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SUBSTANTIATION OF THE TECHNOLOGICAL SCHEMES OF INTENSIVE DEVELOPMENT OF GAS-BEARING COAL BEDS

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ABSTRACT

This paper is focused on improving the economic efficiency and safety of developing gas-bearing coal beads. The main problems with intensive development of pitching gas-bearing coal beds in flanking pillars have been considered. With the Kotinskaya mine of JSC "SUEK-Kuzbass" as an example, it has been shown that in working at gas-bearing coal beads, gas emission management by means of ventilation, degassing, and isolated venting of the methane mixture through the wells drilled from the surface is not efficient and stable enough at the reached depth, and does not always allow to lift limitations by the gas factor on the load on the working faces. Incomplete use of the technical possibilities of the equipment, and deterioration of the performance indicators of development result in losses. Therefore, it is necessary to improve the methods and instruments for gas emission management. To solve this problem, the integrated method was used, which included generalization and analysis of the theory and practice of developing gas-beating beds with long faces, and gas emission management at excavation sites. Based on the results of field and computational studies of the technological schemes parameters influence on the efficiency of gas emission management at an excavation site, nonlinear dependence of allowable loads on the working faces has been established by the gas factor based on the parameters of the technological schemes, and ventilation and degassing in case of intensive development of pitching gas-bearing coal beads. Several recommendations have been given for choosing the location and section size of the intermediate roadway for gas emission management in the goaf, as well as recommendations for choosing the parameters of degassing with drilling wells from squaring up, venting the goaf with two air supply openings and isolated removal of methane-and-air mixture. A process scheme has been developed with the use of an intermediate roadway that ensures effective gas release management and eliminates the need for drilling wells from the surface into the mined-out space for mining gas-bearing coal beds.

Keywords: coal bed, methane, degassing efficiency, numerical modeling, longwall face, process scheme, recommendations.

1. INTRODUCTION

Increasing the depth of mining and the load on the working faces results in uncreased volume of gas in the goafs. In these conditions, the load on the working faces by the gas factor often exceeds the load by the technical capabilities of mechanized purging complexes. This results in losses from insufficient use of the capabilities of modern high-performance mining equipment, which significantly increase if only one working face is present in the mine.

To date, considerable experience has been accumulated and generalized in gas emission management in course of intensive working of gas-bearing coal beds [1]. With significantly increased dimensions of the goafs, the required effect is achieved by the use of combined methods of active degassing of the methane release sources, and direct-flow ventilation. In the considered conditions, combinations of various types of underground and surface-level wells are of interest [2], which make it possible to degas almost all sources of gas release in a goaf. At the same time, in the conditions of intensive coal bed mining, the means of gas emission management do not always make it possible to remove the working faces load limits by the gas factor [3, 4]. Since most mines in Russia develop gas-bearing coal beds, more and more enterprises switch to the "mine - longwall face" structure, and the issue of substantiating the parameters of process schemes that ensure efficient and safe development of coal beds with full use of the technical capabilities of the mechanized purging complexes is relevant [5, 6]. It should be noted that in most regions of Kuzbass, coal beds are characterized by low natural permeability, which dramatically reduces degassing efficiency in developed coalbeds, showing higher requirements to the efficiency of degassing other methane sources [7].

A considerable portion of methane gets to the roadways of the goafs from the mined-out space [8, 9]. At the same time, the schemes of removing the methane-and-air mixture from the mined-out space with surface modular degassing units (MDU) through wells drilled from the surface, which are used in the mines of Kuzbass, are costly and do not ensure the required level of stability of gas emission management. With increasing the depth of mining, such schemes become more costly and less sustainable.

2. METHODS

In order to substantiate the technological schemes of intensive mining of a pitching gas-bearing coal bed that ensure efficient gas management without the use of surface MDUs, a complex of research was conducted. The main objectives of the research were:

- Analysis of the world experience in intensive mining of gas-bearing coal beds.
- Field studies of the influence of process scheme parameters on the efficiency of gas emission management in the goaf.

