A STUDY OF GAS DRAINAGE METHODS EFFICIENCY IN KOTINSKAYA MINE IN RUSSIA

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ABSTRACT

The aim of the work was to study the experience and effectiveness of applying various methods of gas drainage in the mining of a thick coal-seam 52 in the geological conditions of the Kotinskaya mine, Russia. The range of gas drainage methods used at the mine included: preliminary methane drainage (predrainage) of the working seam, drainage from the goaf by vertical wells drilled from the earth's surface; drainage from the goaf by horizontal wells drilled through the pillar from the roadway; drainage from the goaf using a main gas drainage pipeline, installed behind a brattice and connected to a gas-exhausting fan mounted on the earth's surface. During the work, the gas control equipment data and the longwall face productivity data were analyzed. As a result of the studies, the dynamics of the emitted gas of the longwall face was established, the dependences of gas content of the longwall face output were obtained, and the relative cost of various gas drainage methods was established. The conclusion is that the low efficiency of predrainage of the working seam. The scientific novelty of the work is to establish the influence between zones of geological dislocations and the speed of advance of the longwall face and the volume of emitted gas of the block.

Keywords: underground mining, coal seam, longwall, methane emission, gas drainage, predrainage, postdrainge, longwall face output.

1. INTRODUCTION

Increased productivity of longwall faces is possible due to the use of modern reliable equipment with improved power-to-weight ratio in coal mines. An increase of a face output during the mining of suite of flat-lying gas-bearing coal seams has led to an increase of the volume of emitted gas of blocks. To ensure the safety of mining in coal mines, various methods of controlling gas emission are used: the ventilation - to dilute the gas to safe concentrations, the isolated gas drainage of the methane-air mixture and the gas drainage. Gas drainage in mines can be carried out by various methods: predrainage without destressing is carried out before drivage of roadways by drilling wells from the earth’s surface, predrainage with destressing (while developing seam roadways) is carried out before face retreating or advancing, ongoing drainage is aimed at removing methane, which released into the worked out space from overlying strata, which fell into the undermining zone (underworking strata) or underlying strata that are in a stress relief zone (overworked seams). The methane content of the block is determined both by the gas content of the working seam and the underworked (overworked) seams, and by the productivity of the working longwall face. Different gas drainage methods have different parameters and have different efficiency, while removing part of the methane. In the most difficult mining and geological conditions, several gas drainage methods are used simultaneously.

The problem of ensuring safety during underground mining of suite of gassy coal seams remains very relevant for Russia [1-3], and the issues of choosing a gas drainage method and determining its rational parameters are relevant for all coal-mining countries [4-7]. In this paper, we analyze the effectiveness of the use of a complex of gas drainage methods, during mining of coal seam 52 in the longwall panel 5208 of Kotinskaya mine (Kuznetsk coal basin, Russia).

2. DESCRIPTION OF MINING AND GEOLOGICAL CONDITIONS

The Kotinskaya mine is mining a suite of gas-bearing coal seams, including 13 coal seams (Figure-1). Seams 50, 52, 58 have the greatest thickness. Information on the thickness and gas content is presented in Table-1. Currently, the seam 52 is mining. The thickness of seam 52 within the longwall panel 5208 under consideration varies from 4.18 to 4.45 m (average 4.31 m), the dip angle of the bed is 6-70, depth: 250-360 m. The natural methane content of the seam within the longwall panel of 5208 is 8-10.6 m3 / ton. Seam 52 is prone to spontaneous combustion. Expected intake airflow to the face 5208: from 560 to 690 m3 / hour.

