CHOOSING AND SUBSTANTIATING THE METHODS OF MANAGING GAS EMISSION IN THE CONDITIONS OF THE KOTINSKAYA MINE OF JSC SUEK-KUZBASS

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ABSTRACT
This research is focused on choosing and substantiating efficient methods of gas emission control in the working areas in course of intensive mining of gas-bearing coal beds. The methods of predicting methane release in the working area have been analyzed. The reasons why the accuracy of determining the expected methane emission is associated with great difficulties are shown. By the results of field observations, efficiency of methods of control of gas emission management in a working area has been assessed. The influence of working face daily load on methane release into the longwall face has been determined in the conditions of the Kotinskaya mine. Parameters have been substantiated, and control modules of gas emission management in the working areas have been formed. An example of a gas emission control module layout has been shown. A set of recommendations has been developed for intensive and safe preparation and mining of working areas in gas-bearing coal beds. Economic effectiveness of the recommendations and the areas for their rational use have been evaluated. The areas of further research, which are required to improve the efficiency and safety of mining operations in development of contiguous coal beds, have been determined.

Keywords: underground mining, coal beds, methane capacity, working face load, working area, gas emission management.

1. INTRODUCTION
Coal deposits of Russia, as compared to the foreign ones, are characterized by higher gas content, considerable depth of mining, and complex mining and geological conditions in their development. Over half of underground coal mining is allocated to category III and over-category in terms of methane content, which are hazardous in terms of emissions.

In the main coal basin of Russia, the Kuzbass, about 64% of long working faces operate in the conditions of natural gas presence in developed beds in the amount of over 10^3 t. About 82% of the mines operate in the conditions that are dangerous in terms of rock burst shocks, and 79% operate in the conditions that are hazardous in terms of spontaneous combustion of coal. Ensuring safe operation in these conditions requires the use of special measures aimed at their prevention, which results in increased operating costs [1]. Maintaining high level of performance indicators, and further increase of productivity in the conditions of increasing the depth of mining is limited by such factors as rock pressure, water inflow into roadways, and increased methane emission [2]. All these factors have significant influence on operation of working faces in particular, and on operation of the whole mine in general. Their negative manifestations result in downtime of mining and preparation areas, which results in considerable financial losses.

Operation of mines with high load on highly gaseous coal beds is only possible with the use of highly efficient degassing of the underground working areas together with the use of efficient ventilation schemes [3], which is also confirmed by the experience of coal mining in the mines of China [4, 5]. Some authors see an alternative solution in the use of advance degassing. Similar methods are used in domestic [6,7] and international practice [8, 9]. In modern mines, the "mine-longwall face" structure is more and more widely used, which features the maximum concentration of mining operations and ensures mine production capacity of more than 12 million tons/year or more from one working face [10]. Increasing the depth of mining, increasing the loads on the working faces results in an uncreased volume of gas in the working areas. In such conditions, gas emission management by means of ventilation, degassing and isolated removal of the methane-and-air mixture does not always allow to remove load limitations on working faces by the gas factor. The discrepancy between the expected and the actual methane emission greatly complicates choosing the means of gas emission management in the working area. Therefore, future research should be focused on searching for new models of gas emission with development on this basis of technical solutions that ensure reliability of parameters calculation and efficiency of schemes for venting working areas with loads on working faces that correspond to technically achievable levels [11].

2. METHODS
A method of structural and parametric optimization is proposed for gas emission management schemes in working areas. In accordance with the recommended method, we propose assessing the possibility of gas emission management by means of ventilation for the given parameters of process flow in mining working areas. If ventilation cannot ensure the content of methane in the outgoing jet in the roadway of less than 1%, possible variants should be considered to change the key parameters of the process schemes of mining the working area, which influence methane release and gas balance in the working area. These parameters
include: the length of the longwall face, the load on the working face, the scheme of preparation and venting the working area. It should be noted that these parameters largely determine the performance indicators of mining the reserves, therefore the necessary prerequisite for using this approach to gas emission management is comparative economic assessment of mining operations for the initial (design) variant, and the variant based on changes in the parameters of process schemes for ensuring gas emission management by means of ventilation.

One of the main areas in optimization of the process scheme of the working area is ensuring the conditions for the isolated removal of the methane-and-air mixture, and reducing the concentration of methane in the working face and at the junctions with the zonal roadways by forming controlled leakage into the mined-out space (MOS).