- Numerical simulation of the influence of gas emission management methods and modes of ventilation for various parameters of the process scheme on the load on the working face.
- Development of recommendations for defining process scheme parameters in course of mining gas-bearing coal beds in the «mine - longwall face» mode.
- Assessing efficiency and determining the application scope for the developed recommendations.

For the field research, the "Kotinskaya" mine of JSC "SUEK-Kuzbass" was chosen in the Sokolovsky coal field of the Erunakovsky coal-bearing area of Kuzbass. The gas situation in goafs 5209 and 5210 was studied for the period between January 2014 and September 2015 with the use of automated monitoring sensors that record exact time of the measurement, concentration of the main mine gases, and the quantity of supplied fresh air. The measurements were made several times per minute with a sensor, which made it possible to quickly and accurately assess the situation in the goaf in real time, or to reconstruct the events using the archived data. The general scheme of the goaf and gas management is shown in Figure-1.

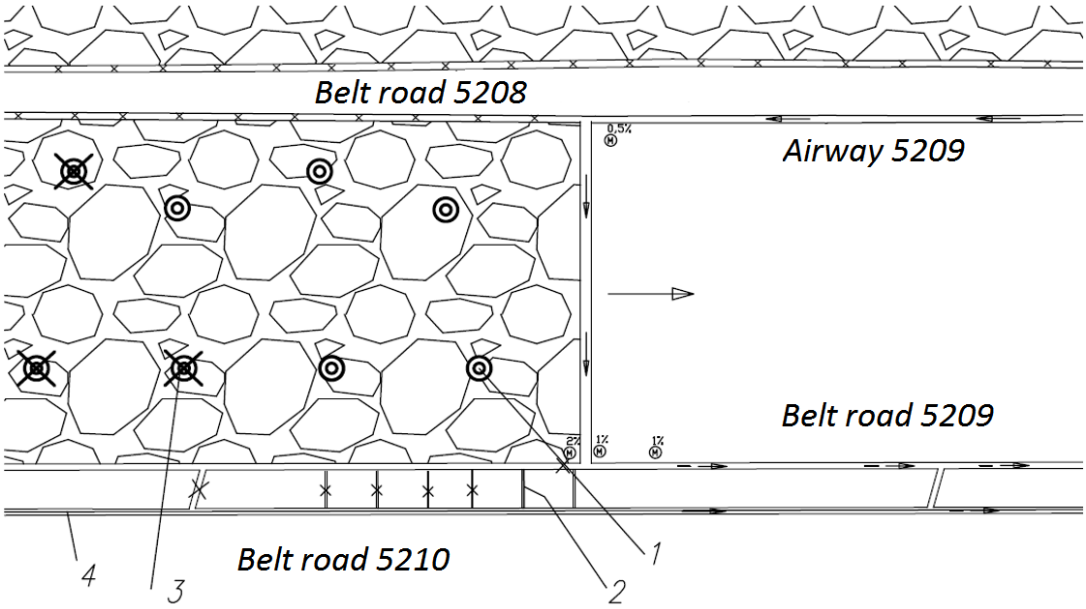

Figure-1. The process scheme of the goaf at the Kotinskaya mine: *1*- degassing wells drilled from the surfaceinto the rock cavity; *2* -raise wells; *3* - gotten wells; *4*- the degassing pipeline

To ensure isolated removal of methane-and-air mixture (MAS) from the mined-out space, wells drilled from the surface into the rock cavity are used. 5 wells operating at the same time were connected to mobile MDUs with the total air flow of 230 m^3/min. Also, for MAS removal from the mined-out space of a goaf, raise wells drilled through the bearer from the belt road are use. The raise wells are connected to the degassing pipeline and to the vacuum pumps on the surface.