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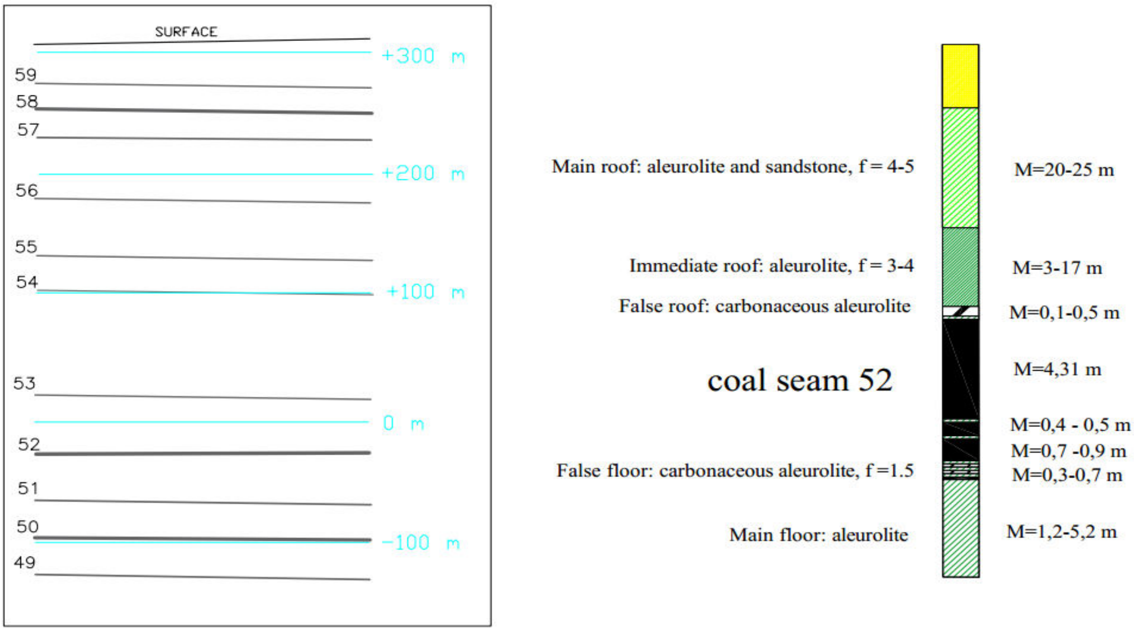

Figure-1. Geological section of the rock mass and lithological column for the developed reservoir 52.

Table-1. Characteristics of coal seams.

Coal seam	Seam height, m	Distance from the seam 52, m	Predicted methane content, m^3 / ton				
			Hypsometric mark, m				
			+200	+100	±0	-100	-200
58	4.26	188	0-4.0	7.0-7.5	-	-	-
57	2.03	148	0-4.0	7.0-7.5	9.0	-	-
56	0.46	120	0-4.0	7.0-7.5	9.0	-	-
53	1.28	48	0-4.0	7.5	9.0	11.0	-
52	4.38	-	0-4.0	7.5	9.0-9.5	11.0	-
51	2.64	33	0-4.0	7.5-8.0	9.0-9.5	11.5	12.5
50	3.90	59	0-4.0	7.5-8.0	9.5	11.0-11.5	12.5
49	2.7	84	0-4.0	7.5-8.0	9.5	11.5	12.5

The length of the longwall panel 5208 is 3975 m and the width is 275 m. The development of the panel is carried out using double-gallery with arch support system, carried out on each side of the longwall panel. Cross section of developing entries (headgate and tailgate) is 20.3 m3. The equipment is used in the face 5208: Eickhoff Shearer Loader SL 500; support DBT 220/480, face conveyor DBT PF 4/1132. The planned longwall face output is 18350 tons / day.

To reduce gas emission from the working seam in the longwall face 5208 before the actual mining predrainage of the working seam is used, using wells 3 (Figure-2) drilled from the ventilation drift. The diameter of the gas drainage wells is 76 mm, the length is up to 280 m. In total, 273 wells were drilled. During the period of work of the face 5208, a combined ventilation scheme is used (Figure-2). Fresh air in the volume of 2800 m^3 / min is supplied to the face via the double Tailgate 5208. Passing through the face the air stream is divided. The first part of the air goes through the goaf space into the gas drainage pipeline 4 (Figure-2), brought in by the brattice. The other part goes into vertical wells 1 (Figure-2), drilled from the earth's surface. The third part goes through wells drilled through the pillar, and the main stream (up to 2400 m^3 / min) of air leaves the face to Headgate 5208.

