches its maximum and, depending on the mass of the ejected coal, can be more than 90%. The dependence of the amount of methane released into the mine atmosphere during the gas-dynamic phenomenon on the mass of the ejected coal [2] is shown in Fig. 5.

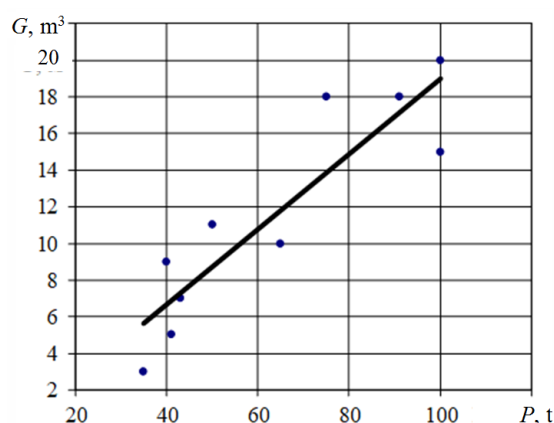


Figure 5 – Dependence of the amount of methane released into the mine atmosphere on the mass of the ejected coal

Having processed the experimental data, we found the dependence between the amount of methane and the mass of the ejected coal in the dead-end working, which is

$$G = 0.2049 \cdot P - 1.5165; R^2 = 0.8102,$$

where G is the volume of methane released, m^3 , and P is the mass of ejected coal, t.

Using the method of seismoacoustic emission (SAE) and the spectral density index, three stages of roof caving manifestations were identified (caving of the immediate roof, of the main roof, and overall failure), which are determined by the nature of interaction between the main and immediate roof. Each of the stages is characterized by certain parameters of SAE activity.

Currently, promising research directions include the development of the methods for controlling gas flow beyond the zone of solid phase outburst. Their implementation in industry is aimed at improving the safety of mining operations in outburst-prone seams. The conducted studies indicated that there are possibilities for significantly reducing the negative impact of the shock wave front when the gas-dynamic phenomenon propagates through the network of mine workings.

For this purpose, based on the analysis of studies [10], the following is recommended:

1. At a distance of 20–40 m from the face of the dead-end working, it is necessary to construct a rope stopping: despite the possible equality of the force parameters of the solid and gas phases, the main destructive effect is exerted by the solid phase of the flow due to the concentrated nature of the impact and the almost instantaneous conversion of its kinetic energy into destruction work. Therefore, methods of controlling the kinetic energy of the two-phase outburst flow are implemented using various types of barrier stopping. During inelastic impact and a change in the trajectory of the fragment motion, their velocity is damped by directing them to the walls of the workings, or onto the destroyed rock mass.

Therefore, it is recommended to ensure the localization of the solid phase during the outburst by constructing curtain-type barriers in the form of rope stopping (rigid or with damping) at a distance of about 20 m from the face of the working. This ensures the separation of the solid phase from the gas phase.

2. At a distance of 250–500 m from the face of the dead-end working, it is necessary to install means for localization of the methane-air mixture during the propagation of the GDP along the network of mine workings.

Table 2 presents the parameters of the interaction of the shock and reflected wave front with the walls of the mine workings when passing the cross-sectional expansion of the mine workings, curvatures and turns [9].

Analysis of the table data shows that the effectiveness of different types of barriers is determined by their aerodynamic characteristics and ability to influence the parameters of the shock wave. In particular, shale and labyrinth barriers are characterized by higher frontal resistance ($180 \text{ Pa}\cdot\text{s}/\text{m}^3$ and $230 \text{ Pa}\cdot\text{s}/\text{m}^3$,

respectively), which provides more intensive interaction with the flow and partial damping of its energy.

Table 2 – Parameters of the shock wave core propagation in the mine atmosphere when passing the cross-sectional expansion of the mine workings, curvatures and turns [9]

Type of Barrier	Frontal Resistance k , $\text{Pa}\cdot\text{s}/\text{m}^3$	Aerodynamic Resistance b , $\text{Pa}\cdot\text{s}/\text{m}^3$	Air shock Wave Front Velocity V , km/s
Water curtain	110	25	3.3–4.9
Water barrier	105	33	7.1–8.8
Shale barrier	180	15	8.3–9.2
Labyrinth barrier	230	30	6.2–7.1

Devices for water-based localization (water curtain and water barrier) have relatively lower or moderate resistance values, however they effectively influence the airflow dynamics due to the additional mechanisms of energy dissipation associated with gas-water phase interaction.

