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# GAS CONTROL IN MINES OF THE KARAGANDA BASIN (REPUBLIC OF KAZAKHSTAN)

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**Annotation**
Subject of the study are various research works which are carried out concerning issues of degassing, ventilation, management of gas release, etc. The following methods were used for the study: analysis, generalization, experimental works. Purpose is summarizing the experience of gas emission control in complex mining and geological conditions of mines in a number of Karaganda Basin (Republic of Kazakhstan) in the work of high-productivity mines, where the level of absolute gas content reaches very high values. In conclusion of the study it should be noted the experimental work with a total duration of 5 months in four faces at three mines of JSC "ArcelorMittal Temirtau" CD showed that the allowable methane content in the outgoing jets of faces and mine sections of 1.3% creates conditions for more rhythmic and uninterrupted operation of mine sections, compared with the limit methane content of 1.0%. The use of this modern high-precision system allows continuous quality control of the mine's atmosphere and promptly and automatically cut off

electricity in areas with high methane content or violations of the ventilation mode (reduction of air supply).

## Introduction

**Statement of the problem of coal mining.** Within the framework of the implementation of the third Program of accelerated industrial-innovative development until 2030, the mining and metallurgical complex of the Republic of Kazakhstan is assigned the role of one of the driving forces of the Republic's economic development, a major factor in the formation of macroeconomic indicators. The main task of MMS industries is to provide conditions for the structural reorganization of the national economy and the creation of new knowledge-intensive production of high-tech end products that are competitive in world markets. At the same time, the coal industry continues to play an important role in the country.

The coal industry has been one of the most important industries in many countries of the world for decades and even centuries. In recent years, the importance of this mineral for developed European countries has begun to decline due to its negative impact on the environment and the climate. The opportunity to switch to alternative energy sources has also played a role.

However, the production and use of coal continues in the global energy industry, as evidenced by the examples of leading countries in the world, such as China, the United States, India, Australia, Russia, Kazakhstan, etc., which occupy the leading position in terms of coal production in the world and year by year increase its production.

The introduction of modern innovations in the processing and use of coal can allow the transformation of coal into a relatively clean source of energy.

In the Republic of Kazakhstan, the growth in production of this type of raw materials is largely due to the needs of metallurgy. Kazakhstan is the world's ninth-largest coal producer (over 100 million tons per year).

**The main directions of complex innovative scientific and technological development of underground coal mining**. The main directions of complex innovative scientific and technological development of underground coal mining at the existing and newly designed mines should be based on the realities of the modern world and provide for the creation and implementation of modern innovative technologies based on the use of highly productive types of mining equipment and be safe not only technically, but also environmentally. By the example of mines in the Karaganda coal basin is particularly important problem of creating safe mining conditions for the development of high-gas content and outburst coal seams.

Priority areas in the use of modern innovative solutions and modernization of mining equipment, taking into account current trends in the development of mining production should consider the following key points:

- comply with environmental safety requirements, including the prevention of environmental pollution, zero-waste mining and processing of extracted raw materials, rational use of land with subsequent restoration, etc.;
- Ensure technical safety of mining operations and create a comfortable environment for workers and engineers;
- Ensure high productivity through the use of modern, high-performance and reliable hardware and technology, as well as other aids;
- create the possibility of wide implementation of remote control of mining equipment, as well as promote automation and robotization, with the possible use of artificial intelligence;
- Provide for the effective management of the gas environment, guided not only by the pursuit of increased productivity and personal safety of working people, but also by concerns for global environmental and climate security [1].

**Highlighting an unresolved problem.** In recent years, the mines of the Karaganda Basin are widely used mechanized mining complexes of foreign firms and companies (Germany, Poland, etc.), allowing to achieve high average daily loads from the working faces.

The Karaganda coal basin is one of the largest coking coal producers among the CIS countries and, at the same time, one of the most gas content basins in the world [2,3,4]. The main barrier to achieving high coal production is the high methane gas content. High loads on the face, reaching 6-8 thousand tons of coal per day from a single longwall face, became possible due to the use of modern equipment and high efficiency of methods used to control gas emission in the mines [5].

To ensure stable and high coal production and create safe working conditions in the basin, various measures are taken to reduce the gas content of seams, various methods and schemes of degassing of developed and adjacent satellite seams, as well as mined-out spaces are tested and implemented [6-10].

**Choosing the unresolved part of the general problem.** When mining high gas content coal seams, high loads on working faces equipped with modern coal mining equipment are accompanied by large methane emissions from the developed and adjacent seams, which significantly affects the efficiency of high-capacity clearing equipment, since the gas factor limits the productivity of the shearers. Consequently, the issues of gas emission in the mines of the Karaganda Basin is an important problem on which should conduct extensive research and experimental work.

**Formulating research goals**. The relevance of the issues of gas emission control is due to the fact that today's modern high-productive work of the working faces in the basin is possible through the use of integrated methods of degassing, reducing the gas content of mining areas by 70-90%, as well as the development and implementation of technical solutions to reduce the natural gas content below the critical value.

In this direction in the basin in cooperation with scientific institutes and institutions various research works are carried out concerning issues of degassing, ventilation, management of gas release, etc.

In this work, on the basis of experimental studies conducted in mining areas is summarized the experience of gas emission control in complex mining and geological conditions of mines in a number of Karaganda Basin in the work of high-productivity mines, where the level of absolute gas content reaches very high values.

**Experimental work to control gas emission with a maximum methane content of 1.3% at mining section 321K10-yu of Abaiskaya mine**

The 321$K_{10}$-yu longwall-field is located in the southern part of the Abaiskaya mine. The size of the excavation pillar along the strike - up to 695 m, and along the dip of the layer - 176 m. The bedding is gentle undulating. Seam inclination – 10-20°. Depth of development - 428-493 m. Industrial reserves of the working area amount to 725 thousand tons.

Formation $K_{10}$ has a complex structure and is characterized by a very consistent thickness - up to 4,85 m. Useful seam thickness -

4,34 m. Extracting seam thickness - 3,9 m.

The main roof of the $K_{10}$ formation is composed of sandstones up to 19-24.0 m thick and with a strength of up to 55-56 MPa. The immediate roof is composed of claystones 5.3-8.0 m thick, with a strength of up to 28 MPa. The ground is composed of claystone up to 3.0 m thick, with a hardness of up to 26 MPa.

Maximum gas content of the formation - up to 24.0 m3 per ton of rock mass, volatile content - 20.2%. Moisture content of the formation – up to 4,5%.

The coals of the formation are slightly fissured, predominantly semi-matte. Coal hardness on Prof. Protodiakonov's scale - up to 1,5. Formation $K_{10}$ from a depth of 260 m is classified as dangerous by sudden coal and gas emissions.