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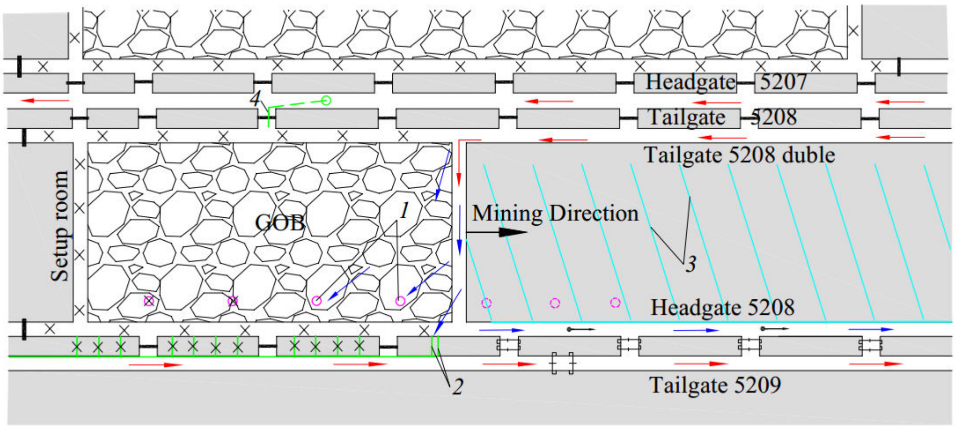

Figure-2. The gas emission control circuit at the longwall 5208.

3. RESULTS AND DISCUSSIONS

Predrainage of the working seam has been carried out since May 2010. The 600,000-700,000 m^3 of methane was removed monthly. After 8 months of predrainage a total of 5 million m^3 was removed from the seam. In January 2011, coal-face work began, during which, until the main roof weighting, methane was released mainly from the working seam and methane was removed by ventilation (Figure-3). After the roof weighting and the increase of underworked zone permeability, methane began to flow into the goaf from the adjacent upper seams. As can be seen from the Figure-3, the gas emission of the longwall face varied from 15 to 90 m^3 / min (average gas emissions was 40 m^3 / min), decreasing to 5 m^3 / min during the stoppage of a longwall face. The reasons for a significant change in gas emission are, firstly, an growth in gas evolution in the zone of geological dislocations (consequences of the longwall face work in August-September, 2011), and secondly, the influence of geomechanical processes on gas evolution. The previous studies established[8], the maximum gas emission at the Kotinskaya mine is observed when the longwall face advances every 25-50 m along the length of the panel, which is explained by an increase of the permeability of the underworked strata in the mining area after each weighting of the main roof.

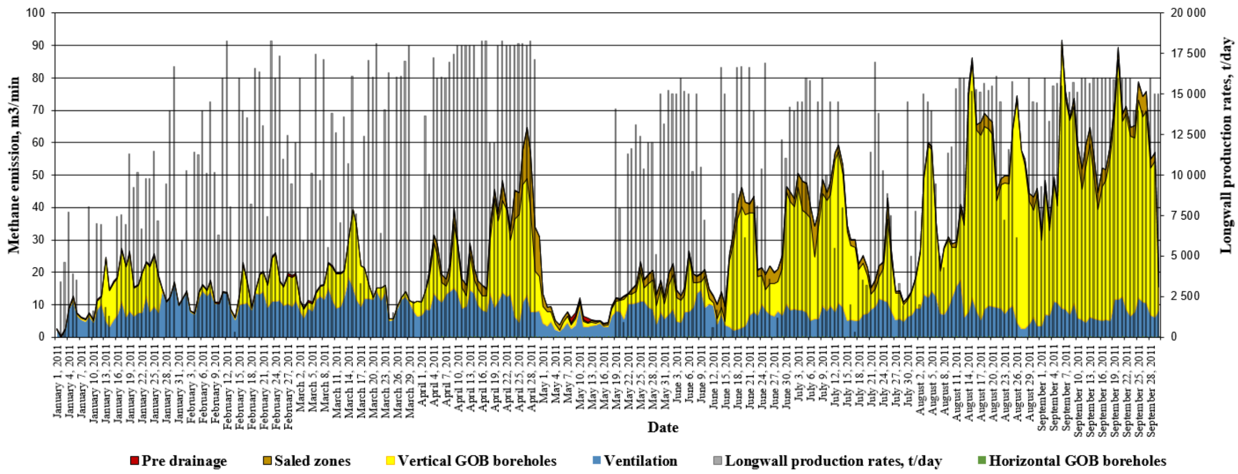

Figure-3. Dynamics of methane emission and longwall face 5208 production rate.