The values of the shock wave front velocity vary widely depending on the type of barrier. The lowest velocities are observed when using a water curtain (3.3–4.9 km/s), which indicates its effectiveness in reducing wave intensity. At the same time, shale barriers correspond to higher velocities (8.3–9.2 km/s), which indicates a lower wave damping effect, but a greater ability to counteract the mechanical impact of the solid phase.

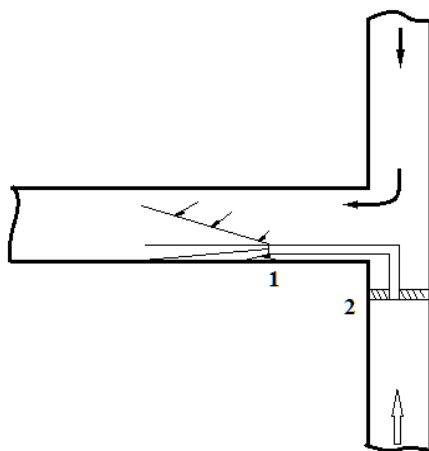
Thus, the results in the table demonstrate that different types of barriers implement different mechanisms of influence on the gas-dynamic process: water-based barriers act mainly through energy damping, while solid structures - through mechanical resistance and changes in the flow structure. This must be taken into account when choosing means for localizing gas-dynamic phenomena in mine workings.

Fig. 6 demonstrates the scheme of the GDP propagation through the network of mine workings and the method for controlling the outburst flow. The research results prove the fundamental possibility of controlling the outburst process in the zone of two-phase flow propagation. However, technical and technological difficulties of implementing such methods limit their practical application. To date, they have not essentially progressed beyond the stage of laboratory and mine research.

Although the solid and gas phases of the flow may have similar force parameters, the main destructive effect is still exerted by the solid phase of the flow due to the concentrated nature of the impact and the almost instantaneous transition of its kinetic energy into destructive work. Therefore, methods of controlling the kinetic energy of a two-phase outburst flow using various types of barrier stoppings, based on direct force counteraction to the impact of flying rock fragments, do not give the desired results, it is necessary to search for the innovative technical solutions.

A flow distribution method was developed for predicting flow distribution in the mine ventilation network in the event of outbursts in any of its branches, which allows identification of network sections at risk of fresh air stream displacement. Summarizing the numerical results, it should be noted that the ventilation stream dis-

placement typically occurs when the gas flow rate exceeds the air consumption in the mine by 25% under normal conditions. This means that at a methane flow rate of 5–10 m³/s, conditions are created for gas accumulation in local air supply workings. Displacement of fresh air in ventilation shafts can occur at a methane flow rate of more than 70–120 m³/s.



1 – means of outburst localization; 2 – stopping

Figure 6 – Localization of methane-air mixture during the GDP propagation in the network of mine workings

The regulation of aerodynamic resistance should be installed in ventilation network sections that are dangerous for displacement, particularly at the junction of the roadways, where fresh and return airflows meet. Structurally, adjustable aerodynamic resistance can be of different types: stoppings with single- or double-leaf doors, shelves with latches, parachute stoppings, etc. Their choice depends on the specific conditions of use. The main requirements for them are as follows.

1. Under normal conditions, they should not affect flow distribution, ensuring free passage for transport and personnel, i.e. under these conditions, the adjustable aerodynamic resistance should be minimal.

2. In the event of an outburst, the cross-section of the mine roadway where the resistance is installed must be effectively blocked (aerodynamically sealed) to prevent the danger of displacement of fresh ventilation air and gas accumulation in the mine working. In this case, of course, the stopping must withstand the pressure of the gas-air outburst flow.

After the outburst process ends, the adjustable aerodynamic resistance should return to minimal values and not impede the restoration of conditions for the normal ventilation functioning. That is, the stopping should operate only during the outburst for the duration of the event.