The longwall was equipped with a 20KP-70K mechanized complex, an SL-300 combine. Cutting cross-section - 7,26 $m^2$.

Planned production - 3,000 tons per day. Operational coal losses at the longwall face 170 thousand tons or 21.2%.

Ventilation of the excavated area is carried out by the return-flow scheme. According to calculations, with a planned production of 3000 tons/day the following project values were assumed: the relative methane emission from the mined layer - 7.38 $m^3$/t, from the mined-out space - 48.26 $m^3$/t. Relative methane emission at the working area - 55.64 $m^3$/t. Absolute gas content of the area is 115.9 $m^3$/min. After removal of methane by degassing means, the absolute gas content of the area is 13,52 $m^3$/min, the air consumption at the area - 1730,0 $m^3$/min, in the mine working - 1331 $m^3$/min.

**Studies of gas emission into the 321$K_{10}$ longwall face and adjacent workings**

During long-term observations from December 2011 to February 2012, general data were obtained on the total methane content of the 321$K_{10}$-yu mine area in terms of methane removal from the longwall face through ventilation, as well as on methane extraction by degassing means, including vertical wells, drainage adit, degassing pipe in the upper face and formation wells [5].

According to the data collected, Fig. 1 shows graphs of daily coal production, methane extraction by means of ventilation and degassing for the above period.

As Fig. 2 shows, the daily production of coal with a plan of 3,000 tons per day, as a rule, exceeded the plan by up to 1,6 times.

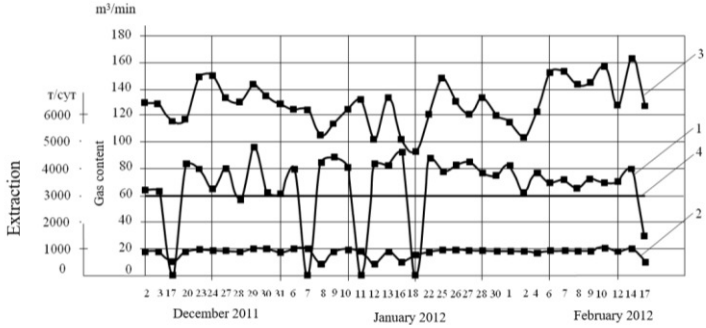


**Fig. 1.** Coal mining, gas content and degassing efficiency in the 321K10-yu longwall of the Abaiskaya mine: *1* - coal mining; *2* - ventilation gas content; *3* - gas content: venting + degassing; *4* - planned production

According to the data obtained during the observations the general methane content of the mine area was 104.7-148.9 m$^3$/min, including 15-19.35 m$^3$/min that was extracted by means of ventilation. The largest volume of extracted methane (101-130 m$^3$/min when operating in production mode, and 78.1-96.2 m$^3$/min on Sundays) falls on degassing facilities. This extracts from the gas draining adit - 47.75-98.23, m$^3$/min. By means of a pipe, connected to the top face, 7.2-25.7 m$^3$/min were capped. The lowest gas extraction values occur on non-working days of the week. Vertical wells extract 3.49-8.06 m$^3$/min, and formation wells extract 4.54-9.9 m$^3$/min. The greatest volume of gas emissions occurs on days with high coal production (4,400-4,800 tons per day), and when there is a secondary collapse of the main roof.

At the 321K10-yu face coal was mined in December 2012 when the operation level of the safety shutdowns by the ACS MA system was set at 1.0% of the volume methane content, and in January-February 2012 at 1.3% of the methane content. During the period under review, coal production ranged from 3,133 to 4,800 tons per day.

In accordance with the approved methodology, the purpose of mine experimental studies is to assess the state of the aerogas situation in the face and adjacent workings when setting the threshold of operation of protective shutdown of electrical equipment equal to 1.3% vol. $CH_4$.

The essence of the experimental studies in mine conditions is to determine the amount of air entering the face and the concentration of methane in the planned points of the area.

As a result of measuring the amount of air and methane content in the longwall, a large amount of data was obtained in tabular form on 8 pp. [5].

From these data it follows that during the operation of the longwall face 321K$_{10}$-u in January-February 2012 the methane content in the area of the working face was mainly 0.5-0.6%, at the point No. 3 (15 m from the windway) - 0.6-0.8%, at the point No. 4 (the couch at the junction of the face with the windway) - 0.6-0.9%, mainly at the point No. 5 (in the outgoing air stream) - 0.8-0.9%. On Sundays, the methane content decreased significantly and was 0.2-0.3% in the middle part of the face, at point No. 4 - 0.3-0.4%, at point No. 5 - 0.4-0.5%.

Fig. 2 shows the distribution of methane concentration in the middle part of the face along its cross section at the set points, depending on the speed of the combine.

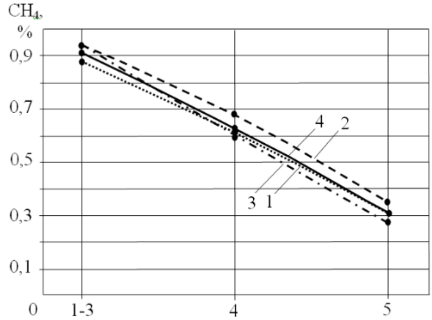


**Fig. 2.** Distribution of methane concentration in the middle part of the face along its cross section at the established points: *1* – at a speed of 2 m/min; *2* – at a speed of 6 m/min; *3* – at a speed of 10 m/min; *4* – average for all directions

As can be seen from the figure, with the increase in the feed speed of the combine in operating mode from 2 to 10 m/min, the methane content in the air stream increased by 0.1-0.3%. It also follows from the figure that in the air stream adjacent to the chest of the working face, the methane content is the highest and amounts to 0.8-0.95%. As methane concentration decreases to 0.2-0.4% as it moves away from the mine face toward the mined-out space. This pattern is typical for the middle part of the face along its length.

In December 2011, the system was set to a limit concentration of 1.0% outgoing air from the face and section. Figure 3 shows a fragment of the trend for the period from 19,00 h. 02.2011 till 01,00 a.m. 03.12.2011.

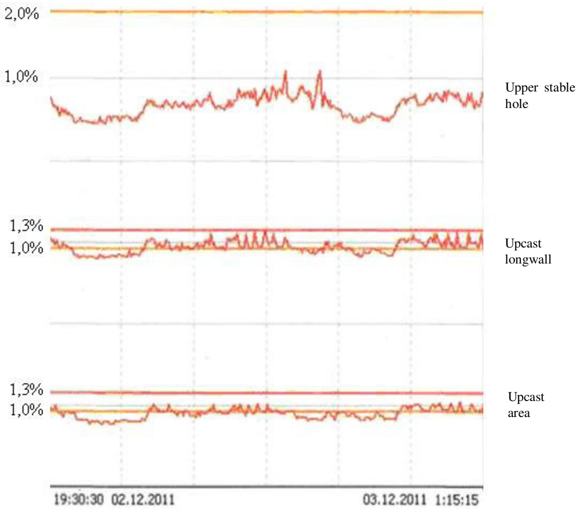


**Fig. 3.** Trend of methane content in the 321K10-yu mine area when sensors are installed at 1.0%

As it follows from Fig. 3, in 4 hours there were 18 registered excesses of the permissible limit of methane concentration in the air flow coming from the face and 15 in the air flow coming from the area.