Analysis of the forecasted (calculated) and actual performance and methane emission of the longwall face 5208 (Table-2) showed that the actual face output was 25% lower than planned. At the same time, work in the zone of geological dislocations was accompanied by a 10-15% decrease in output and a 20% increase in the methane emission of the coal face. The decrease in the output of the face was associated with an increase of the gas emission in the goaf and reaching a peak of permissible methane concentration value (Table-2 presents the daily average gas emission data). The concentration of methane in the methane-air mixture removed from the goaf during the period of advancing in geological dislocation zone reached 95-97%, which indicated the inadequate efficiency of the goaf drainage.

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Table-2. Indicators of gas mobility of the extraction site 5208.

Indicators	The productivity of the longwall face, ton / day	Methane emission of the longwall face, m^3/ min	Methane emission of the goaf, m^3/ min	Capturedmethane volumes, m^3/ min
Planned (estimated)	25 000	21,70	67,19	88,89
Actual (average)	10 628	8,6	29,0	45,8
Actual (maximum in the area of geological dislocations)	16 100	17,5	80,2	97,7
Actual (maximum outside the zone of geological dislocations)	18 300	18,3	66,9	85,2

Figure-4 presents data on the relationship between the concentration of methane at the headgate (in T-intersection) of the face and the face output. Figure-4 shows that the work of the working face with output of 6000-18300 ton / day is characterized by similar values of methane. At the same time, a significant variability in methane emission is also associated with the influence on the gas evolution in geomechanical processes occurring in the goaf (collapse of the main roof). The pie chart (Figure-4) shows the shares of gas drainage methods and ventilation of captured methane. As can be seen from the pie chart, the biggest percentage of captured methane carry out by vertical wells, drilled from the earth's surface in the goaf, at 38.7% and pipelines behind brattices at 37.9%. Less than 20% of the methane is removed by ventilation.

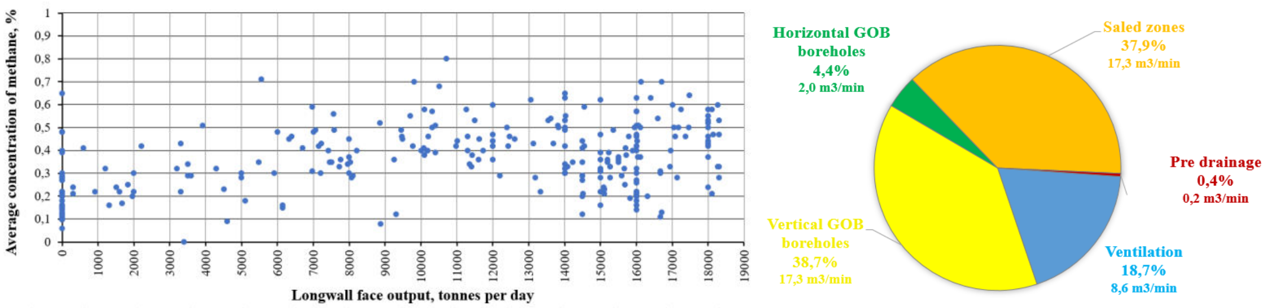

Figure-4. The average concentration of methane at the end of the longwall face and the distribution of captured methane.

To evaluate the economic efficiency of using various gas drainage methods, we performed an analysis of data about the costs of drilling wells, the installation of gas drainage pipelines and the operation of exhausting fans. The results of the analysis of economic efficiency are presented in Table-3.

Table-3. The cost of methane extraction with various gas drainage methods.