It has been found that in the total amount of the methane released from the goaf, 9-15% of methane come from the working face, and 85-91% - from the mined-out space. Particular attention should be paid to short outbursts of methane concentration that cannot be traced with the use of the technological, gas-dynamic or geomechanical processes that occur in the goaf. The danger of these outbursts is in their being sudden and unpredictable. The duration of an outburst is about 10 minutes, with a 3- or 4-fold increase in methane concentration. When the load on the working face is about 15,000 t/day, the maximum permissible concentrations of methane in the stream from the longwall face are reached repeatedly.

For experimental and analytical study of the influence of process scheme parameters on stability of gas management in the goaf, a computational model was created in Ansys CFX. The computational domain was divided into a certain number of non-overlapping reference volumes so that each tie point was contained in a separate reference volume. In building the computational model, the long experience of Russian scientists from [10, 11] was taken into account, which shows systematic approach to solving problems of the gas emission dynamics in the purging areas of coal mines. Colleagues from the US [12,13] and China [14, 15] attach particular importance to characterization of the mined-out space.

3. THE RESULTS OF THE STUDY

Figure-2 shows the results of computational modeling of loss of function in one of the 5 active wells drilled from the surface. As one can see in the Figure, loss of function in one of the 5 active wells immediately results in noticeable changes in methane distribution in the goaf, leads to increased methane concentration in the area of

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methane release from the mined-out space into the longwall face.

Methane concentration in local clusters in the longwall face exceeds 1%, and in belt road it increases from 0.65%, with all wells operating, to 0.9%. The results of modeling are confirmed by comparison to the results of field study, which proves low resistance of gas management with the use of wells drilled from the surface in the gas management scheme adopted in the mine.