This setup leads to arrhythmic operation of the shearer, a significant loss of working time and coal production due to frequent stoppages.

At the same time in the upper stable hole, due to degassing by means of a pipe, introduced into the windway, during the considered period of time there was only a small excess of methane content of 1.0% (at the permissible 2.0%).

Thus, at the limit concentration of methane in the air jets coming from the face and the area, equal to 1.0%, the rhythm and controllability of production processes are violated, which reduces the safety of production.

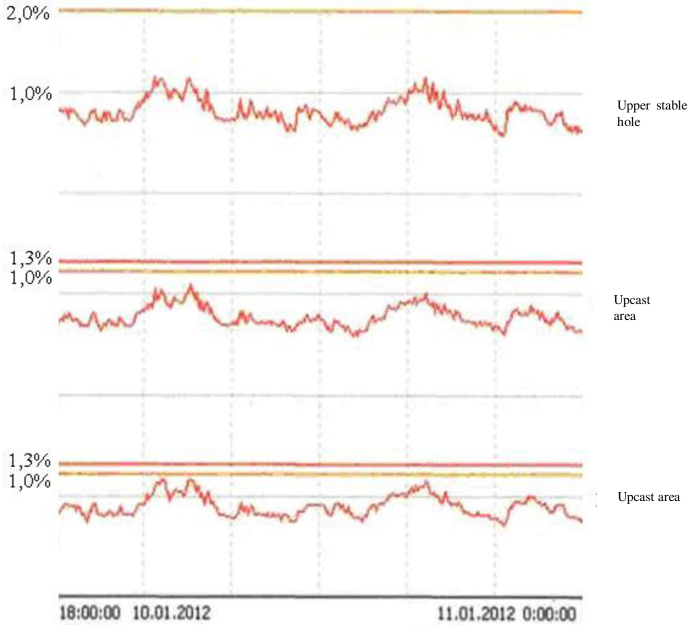


**Fig. 4.** Trend of methane content in the mine atmosphere of the 321K$_{10}$-yu mine area when setting the system thresholds to 1.3% vol. $CH_4$

In January 2012, the system was reconfigured at the mine area to the limit concentration of the air jet upcast from the face and the area, equal to 1.3%. Fig. 6 shows a fragment of the trend for the period from 18.00 to 24.00. 10.02.2011.

The daily load on that day was 4,420 tons. As can be seen from the presented fragment of 6 hours, during this period not a single case of exceeding the established level of methane concentration of 1.3% was recorded. At the same time, there were 4 cases of exceeding the permissible limit in the upcast air stream from the face, equal to 1.0%, and 5 cases of exceeding the permissible limit in the upcast area. Thus, the experiment allowed to establish that reconfiguring the system to the limit concentration of methane in the air jets coming from the face and the area, equal to 1.3%, allowed to provide a rhythmic and stable operation of the working face, which increased the safety of mining at the site.

In accordance with the "Methodology of experimental studies to substantiate the maximum methane concentration in the upcast air stream of the mine site" in the longwall face 321K10-yu of mine "Abaiskaya" on 12.02.2012 an experiment was made to assess the effect of air flow on changes in the methane concentration at specified points of observation (see fig. 5-7).

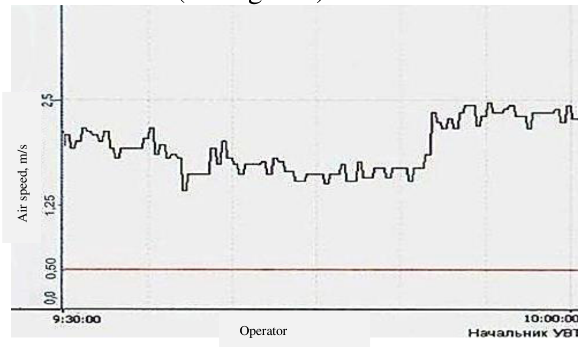


**Fig. 5.** Air speed in the upcast face stream 321K10-yu of Abaiskaya mine

In the course of the experiment it was found by measurements that 2167 m$^3$/min air was supplied to the site to ventilate it. At a certain moment the air flow was reduced to 1935 m$^3$/min, and then after 5 minutes the air flow was 1513 m$^3$/min, and in this mode the face was ventilated for another 10 minutes, after which the previous mode of ventilation was restored.

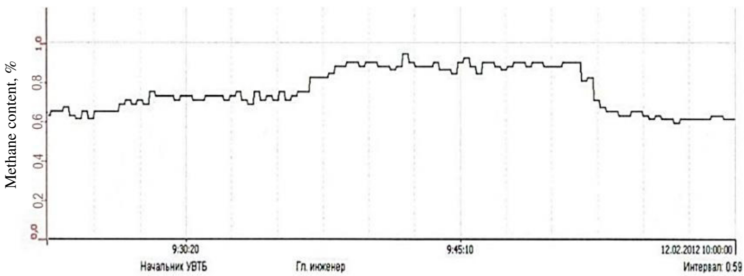


**Fig. 6.** Methane content in the stable hole of the longwall face 321K10-yu of Abaiskaya mine

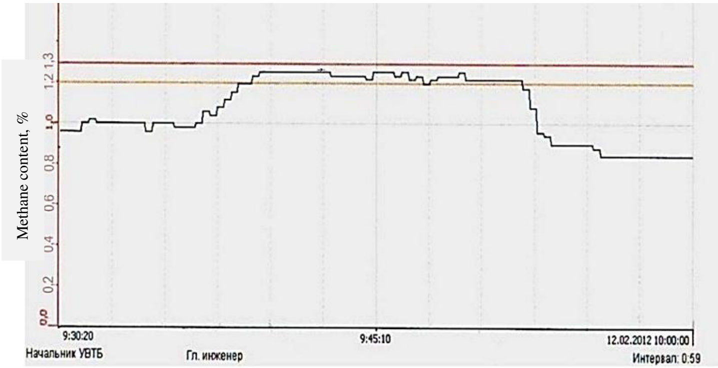


**Fig. 7.** Methane content in the upcast face 321K10-yu of Abaiskaya mine

The results of measuring the amount of air supplied to ventilate the face and the methane content in the observation points are shown in Table 1.