Drainage method	Value, USA $	Total methane capture, m^3	Relative drainage cost per m^3 (USA $/$m^3$)	Coal production, ton	Relative costs, USA $ per ton
Predrainage	1 275 946,0	11 096 400	0,11	-	0,23
Sealed area	539 238,5	68 010 192	0,01	-	0,10
Vertical GOB boreholes	4 643 353,3	62 840 808	0,07	-	0,83
Horizontal GOB boreholes	540 479,3	22 973 300	0,02	-	0,10
TOTAL	6 999 017	164 920 700	0,04	5 593 000	1,25

The most cost-effective methods of gas drainage is the drainage of the goaf using a main drainage pipeline, installed behind a brattice. Using this method of gas drainage, you only need a couple of wells drilled from the earth's surface to exhaust captured methane. The method is effective at the longwall panel 5208 due to the presence of additional supported Tailgate 5208. Gas drainage using horizontal wells drilled from the Tailgate 5209 is the second most effective gas drainage method. The cost of methane removed in this way is about US$ 20 per 1000 m3. However, the small diameter of the wells and the restriction on the concentration of methane in the pipelines, laid in the mine roadways, limit the possibilities of this method. In connection, the main objective of this method is to ensure leaks at the longwall face end to reduce methane concentration there. The second productive method of drainage is by using wells, drilled from the earth's surface. The high cost of drilling and a large number of wells make methane more expensive at US$70 per 1000 m3. However, this method, when rational parameters are being chosen, is the main and most effective way to remove methane in the longwall panels at gassy mines. The least effective is the predrainage of the working seam, which accounts for 18.2% of the total cost of gas emission management and only 6.2% of the total methane captured. The low efficiency of predrainage is due to the low permeability of the coal seam. Considering that the permeability of the working seam will only decrease with increasing depth, the effectiveness of predrainage will decrease, and therefore its use is not economically feasible. It should be noted that one of the most effective modern method of selecting and substantiating the parameters of ventilation schemes and methane emission control is computer simulation using Computational Fluid Dynamics (CFD) approaches [9-10].

4. CONCLUSIONS

The analysis of the efficiency of gas emisson control in the longwall panel 5208 of the Kotinskaya mine allowed us to draw the following main conclusions:

a) The applied set of measures for the gas drainage of the working seam and the goaf are not effective enough, since the planned output of 25,000 ton / day was not achieved (the actual output did not exceed 18300 ton / day). At the same time, the main limitations were associated with reaching the maximum permissible concentration of methane (3.5%) in the gas drainage pipeline connected to horizontal wells drilled from Tailgate 5209 and the insufficient productivity of the used gas drainage installations (two units with a nominal fan delivery of 150 m3 / min and an actual 80 m3 / min each). To remove the limitation, it is recommended to increase the productivity of this method of gas drainage through the use of a UVCG-9 exhausting fan with a delivery of up to 900 m3 / min and instead of linking wells using a pipeline that was installed behind brattice in the ventilation cross slit from Tailgate 5209.

b) The work of the longwall face in areas of geological dislocatons in the mine Im. V.d. Yalevskogo was accompanied by an increase in the gas emission of the goaf spaces by more than 20%, which is due to the high permeability of the rock mass in the zone of influence of geological dislocatons, which creates conditions for gas migration from seams and rocks outside the zones of influence of coal-face work (underworking and overworking). To reduce the negative impact of geological dislocatons, it is recommended to drill additional vertical gas drainage wells in zones of their influence to increase the volume of methane removed from the goaf and increase the face output.

c) The use of predrainage of the working seam by in-situ wells (without hydraulic fracturing) in the mine Im. V.d. Yalevskogo is characterized by high costs for its implementation (18.2% of the total cost of gas drainage) and low efficiency (6.2% of the total volume of methane removed). As a measure to compensate for the lack of predrainage and to ensure effective dilution of methane in the longwall face to a safe concentration, it is proposed to increase the air flow in the longwall panel to 3000-3600 m3 / min.

d) An analysis of the dynamics of gas emission in the longwall panels confirmed the presence of a periodic substantial increase in methane evolution in the goaf, due to the periodicity of geomechanical processes (collapse of the main roof). A significant number and high variability of factors affecting roof-caving increment of the main roof (physicomechanical properties of the rocks, the speed of advance of the longwall face, geological dislocatons, etc.) along the width and length of the panel lead to significant changes in the frequency of increase in gas emission in the goaf. That makes the prediction of their frequency and magnitude difficult and determines the need for calculating the parameters of gas emission control taking into account the maximum possible methane emission. In the conditions of the mine Im. V.d. Yalevskogo the increase in gas emission of the goaf occurs with a each 25-50 m along the length of the longwall panel. The distance between the vertical gas drainage wells is recommended to be taken in the given range (about 40 m).

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