The means recommended for localization of methane-air mixture during the GDP propagation through the network of mine workings are based on the results of accident investigation. Most miners perish when exposed not only to the explosion flame, which has the smallest area of propagation, but also from damaging factors: shock

wave, flying fragments and objects, the presence of toxic explosion products, including methane, in the mine atmosphere.

The main task of the control effects on the kinetic energy of the outburst is to change the conditions of the two-phase flow at the boundary between the two media. It is necessary to determine such parameters of the control actions, at which the outburst is suppressed, or its consequences are minimal. The control parameters include the roadway volume W_i , the initial barometric pressure P in the roadway volume and the aerodynamic resistance of the ventilation network. Control of the process of the solid phase outburst shows that by changing the backpressure it is possible to regulate the initial velocity of the solid phase and the gas flow rate. Beyond the outburst zone, control of the gas phase is arranged by installing various obstacles.

Thus, existing systems do not provide effective mitigation of the damaging factors of the shock wave, gas contamination of roadways, or methane–dust–air explosions, and the mutual arrangement of the devices within these systems is not aimed at achieving these objectives. Moreover, the use of force-based tools to reduce damaging factors causes significant dynamic loads on their elements and, as a consequence, their destruction.

The developed system has several distinctive features, the essence of which lies in the controlling the damaging factors, namely, the parameters of the front of the direct and reflected shock wave, the pressure in the core of the shock wave front, and the reduction of gas contamination in the mine atmosphere.

When registering a sudden coal and gas outburst, the system enters a state of readiness to reduce the damaging factors. Fig. 7 shows a functional diagram of the controlling and monitoring unit (CMU) when vacuum cylinders are located in the roadway. The system has a modular autonomous structure and consists of an acoustic vibration sensor D, mounted in a borehole and connected to the CMU. The vacuum cylinder, mounted on brackets, is attached to the sidewall between the support frames of the roadway. The CMU consists of sensors 1–7 installed on the cylinders, a controller 8, monitoring units 13–15 and control units 9 and 10, execution sensor 11, elements of the telecommunication system for information exchange 14 and 15 and unit of the final operation 16. Vacuum cylinders (30–40 pcs.) are installed sequentially along the length of the roadway at a distance of a quarter of a wave. When the sensor 11 registers a seismic signal from a sudden outburst, the system enters a state of readiness to perform protective functions. The controller 12 blocks the system activation in the event of a false emergency signal. As the shock air wave front moves through the roadway, the valves of the vacuum cylinders open, thereby reducing the overpressure and methane concentration. Thus, methane is utilized, the overpressure is reduced, and the parameters of the destructive force of the sudden outburst are changed.

Thus, means and method for localizing gas outburst have been developed, which control the parameters of the shock wave pressure and methane concentration in mine workings in the form of vacuum traps, water curtains and barriers, which reduces the negative impact on the condition of roadways, and support structures and equipment during the gas-dynamic phenomena. Some provisions of this research have become an integral part of Ukrainian patents [12, 13].

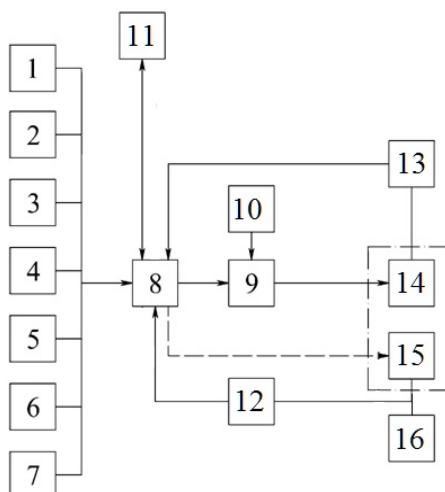


Figure 7 – Functional diagram of the control and monitoring unit with vacuum cylinders installed in the roadway

4. Conclusions

The patterns of gas-dynamic phenomena formation and propagation in the network of mine workings, as well as their influence on the aerodynamic regime of the mine atmosphere were investigated during this research. It was established that the main volumes of gas release are localized in the face zone, and the dynamics of methane concentration changes exhibit either gradual growth or pulse spikes, which can serve as a diagnostic indicator of approaching gas-dynamic phenomena.