Table 1

Results of measuring the amount of air supplied to ventilate the 321K10-yu face and the methane content in the observation points

| Measurement time, hr min | | 9.15 | 9.37 | 9.42 | 9.57 |
|---|---|---|---|---|---|
| Incoming stream | air speed, m/s | 2,6 | 2,34 | 1,83 | 2,64 |
| | amount of air, $m^3$/min | 2167 | 1935 | 1513 | 2183 |
| Upcast stream | air speed, m/s | 2,6 | 2,3 | 1,6 | 2,8 |
| | amount of air, $m^3$/min | 1850 | 1628 | 1154 | 1990 |
| Methane content according to the portable device in the points, % | 1 | 0,0 | 0,0 | 0,0 | 0,0 |
| | 2 | 0,61 | 0,73 | 0,90 | 0,59 |
| | 3 | 0,9 | 1,08 | 1,26 | 0,84 |

Recorded trends of the automated control system of the mine air (ACS MA) based on the equipment of "Davis Derby Ltd" (Great Britain) and sensors manufactured by "Wölke Industreelektronik GmbH" (Germany) are shown in Fig. 5-7 [11].

The results of the experiment showed an inverse dependence of methane concentration on the amount of supplied air for ventilation, i.e. at reducing the amount of air supplied to the face by 30% (from 2167 to 1513 $m^3$/min), the methane concentration in the upcast face stream increased by the same value after 1-2 minutes.

With the recovery of the previous mode of ventilation (the amount of air increased from 1513 to 2183 $m^3$/min) after about 1 minute, the methane content in the upcast stream of the area decreased from 1.26 to 0.84%.

A similar pattern was observed in the upper part (in the stable hole) of the face.

Thus, the experiment showed a virtually synchronous relationship between the amount of air supplied to ventilate the face and the methane content in its mine air.

Safety assessment of the mine area by the gas factor can be made by the frequency of its gassing, i.e., by the frequency of power outages established by the automated control system of the mine air (ACS MA) and by the gassing factor.

The indicator of the frequency of gassing can be considered the average number of gassings for the mine area per unit of time considered (turn, day, month).

The gassing ratio is defined as the ratio of the total downtime of mining equipment due to shutdowns by the automated control system of the mine air (ACS MA) to the working time of the mining area (turn, day, month).

The gassing coefficient can be determined by the formula

$$K_{gassy}=\Sigma T_{gassy}/T_{\text{work}}, \quad (1)$$

where, $\Sigma T_{gassy}$- total downtime of mining equipment due to shutdowns by the automated control system of the mine air (ACS MA) for the considered period of time, hour; $T_{\text{work}}$ - the considered period of the working time of the excavation area, hour; is calculated by the formula

$$T_{work}=\text{N}24, \quad (2)$$

where: $N$ – number of days of work at the mine area, units; *24* – number of hours per day.

At the 321$K_{10}$-yu longwall face, coal was mined in December when the operation level of protective shutdowns of electrical equipment was set at 1.0%. In 12 days, there were 226 shutdowns for a total of 1,053 minutes (17.5 hours). The frequency of gassing was 19 shutdowns per day. The gassing ratio was $K_{gassy}$=0,06. The average daily load for the time period considered in December was 3,544 tons.

Fig. 8 shows a histogram of the frequency of the shearer's shutdowns depending on the location of its work.

The analysis shows that the most frequent cut-offs occurred in the middle and upper parts of the longwall face (80-160 m).

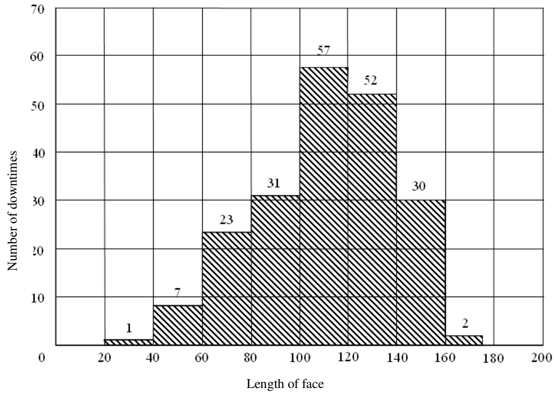


**Fig. 8.** Histogram of combine cut-off frequency depending on the combine's workplace in the longwall when the system operation level thresholds are set to 1.0% vol.$LH_4$

**Experimental work at the $71K_{10}$-in working area of the Saranskaya mine**

The longwall face $71K_{10}$-v was partially worked over by $K_{14}$ seam faces in 1985-88. The distance between layers $K_{10}$ and $K_{14}$ is 203 m.

Total geological thickness of layer $K_{10}$ - 4.65 m (including 3.73 m of coal mass). Extractable thickness of layer $K_{10}$ - 3.8 m (including 3.37 m of coal mass). Adjacent strata of layer K10 is 0.4-2.3 m thick and is represented by weak claystone's of strength $f$=2-3, prone to collapse. Above the adjacent strata are sandstones of the main roof of strength $f = 5 \div 6$ and a thickness of 24.9-30.2 m. Sandstones of the main roof difficult to collapse. Between the adjacent and the main strata, there is a layer of siltstone with a strength of $f = 3 \div 4$ and a thickness of 3.0-3.5 m. In the ground of layer K10 there are siltstones of 6-7 m thickness and strength $f$=2-3 or siltstones of 6-17 m thickness and strength $f$=3-3,5.

The seam inclination K10 is 13-140. From the installation chamber, the excavation pillar was mined along the formation decline at an angle from 11 to 140.

Strength of coal seams $f$=0.7÷1.0, rock $f$=1.5÷2.0 on the scale of prof. Protodiakonov. The density of mined rock mass will be 1.56 t/m$^3$, and coal - 1.44 m$^3$/t.

Mining layer $K_{10}$ is dangerous in terms of sudden coal and gas emissions.

The gas drainage entry 71$K_{11}$-v along the $K_{11}$ formation was passed at the longwall-field 71$K_{10}$-v. In terms of height, the soil of the gas drainage entry is located 22-35 m above the roof of the $K_{10}$ formation. Between the $K_{10}$ formation and the gas drainage entry 71$K_{11}$-v are sandstones of the main roof of the $K_{10}$ formation. The method of roof control - full collapse. The pitch of the main roof is 90m.

The length of the working pillar - 1500 m. The length of the face - 176m. Depth of mining - 670 m. Balance reserves - 1178 thous. tons. Planned production of 3150 t/day.

The longwall is equipped with a mechanized support 2UKP-5, including - a shearer - SL-300, a face conveyor - KS-34. In the conveyor entry there is an overloaded PSP-308, a crusher DU-910, belt conveyors Gvarik 1000, 3LKR-1000. The cross-section of the mine working is 11.42 m$^2$.