If changing the parameters of the process scheme cannot be changed, or such a change is not economically expedient, and in case of failure to observe the conditions of methane content in the jet from the roadway, the use of degassing is mandatory. Considering the high costs and low efficiency of preliminary degassing, this method is not considered in this paper, and preliminary degassing (degassing of the developed bed) and current degassing (degassing the mined-out space and accompanying beds) are recommended as the main methods of degassing.

The structural optimization of working area degassing scheme includes feasibility study of one or a combination of several methods of degassing, based on assessing the technical feasibility and the economic efficiency of their implementation. Next, the parameters of the selected degassing scheme for specified mining-and-geological conditions are optimized with the consideration of their changing in the area (bed, or part of the mine field), and over time with development of reserves and mining operations.

It should be noted that structural and parametric optimization of gas emission management should be performed for each working area with consideration of updated data about efficiency of the methods and schemes implemented in mining resources in the adjacent extraction pillars. Besides, changes in the geological and mining conditions with development of works within even a single bed in the mine field may result in significant changes of efficiency of various schemes and methods of gas emission management in the working areas, and to significant changes in their implementation costs [12]. Thus, assessment of the economic efficiency of implementation of gas emission management in a working area is a decisive step in their structural and parametric optimization.

For the conditions of the Kotinskaya mine, the specifics of the mining conditions in beds 52, 50 and 49 in terms of gas emission management in the working areas is mainly determined by occurrence of beds in suites, and, as a result, by prevailing of the gas emitted from the mined-out space in the gas balance of the working area (up to 90%) [13, 14]. This distribution of gas sources has predetermined a wide use of mined-out space degassing schemes, or schemes with venting and isolated removal of methane-and-air mixture in order to minimize the inflow of methane from the mined-out space into the face space of the longwall face.

It should be noted that mining bed 52 is characterized by complex conditions for gas emission management, which are characterized by the presence of upstream (in 40-45 m) and downstream (in 35-40 m) gas-bearing reservoirs with the capacity of 1.3 m and 1.9 m, respectively. The loads on the working face of 15-25 thousand tons/day achieved in the working areas in mining the bed predetermine a significant amount of methane released from the developed reservoir, and large volumes of gas from the mined-out space, related to gas release from these beds in the unloaded areas formed in the roof and the floor of mined-out spaces, and increased fracturing in the roof of the mined-out space. Thus, during intensive mining of bed 52, effective gas emission management in the working areas cannot be ensured by means of ventilation and insulated withdrawal with the use of traditional ventilation schemes and preparation of the working area without degassing. Thus, the use of degassing is a prerequisite of ensuring safety and efficiency of mining operations by the venting factor. A complicating factor is the presence of geological faults within the working area, in the zone of influence of which the absolute gas emission may reach 150-200 m³/min.

3. THE RESULTS OF THE STUDY

Modules of gas emission management have been formed in the working areas of the Kotinskaya mine. The modules have been formed based on the algorithm described above. The proposed gas emission management in the working areas have been designed for the conditions of the Kotinskaya mine of OJSC "SUEK-Kuzbass" with consideration of various methods of mining beds 52, 50 and 49. Each module consists of ventilation and degassing schemes that meet requirements [14, 15] and involves the use of one of the variants of isolated removal of the methane-and-air mixture proposed for these particular conditions, as regulated by the normative documents [16]. Figure-1 shows the layout of the modules based on the scheme of working areas preparation with paired roadways and return-flow scheme of venting the working area. As one can see in Figure-1, with an increase of methane release in the roadways of the working area, various schemes of degassing and isolated removal of the methane-and-air mixture are proposed, whose specific combination is defined by the gas balance in the working area, and by the cost of implementation of the chosen method and degassing scheme in specific geological and mining conditions.
It should be noted that the gas balance in the working areas is crucial for choosing the module configuration variant.

In using the return-flow venting scheme in the conditions of the Kotinskaya mine, removing the restrictions of the load on the mining face by the gas factor is ensured by meeting two conditions:

a) dilatation of the gas emitted from the developed bed by means of ventilation;
b) complete elimination or minimization of income of the methane releases from the mined-out spaces.

The first of these conditions with limited air throughput of the working face may be achieved in several ways:

- by relative reduction of gas emission due to the preliminary degassing of the developed bed;
- by ensuring leaks from the bottom-hole space into the mined-out space due to isolated removal of the methane-and-air mixture, or with the use of degassing wells drilled from the surface.
- The second condition also has several variants:
  - reducing methane release from the accompanying beds in the zone of intense fracturing in the reservoir roof and unloading in the floor of the bed;
  - by ensuring leaks through the mined-out space due to isolated removal of the methane-and-air mixture, or with the use of degassing wells drilled from the surface.