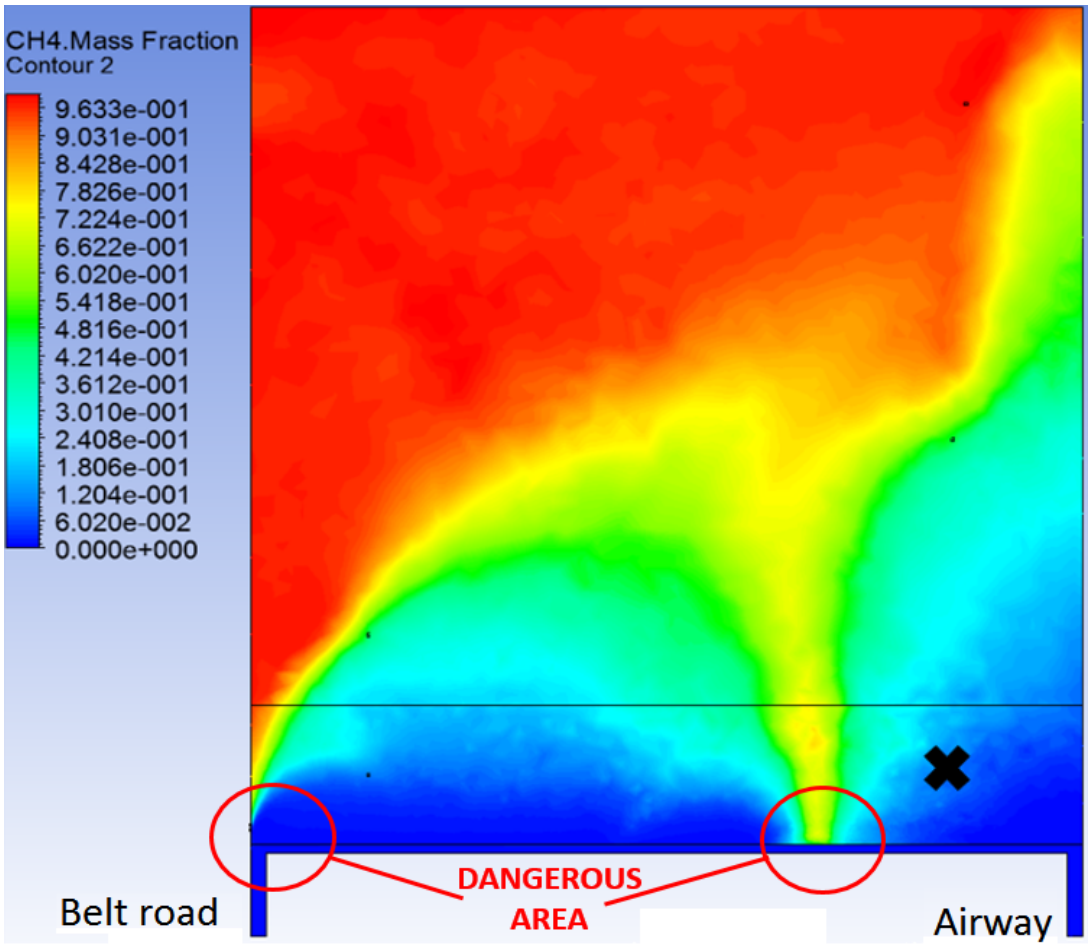

Figure-2. Distribution of methane in the goaf in case of loss of function in one of the wells.

To improve the efficiency of gas release management and for removing the limitations on the working face by the gas factor, the paper proposes an alternative to the existing use of wells connected to the MDU, which is the process scheme of preparing the goaf with paired roadways and an intermediate roadway for letting a refreshing stream of air into the longwall face (Figure-3).

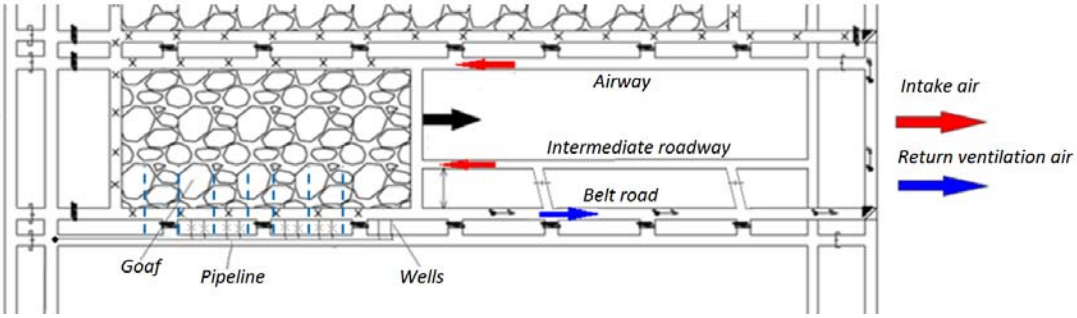

Figure-3. The process scheme of preparing and mining gas-bearing coal beds with the daily load on the working face of 25,000 tons/day.

The main parameters for the intermediate roadway are free clearance, the distance to the belt road, and the amount of air supplied to the airway. The cross section of the intermediate airway is 12 m^2, which allows supplying the required amount of air at the lowest possible cost of drilling and maintenance.

Options of preparing with various distance between the belt road and the vent road have been considered in the range between 40 m and 100 m, and with the values of the amount of air supplied through roadways varying from 750 m^3/min to 2,000 m^3/min, isolated removal of MAS from 250 m^3/min to 500 m^3/min, and loads on the working face from 15,000 tons to 25,000 tons per day. Isolated removal is envisaged through the underground wells drilled from the adjacent roadway through the strip bearer; in various situations, wells may be drilled parallel to the ground, or into the rock cavity. The results of modeling are shown in Figure-4.