Gas content of the formation under the project is 13.5 m$^3$/t, methane emission from the developed layer - 4.2 m$^3$/t, from the worked-out space - 18.4 m$^3$/t, including 13.34 m$^3$/t from six undermined layers, from three overworked layers - 0.45 m$^3$/t. Relative gas content of the area - 21.45 m$^3$/t.

The amount of air at the conveyor entry (incoming stream of the mining area) - 1890 m$^3$/min. Air quantity at the ventilation entry (outgoing stream of the mine area) - 1,560 m$^3$/min. The cross-sectional areas of the conveyor entry 71$K_{10}$-v and the windway 71$K_{10}$-v are 10.0 and 6.5 m$^2$, respectively. The air speed at the conveyor 71$K_{10}$-v and ventilation 71$K_{10}$-v entry is 3.15 and 4.0 m/s, respectively. Air speed along the longwall 71$K_{10}$-v - 3.25 m/s.

Ventilation scheme of the mine area return-flow.

Three methods of degassing were used at the working area:

*a* - formation degassing by rising wells drilled along formation $K_{10}$ from conveyor entry 71$K_{10}$-v;

*b* - Degasification of the mined-out space by the gas drainage entry, passed through the $K_{11}$ formation above the developed layer along the entire length of the excavation field with the possibility of connection to the mine's degasification network both ahead and behind the working face - (brattice No. 5042 and No. 5044 at gas drainage entry $71K_9$-v);

*c* - methane gas suction by means of a pipe set behind the bulkhead isolating the worked-out space of the worked-out longwall (brattice No. 1031 on a field-conveyor gradient $63K_{10}$-v).

*d* - by an isolated outlet at the expense of the general mine depression (brattice No. 25041 at the conveyor entry $64K_{10}$-v).

**Study of gas emissions in the longwall face $71K_{10}$-v and adjacent workings**

Methane concentrations were measured at the designated points shown in Fig. 9. Coal production ranged from 2,000 tons per day (15.01.2012) to 4,320 tons per day (11.02.2012). Air was supplied to the longwall for ventilation from 1,030 to 1,850 $m^3$/min.

The amount of air in the middle part of the face ranged from 950 m3/min (13.01.2012) to 1480 $m^3$/min (07.03.2012). The methane content in the outgoing air stream of the clearing face and the mine area according to the sensor readings was 0.5-1.2%.

General mine methane content in the mine area ranged from 74.4 m3/min (01.02.2012) to 112.55 $m^3$/min (24.03.2012), including ventilation means extracted from 8.4 to 21.36 $m^3$/min. Means of degassing extracted from 48.1 $m^3$/min (06.02.2012) to 79.9 $m^3$/min of methane (24.03.2012).

The largest volume of methane was extracted by means of drainage entry (brattice No. 5044 and 5042) from 41,1 $m^3$/min (06.02.2012) to 72,7 $m^3$/min (24.03.2012), and also by means of isolated methane drainage (brattice No. 5041) from 10,5 $m^3$/min (09.04.2012) to 29,06 $m^3$/min (30.01.2012). Minimum values of gas are extracted by means of formation degassing - 0.6 - 1.8 $m^3$/min. The largest volume of gas emissions occurs on days with high coal production - 4,000-4,200 tons per day.

Fig. 9 shows graphs of daily coal production and methane extraction by means of ventilation and degassing in the mine working area $71K_{10}$-v, and Fig. 14 shows a fragment of the trend of methane concentration in the mine air for the period 20.00 h. 01.03.2012 till 02.00 a.m. 02.03.2012/

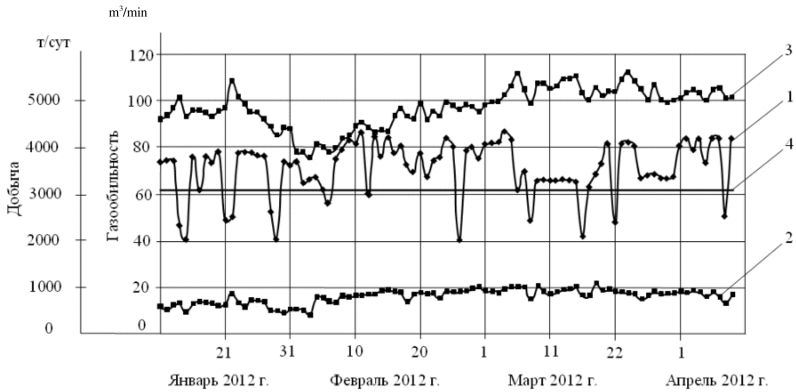


**Fig. 9.** Coal mining, gas content and degassing efficiency in the 71$K_{10}$-v longwall of the Saranskaya mine: *1* – coal mining; *2* - ventilation gas content; *3* - gas content: venting + degassing; *4* - planned production

As Fig. 10 shows, 18 methane exceedances of 1.0% in the outgoing lava air stream and 15 in the area were recorded over a period of 6 hours. Such a system setup would lead to arrhythmic operation of the shearer, a significant loss of working time and coal production due to frequent stoppages. In the upper stable hole, due to degassing by means of a pipe installed in the ventilation tunnel to be extinguished, during the period under review (at the rate of 2.0%) there was only a slight exceedance of 1.0% of methane content.

Thus, at mining of longwall face 71K10-v of mine "Saranskaya" at limiting concentration of air stream coming from the longwall face and the air stream section, equal to 1,3% and the load of the longwall face 4000-4500 tons, the combine stop for the gas factor, but when setting the sensor for the limiting concentration of air stream coming from the longwall face and the section, equal to 1.0%, the work in the longwall face would not be possible. Thus, the mine experiment showed that during the mining of seam $K_{10}$ in the mine "Saranskaya" the most efficient operation of the shearer can be achieved when installing sensors on the outgoing from the longwall air stream to the limit content of methane equal to 1.3%.

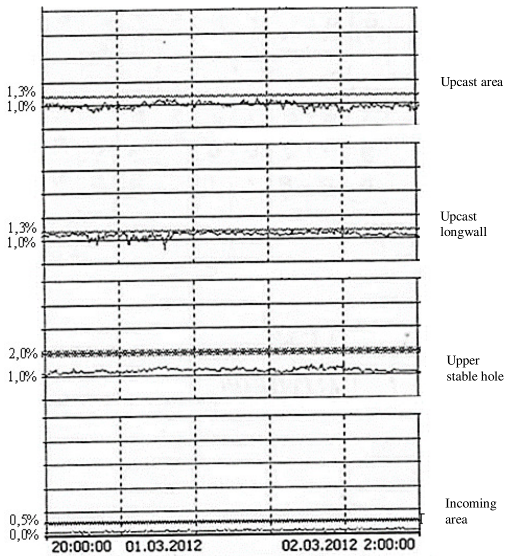


**Fig. 10.** Trend of methane content in the mine air of the mine area $71K_{10}$-v when setting of the system thresholds at 1,3% vol. $CH_4$

The safety of the working area by the gas factor can be assessed by the frequency of power outages installed by the automated control system of the mine air (ACS MA) and by the gassing coefficient.