It was shown that during outbursts, a two-phase flow is formed, in which the solid phase plays a decisive destructive role due to high kinetic energy and concentrated impact, while the gas phase causes prolonged gas contamination of the roadway and creates the prerequisites for explosive situations. It was also established that maximum methane concentrations occurs within the first minutes after the outburst and can exceed 90%, with the dangerous gas contamination zone extending over considerable distances along the roadways.

The interdependence between the volume of released methane and the mass of ejected coal was substantiated, and critical conditions for the displacement of ventilation streams were determined, which occur when the gas flow rate exceeds the air flow rate. This allows for predicting the most dangerous sections in the ventilation network and increasing the efficiency of operational ventilation control.

A set of technical solutions was proposed for the localization and reduction of the damaging factors due to the gas-dynamic phenomena, in particular the use of rope stoppings, means for localization of the methane-air mixture and adjustable aerodynamic resistances. An approach for controlling the parameters of the shock wave and methane concentration using vacuum systems was developed, which ensures a reduction in excess pressure and the level of gas contamination of the mine atmosphere.

The scientific novelty of the work lies in establishing the relationship between the parameters of gas-dynamic phenomena and the characteristics of the ventilation network, as well as in the advancing of approaches for controlling two-phase flows in

mine workings. The practical significance of the obtained results is in their potential use to improve emergency protection systems, to enhance the reliability of ventilation systems and to reduce the risk of accidents associated with coal and gas outbursts.

The obtained results can be applied in the design and modernization of mine ventilation and gas-drainage systems, as well as in the development of regulatory documents on the safety of mining operations.

Conflict of interest

Authors state no conflict of interest.

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АЕРОДИНАМІЧНЕ СЕРЕДОВИЩЕ У ШАХТНІЙ АТМОСФЕРІ ПІД ЧАС ПРОТІКАННЯ ГАЗОДИНАМІЧНОГО ЯВИЩА

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Анотація. Робота присвячена дослідженням формування аеродинамічного середовища в гірничих виробках під час протікання викиду вугілля і газу. Розглянуті основні параметри – швидкість газоповітряного середовища, тиск газу і вплив локальних перешкод та особливості їх подолання. Встановлена концентрація метану у вихідному струмені повітря при викиді метану в зонах розривних дислокацій і флексур при проведенні виробок. Встановлена відносна зміна концентрації метану по

довжині виробки під час газодинамічного явища при мікрОВикидах вугілля, а також визначена залежність кількості метану, викинутого в атмосферу виробки, і зміна тиску фронту ударної та відбитої хвилі у рудниковій атмосфері залежно від маси викинутого вугілля під час газодинамічного явища. Розглянуті способи і засоби локалізації вибухів – заслони і вакуумні пастки. На прикладі викидів вугілля і газу на шахті ім. О.Ф. Засядька виконані дослідження основних факторів, які впливають на аеродинамічне середовище в шахтній атмосфері під час протікання газодинамічного явища. Проведений аналіз динаміки газовиділення та змін концентрації метану у вихідних вентиляційних струменях дозволив встановити характер поширення газових потоків у гірничих виробках та оцінено їх вплив на вентиляційний режим шахти. Визначено особливості формування двофазного потоку, який складається з твердої та газової фаз, а також оцінено їх вплив на технологічне обладнання, кріплення та стан гірничих виробок. Розглянуті деякі заходи локалізації та пристрої зниження вражаючих факторів газодинамічного явища, які забезпечують гасіння полум'я, зниження тиску ударної хвилі, уловлювання осколків і предметів, що розлітаються, а також зниження вмісту метану в рудничній атмосфері. Запропоновано підходи до управління параметрами ударної хвилі та концентрацією метану в шахтній атмосфері, що дозволяє зменшити негативний вплив газодинамічних явищ на стан гірничих виробок і підвищити рівень безпеки ведення гірничих робіт на викидонебезпечних пластах. Отримані результати можуть бути використані при вдосконаленні систем вентиляції та протияварійного захисту шахт.

Ключові слова: газодинамічні явища, контроль, газові потоки, заслони, засоби локалізації.