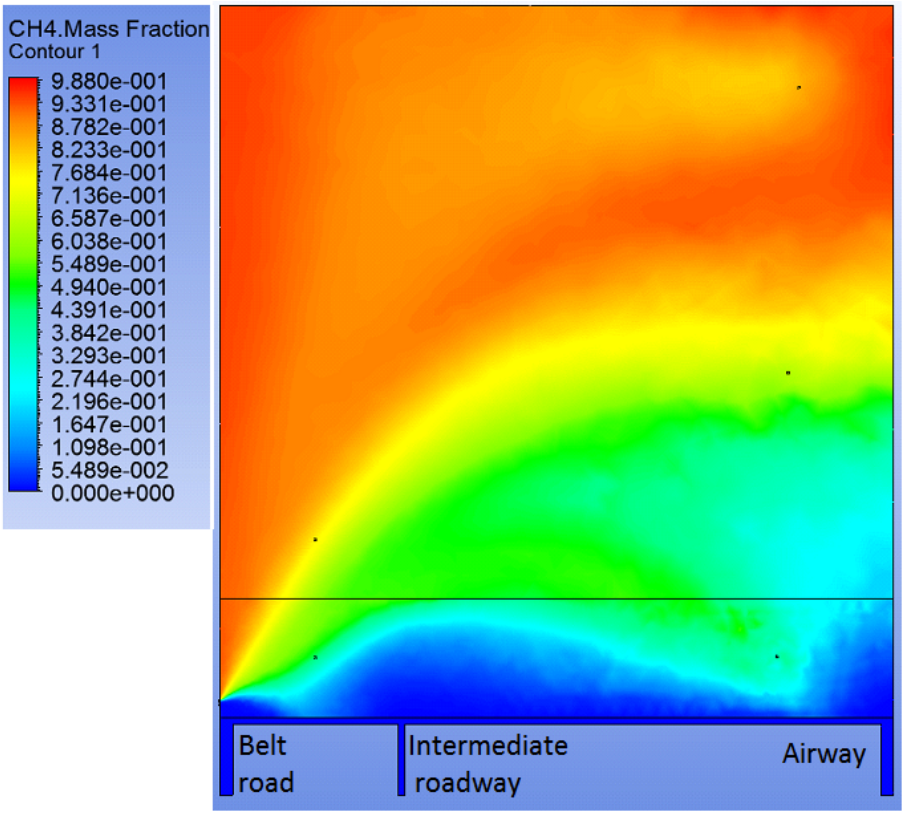

Figure-4. Distribution of methane in the goaf under the load of 25,000 tons/day in preparation of the goaf with three roadways.

4. DISCUSSION OF THE RESULTS

When the distance between the intermediate roadway and the belt road is changed, the distribution of methane in the longwall face and in adjacent workings changes, too. Analysis of methane distribution in the longwall face with the use of intermediate roadway for gas management in the goaf allows drawing conclusions about the limitations for using various process schemes for mining gas-bearing coal beds in the mine-longwall face mode, and the limits of changing parameters of preparing the goaf and the parameters of the means of gas emission management.

Analysis of expenses for preparation and development of goafs for the conditions at the Kotinskaya mine in 2014-2015 showed that about two thirds of the amount was spent on purification and drilling (52% and 20%, respectively), and the cost of gas emission management was 16% of the total cost of mining the goaf [16]. The cost of drilling wells from the surface is 75% of the total cost of gas emission management, which makes it relevant to search for alternative solutions in gas management that would endure lower costs with the required level of reliability.

For degassing the mined-out space of bed 52 at the Kotinskaya mine, 320-380 m deep wells are used, which, if converted into conventional units, means that 13 meters of wells are drilled from the surface for 1 meter of the length of the goaf. The cost of drilling 1 meter of the well is 5.1 thousand rubles (in 2015 prices), which totally amounts to 66.3 thousand rubles per 1 meter length of the goaf. When the length of flanking pillar is 4 km, the cost of drilling only is 265.2 million rubles. The cost of servicing mobile MDUs is 16,243 thousand rubles per year. For degassing bed 50, the cost of drilling per 1 meter of the length of the flanking pillar will increase to 73.4 thousand rubles, due to the increased depth of

development. At the same time, the actual cost of 1 meter of working (the airway) in the conditions of the Kotinskaya mine amounts to 46.3 thousand rubles. With the high cost of drilling and maintenance of wells and MDUs, one of the ways of reducing the total cost of mining may be switching to the proposed process scheme (Figure-3) with gas emission management that does not involve drilling wells from the surface.