Given the specific dynamics of outgassing in the mine's working area, despite the resolution of the permissible methane concentration up to 1.3%, the dispatcher manually stopped mining operations in the longwall at a methane concentration of 1.15%.

According to the measurements performed in the longwall face 71K10-in the period from January 11 to April 9, 2012, there were 166 manual cutoffs of power by the automated control system of the mine air (ACS MA), that is, per day there were made on average 2 cutoffs with an average duration of 16.4 minutes.

The calculations showed that if the limiting concentration of methane is taken as 1.15%, the gassing factor in the longwall face $71K_{10}$-v is $K_{gassy}$=0,003.

Fig. 11 shows a histogram of the frequency of the shearer's shutdowns depending on the location of its work. As can be seen from the figure, the most frequent shutdowns of the ACS MA control system mine air occurred between sections 70 and 90 of the mechanical mounts (over 37% of the total number of shutdowns). This is due to the fact that this area in the return-flow scheme is the least ventilated.

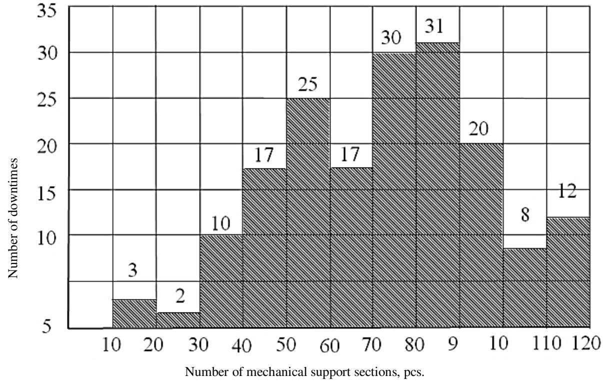


**Fig. 11.** Frequency of system equipment shutdowns depending on the combine's workplace in the longwall

Fig. 12 shows a histogram of the frequency distribution of failures (outages) by the ACS MA system depending on their duration. Figure 16 shows that almost half (48.8%) of all outages do not exceed 10 minutes in time, while 33.7% of outages lasted between 11 and 20 minutes. Thus, the proportion of failures with each of them lasting up to and including 20 minutes was 92.5%.

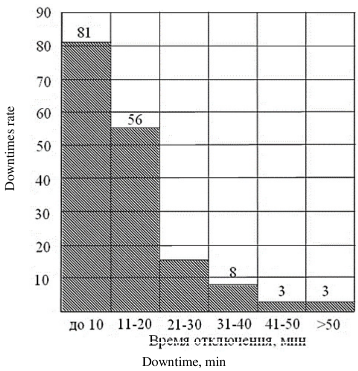


**Fig. 12** . Histogram of the frequency of outages as a function of their duration

At working area $71K_{10}$-v on 03.04.2012 experimental studies of changes in the methane concentration from the amount of air supplied for ventilation were carried out. At the same time 1788 m3/min of air was supplied to ventilate the area, and 1764 m$^3$/min of methane concentration - 0.76% was exhausted from the longwall.

At 12 h. 08 min. air flow rate on the incoming stream was reduced to 1596 m$^3$/min, while on the outgoing face the amount of air decreased to 1570 m$^3$/min (11% reduction from the normal mode). Already after 5-7 minutes, the methane content in the outgoing lava stream has increased to 1.19. Then, at 12 h. 25 min, the amount of air on the incoming stream was reduced to 1420 m$^3$/min. In this mode, the amount of air on the outgoing face stream was 1100 m$^3$/min, i.e., decreased by 38%. Methane concentration in the longwall according to the sensor was 1.05%. In this mode the longwall was ventilated until 12 h 40 min, after which the original ventilation mode was restored.

The results of measuring the amount of air supplied to ventilate the face and the methane content in the observation points are shown in Table 2.

Table 2

Results of measuring the amount of air supplied to ventilate the $71K_{10}$-yu face and the methane content in the observation points

| Measurement time, hour, minute | | | $11^{50}$ | $12^{08}$ | $12^{25}$ |
|---|---|---|---|---|---|
| Incoming into the longwall | air speed, m/s | | 3,55 | 2,99 | 2,66 |
| | amount of air, m$^3$/min | | 1788 | 1596 | 1420 |
| Upcast longwall | air speed, m/s | | 3,0 | 2,6 | 1,8 |
| | amount of air, m$^3$/min | | 1764 | 1570 | 1100 |
| Upcast area | windway | air speed, m | 1,49 | 1,33 | 0,66 |
| | | amount of air, m$^3$/min | 799 | 711 | 352 |
| | cross slit No. | air speed, m | 1,42 | 1,26 | 1,12 |
| | | amount of air, m$^3$/min | 895 | 796 | 705 |
| Methane content by sensors at points, % | | 1 | 0,0 | 0,0 | 0,0 |
| | | 2 | 0,76 | 1,12 | 1,19 |
| | | 3 | 0,84 | 1,03 | 1,03 |

The results of the experiment (see Fig. 13) showed that at reducing the amount of air supplied to ventilate the face by 11% and 21%, respectively, these values increased the methane concentration in the outgoing face stream.

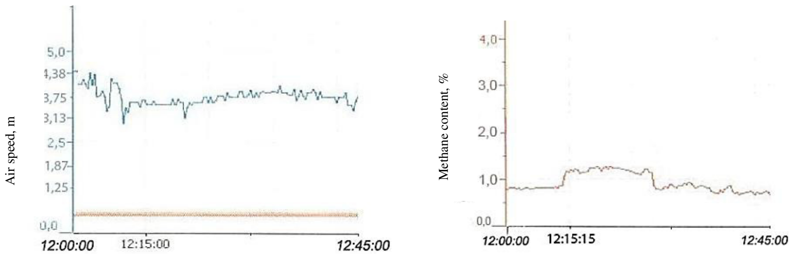


**Fig. 13.** Trend of air speed and methane content in the outgoing flow of the longwall of conveyor entry $71K_{10}$-v of Saranskaya mine

Experimental work at working areas $4.01D_6$-$1_z$ and $4.02D_6$-$1_z$ of the Lenin mine

Excavation areas $4.01D_6$-$1_z$ and $4.02D_6$-$1_z$ are located on the western flank of formation $D_6$.