Thus, in the conditions of the Kotinskaya mine, in case of return-flow venting scheme with the use of degassing wells drilled from the surface, the necessary conditions are observed for lifting restrictions by the gas factor under the condition of sustainable operation of degassing wells.

In this case, the necessary condition for abandoning the use of vertical degassing wells drilled from the surface is changing the ventilation scheme in the working area. An example of a gas emission management module is shown in Figure-2.

4. DISCUSSION OF THE RESULTS

We should stress the need for technical and economic comparison of the variants of implementing various configurations of modules for the specific mining conditions, since the scope of application of various methods of gas emission management has both technical
limitations in implementation, and economic limitations in feasibility.

Figure-2. Gas emission management module: 1 - developed bed; 2 - overworked beds; 3 - mined-out roadway; 4 - mined-out space; 5 - degassing well; 6 - mobile degassing unit; 7 - degassing inclined well; 8 – degassing pipeline; 9 - degassing bed well.

In order to determine the economic efficiency of the developed recommendations for ensuring safe and intensive mining of gas-bearing beds 52, 50 and 49 at the Kotinskaya mine, mathematical modeling of technological schemes with the use of various ways of gas emission management in the working area was performed. In modeling, the following methods of degassing the mined-out space were considered: degassing with raise wells from zonal roadways; degassing with inclined wells drilled into the rock cavity from a zonal roadway, and degassing with vertical wells drilled from the surface. The calculations considered the cost of wells drilling and operation. The parameters of the gas emission management were adopted in accordance with the "Instructions for Degassing Coal Mines"[15] and experience in degassing at the Kotinskaya mine. As the economic-mathematical modeling showed, using an additional roadway for air supply or gas-draining is the most costly way of managing gas emission; in addition, it requires additional substantiation. However, the use of this method has significant potential to empower gas emission management by means of ventilation. The level of unit costs of drilling vertical degassing wells is mainly determined by the depth of mining operations and by the distance between the wells. However, with increasing depth of mining operations, the natural methane content in beds increases, too, which results in an increased density of the wells. Thus, with an increase in the absolute gas content in the working area, unit costs of gas emission management in roadways of the working area increase nonlinearly.

5. CONCLUSIONS

According to the results of studies, the following recommendations may be given to ensure intensive and safe preparation and mining reserves in the working areas of gas-bearing coal beds with long working faces:

- The use of multi-roadway preparation of the working areas is essential for intensive mining of reserves in
the conditions of the Kotinskaya mine, since it not only allows to reduce the time of preparation of the working area, but also provides the conditions for successful implementation of degassing schemes and the isolated removal of the of methane-and-air mixture with the use of the wells drilled from the roadways in the working area. Preparation with twin roadways is the main variant; it can be implemented under the condition of observing the requirements to methane concentration in degassing pipelines located in underground roadways.

- The procedure of mining working areas and the direction of air movement in a longwall face in case of using a return-flow venting scheme should ensure the conditions for degassing and isolated removal of the methane-and-air mixture from the mined-out space in the part that is adjacent to the ventilation roadway (the roadway with the outgoing stream) in order to prevent formation of high concentrations of methane in the gotten part of the venting roadway adjacent to the working face.

- The use of comprehensive degassing, including degassing the mined-out space, adjacent beds and the developed bed, is a prerequisite for ensuring methane safety during mining operations in developing the suite of gas-bearing coal beds with natural methane content over 10 m³/t and the daily load on the mining face over 25,000 tons.

- In developing a bed over 3.5 m thick in the suite of gas-bearing coal beds prone to spontaneous combustion, the use of return-flow venting schemes with isolated removal of methane-and-air mixture is the main technically feasible and economically viable method of gas emission management in the working area. Implementation of this method is based on providing air- and gas-dynamic isolation of the bottom-hole region of the longwall face from the mined-out space by controlled removal of part of fresh air entering the working face. Efficiency of aerodynamic isolation of bottom-hole region is primarily determined by the following factors: longwall face length, permeability of the mined-out space, parameters of extraction pillar preparation, the method of degassing and its parameters.

- The prerequisite for intensive and safe mining coal beds over 15,000 tons with the use of return-flow venting scheme is the use of isolated methane removal from the mined-out space through wells drilled from the surface at the distance of 40-50 m from the ventilation roadway and the belt road with the distance between them not more than 60 m.

REFERENCES


Journal of Mining and Safety Engineering. 24(4): 409-413.