Figure-5 shows comparison of the costs of making additional roadway and drilling degassing wells from the surface for the goaf of similar size (5209) at various depths of mining. As can be seen from Figure-5, costs become comparable at the depth of 220 m; with the further increase of the mining depth, additional roadways become less costly.

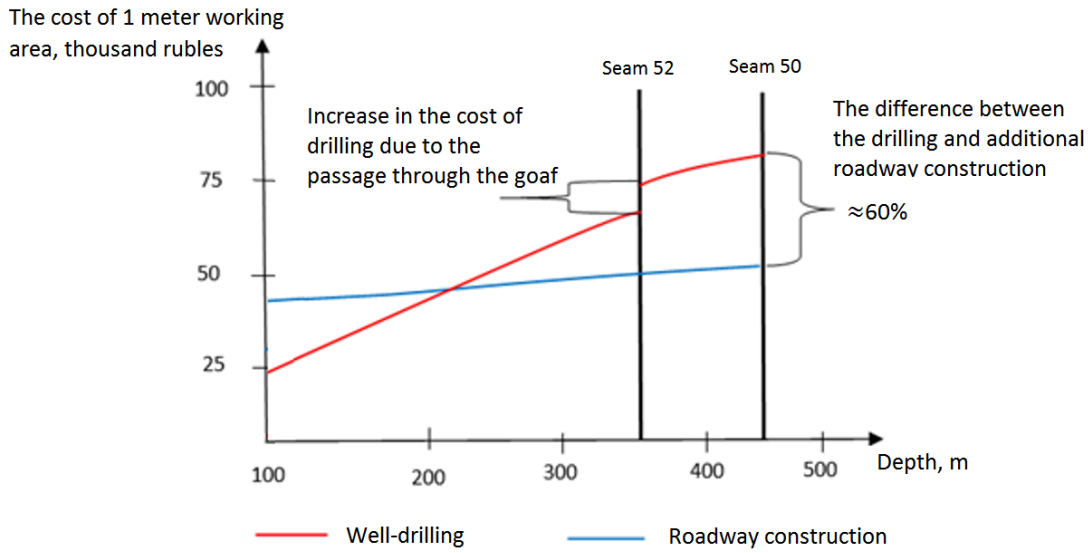

Figure-5. Comparison of costs for drilling wells and drilling additional roadways.

5. CONCLUSIONS

Summing up the results of the study, the following conclusions may be made:

- In case of intensive development of the goafs, the use of wells drilled from the surface and connected to MDUs for isoulated MAS removal at the reached depths of mining in the conditions of the Kotinskaya mine is costly, and does not ensure reliable lifting of the limits of the load on the working faces by the gas factor.
- With increasing the depth of development, the cost of drilling wells from the surface grow, and the stability of the process scheme is reduced, since when wellbores are blocked, gas is accumulated in the workings of the goaf, and emergency stop of the working face occurs.
- Using the process schemes with preparation of goafs with twin roadways and an intermediate roadway for feeding freshening stream of air, in combination with isolated withdrawal of MAS through raise wells, makes it possible to ensure daily loads on the working faces by the gas factor up to 25 thousand t/day without using wells drilled from the surface and mobile MDUs.
- The use of the process schemes with an intermediate roadway becomes economically preferable, as compared to using surface wells and MDUs at the depth of mining 220 m or more.
- For efficient gas emission management with the use of the proposed scheme in the conditions of the Kotinskaya mine, the intermediate roadway should be located at the distance about 70 m from the belt road, and should ensure insulated removal of MAS through raise wells at the rate of not less than 350 m^3/min.
- The expected economic effect of switching to the proposed process scheme without the use of surface wells and MDUs will be at least 80 million rubles per one flanking pillar in bed 52.
- To ensure loads on the working faces by the gas factor over 25 thousand t/day, degassing of the developed bed is required along with the recommended process scheme.

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