Longwall face $4.01D_6$-$1_z$ was excavated along the seam dip at the depth of 550-647 m, and the longwall face $4.02D_6$-$1_z$ - at the depth of 567-661 m. The thickness of the layer at the section of the seam varies from 5 m at the mounting chamber to 6.5 m at the limit of the longwall stop. The average thickness of the layer is 5.8 m.

The adjacent strata are represented by mudstones and siltstones, the main roof is mainly siltstones and sandstones.

The adjacent soil of strata $D_6$ is represented by argillites, prone to swelling (f = 2.7) up to 1.0 m thick, and siltstones of medium hardness, with inclusions of siderite nodules ($f$ = 3.5-4) slightly softened and not prone to swelling.

Formation $D_6$ has a complex structure and includes up to 8 interlayers of claystone and carbonaceous claystone up to 0.14 m thick. The most pronounced interlayer in the upper part of the formation is from 0.09 to 0.14 m thick, represented by weakly clayey mudstone. The remaining interlayers have a variable thickness and the ability to delineation.

The coal of the seam is prone to spontaneous combustion. Formation $D_6$ from a depth of 320 m is classified as especially dangerous by sudden coal and gas releases.

The natural gas content of the layer is up to 19.53 m3 per ton of rock mass, the volatile yield is 23.5%. Reservoir moisture - up to 7.0%.

Ventilation of mine workings was carried out according to the direct-flow scheme with the air stream coming from the longwall.

At longwall face $4.02D_6$-$1_z$, coal mining in January-April 2012 was carried out when setting the threshold for protective shutdowns of electrical equipment equal to 1.3% vol. $CH_4$. During the period under review, coal production was 1,360-3850 tons per day.

**Studies of gas emission into the longwall face and adjacent workings**

The essence of the experimental studies in mine conditions is to determine the amount of air entering the face and the concentration of methane in the planned points of the area.

During the operation of the longwall face $4.02D_6$-$1_z$ in January-April 2012 the methane content at point 2 (in the area of the combine operation) was 0.2-0.9% of the volume, at point 3 (15 meters from the conveyor brake incline $4.02D_6$-$1_z$) - 0.3-1.1%, at point 4 (in the outgoing air stream) - 0.2-1.1%, at point 5 (on the freshing air-floor) - 0.1-0.2%.

Fig. 14 shows the distribution of methane concentration in the middle part of the face along its cross section at the set points, depending on the speed of the combine.

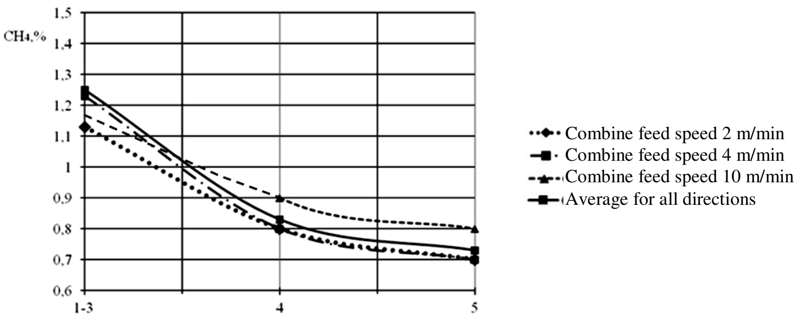


**Fig. 14.** Distribution of methane concentration in the middle part of the longwall along its cross section

As can be seen from the figure with an increase in the feed speed of the combine in operating mode from 2 to 10 meters per minute, the methane content in the air stream increased by 0.1-0.3%. Figure 14 also shows that in the air stream adjacent to the chest of the cleaning face, the methane content is the highest and amounts to 1.12-1.4%. With distance from the mine face toward the mined-out space, the methane concentration decreases to 0.7-0.8%. This pattern is typical for the middle part of the lava along its length.

The longwall face 4.01$D_6$-$1_z$ worked only 11 days during the study period, the methane rate of the mine was 23.99 - 48.14 $m^3$/min, including 8.83-27.62 $m^3$/min that was extracted by the ventilation means. Means of degassing accounts for the following volume of extracted methane: by vertical wells - 10,76-16,19 $m^3$/min, by formation wells - 4,11-6,07 $m^3$/min.

Methane content in mine area 4.02$D_6$-$1_z$ was 15.11-87.78 $m^3$/min, including 8.5-47.42 $m^3$/min extracted by ventilation means. Degassing facilities account for 2.91 to 46.31 $m^3$/min, including 2.0 to 16.5 $m^3$/min by vertical wells, 2.9 to 23.26 $m^3$/min in the upper casing, and 2.91 to 19.5 $m^3$/min by formation wells.

Figure 15 shows a graph of daily coal production, methane extraction by ventilation and degassing means for the period January-April 2012.

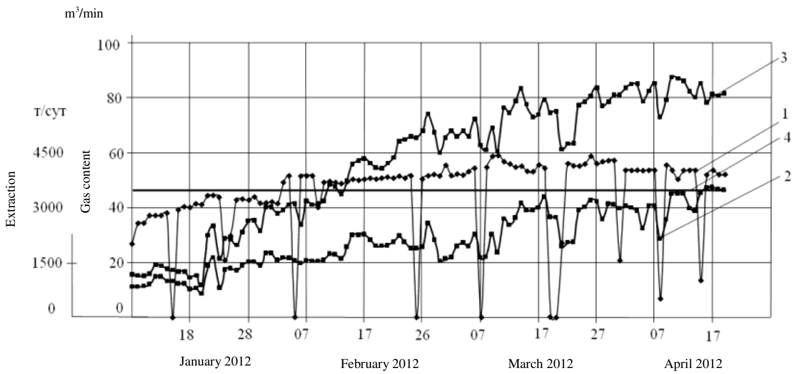


**Fig. 15.** Coal mining, gas content and degassing efficiency in the 4.02$D_6$-$1_z$ longwall face: *1* – coal mining; *2* - ventilation gas content; *3* - gas content: venting + degassing; *4* - planned production

As the figure shows, the daily production of coal at the plan of 4,000 tons per day, as a rule, exceeded the plan by up to 1.6 times.

Since longwall face 4.01$D_6$-$1_z$ worked during the study period only 11 days, only data from longwall face 4.01$D_6$-$1_z$ were used for the analysis.

Fig. 16 shows a fragment of the trend on March 31, 2012 from 14:00 to 2:00 on April 1, 2012.

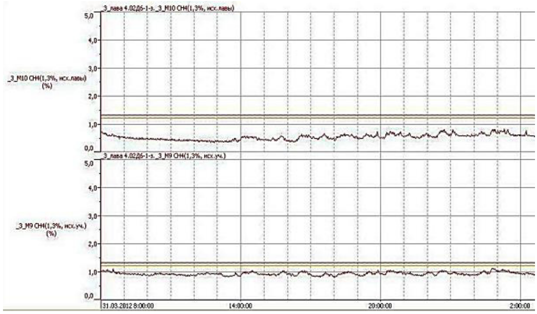

**Fig.16.** Trend of methane content at the outgoing face and mine area $4.02D_6$-$1_z$

The trend fragment reflects the typical gas situation in the mine area $4.02D_6$-$1_z$ when setting the system alarm thresholds equal to 1.3% $CH_4$. There were no sensor shutdowns and the shearer worked continuously. At the same time, as seen in the above fragment, setting the system to 1.0% $CH_4$ would result in multiple stoppages of the harvester by the gas factor.

Fig. 17 shows a fragment of the trend for February 7-8, 2012.

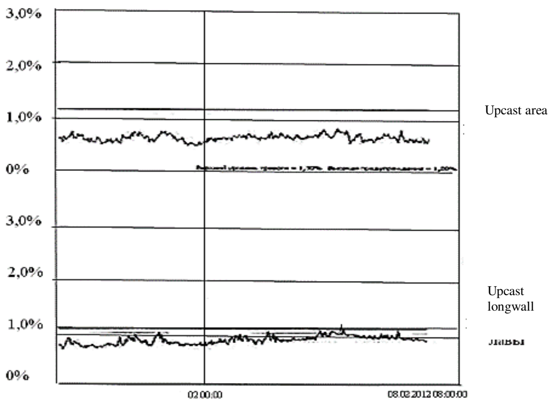


**Fig. 17.** Trend of methane content in the working area $4.02D_6$-$1_z$ area with installation of sensors at 1.3%

As it follows from Fig. 17, on February 8 at 5 hours and 14 minutes there was fixed an excess (1.34% $CH_4$) of the permissible limit of methane concentration on the outgoing face stream. The downtime for the gas factor was 1 min.

Setting the system to the methane concentration limit in the air stream coming from the face and the area, equal to 1.3 %, allowed to provide rhythmic and steady operation of the working face, which increased the safety of mining operations at the area.

In accordance with the methodology of experimental studies, an experiment was performed to assess the impact of air flow on changes in methane concentrations at given observation points.

In the course of the experiment, measurements showed that 2,560 m3/min of air was supplied to the area for its ventilation and 1,576 m3/min for freshing.

The amount of air on the outgoing face stream was 2149 $m^3$/min, methane concentration - 0.73%. At 10 h 20 min, the air flow rate was reduced to 2133 $m^3$/min, the amount of air on the outgoing stream decreased to 1690 $m^3$/min, while the methane concentration on the outgoing stream was 0.79%.

Then at 10 h 40 min the air flow rate was reduced to 1712 $m^3$/min and to 1556 on the freshing stream. On the outgoing at this time, the amount of air was 1,319 $m^3$/min. Methane concentration in the longwall increased to 1.01. In this mode the longwall was ventilated until 11:00 a.m., after which the previous ventilation mode was restored.

Recording of the trends of the automated control system of the mine air (ACS MA) was performed on the basis of the equipment of "Davis Derby Ltd" (UK) and sensors manufactured by "Wölke Industrieelektronik GmbH" (Germany).

The results of measuring the amount of air supplied to ventilate the face and the methane content in the observation points are shown in Table 3.

The results of the experiment showed an inverse dependence of methane concentration on the amount of supplied air for ventilation, i.e. at reducing the amount of air supplied to the face by 38 % (from 2149 to 1319 $m^3$/min), the methane concentration in the outgoing face stream increased by the same value up to 5-7 minutes (from 0,73 to 1,01 %).

Table 3

Results of measuring the amount of air supplied to ventilate longwall face 4.02$D_6$-$1_z$ and methane content in the observation points

| Measurement time, hour, minute | | $9^{50}$ | $10^{20}$ | $10^{40}$ |
|---|---|---|---|---|
| Incoming stream | amount of air, $m^3$/min | 2560 | 2133 | 1712 |
| Freshing stream | air speed, m/s | 1,6 | 3,1 | 1,58 |
| | amount of air, $m^3$/min | 1576 | 3054 | 1556 |
| Upcast longwall stream | air speed, m/s | 3,47 | 2,73 | 2,13 |
| | amount of air, $m^3$/min | 2149 | 1690 | 1319 |
| Methane content by sensors at points, % | 1 | 0,0 | 0,0 | 0,0 |
| | 2 | 0,0 | 0,0 | 0,0 |
| | 3 | 0,73 | 0,79 | 1,01 |

With the restoration of the former ventilation regime (the amount of air was increased from 1,319 to 2,149 m3/min), after about 5 minutes the methane content in the upcast stream of the area dropped to 0.75%.

The results of the experiment in the Lenin mine showed a virtually synchronous relationship between the amount of air supplied to ventilate the face and the methane content in its mine air.

## Conclusions

Thus, the experimental work with a total duration of 5 months in four faces at three mines of JSC "ArcelorMittal Temirtau" CD showed that the allowable methane content in the outgoing jets of faces and mine sections of 1.3% creates conditions for more rhythmic and uninterrupted operation of mine sections, compared with the limit methane content of 1.0%.

It should be noted that the maximum allowable methane content of 1.0% in the air stream coming from the longwall face was established many decades ago, when the methane content in the mine was determined by means of a gasoline lamp. The methane content was measured three times per shift. In the 1960s, gasoline lamps were replaced by gas analyzers (interferometers), through which measurements were also performed occasionally (3 times per shift), and the instruments had an error of ± 0.2% $CH_4$.

At present, JSC "ArcelorMittal Temirtau" CD mines have fundamentally changed the technique, procedure, and quality of methane control. All mines are equipped with the automated control system of the mine air (ACS MA).

In this case, the functions of automatic gas protection and control of the mine atmosphere are performed by sensors of methane content in the mine atmosphere and sensors of flow rate of air supplied for ventilation of workings (mining faces and dead-end workings).

Accuracy of methane concentration measurement by GMM01.04 sensors used in the mines is equal to ±0.1% of CH4 in the automatic gas control system (ACS MA).

The use of this modern high-precision system allows continuous quality control of the mine's atmosphere and promptly and automatically cut off electricity in areas with high methane content or violations of the ventilation mode (reduction of air supply).

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Based on our research results, and taking into account the experience of mines in developed coal-mining countries of the world [1], where at the current level of air control the permissible methane concentrations in the outgoing streams of mine workings have been revised to 1.5-2.0% (in the USA - 2.0%, Germany - 1.5%, Great Britain - 2, 0%, China - 1.5%, Australia - 2.0%, Ukraine - 1.3%, Russia - 1.3%), in accordance with the current level of methane concentration may be increased up to 1.3% in the outgoing streams of underground workings and working areas with reversible and direct flow ventilation schemes and automated system of continuous control of the mine air.

**Acknowledgements**

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