Analysis of ways to reduce the risks of ignition of coalbed methane

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Abstract. The paper presents data on the explosion hazard of methane under different conditions, taking into account the change in its concentration. The main emphasis is on the analysis of methane ignition conditions during drilling and blasting operations. Methods for determining the amount of methane released into the atmosphere during these works are analysed, as well as other factors that determine the conditions for the formation of hazardous situations and negative environmental (climatic) consequences. In addition, the mechanism of coal ignition during methane combustion is analysed. The most dangerous concentrations of oxygen and methane are revealed. Key trends in reducing gas emissions and determining their amount are identified. Measures in the field of environmental protection and integrated development of the Earth's subsoil are proposed.

1. Introduction
The deepening of mining operations determines the increase in the gas content of coal seams and, as a consequence, an increase in gas release. At a depth, this factor is important both in the underground and in the open-pit coal mining, especially during drilling and blasting operations (DBO), since there is a danger of ignition of the emitted gas.

The first cases of methane ignition during blasting operations at the Bachatsky open-pit mine were noted at a depth of 80-100 m from the surface [1]. During mining operations at depths of 150-200 m, there were cases of ignition of gases with a column of flame up to 50-80 m and further combustion in the area of destroyed coal. These phenomena were recorded practically near the border of the methane zone, corresponding to the gas content of the layers in 5 m³/t. The gas content of coal seams at depths of 340-370 m is 20-21 m³/t. Therefore, unlike most other open pit coal deposits, the Bachatsky coal deposit has significant coal bed methane resources.

After that, cases of breakage of detonation of borehole charges of industrial emulsion explosives were recorded. It was revealed that these charges burned out at depths of 16-22 m and in borehole diameters of 140-295 mm. The cliff occurred at a distance of 1-2 m from the militant.

Due to the fact that DBO were carried out in rocks prone to the release of flammable gases, in particular methane, this creates a risk of its ignition and imposes increased requirements on the quality of DBO [2]. It is important to note that as a result of DBO, there is a small amount of losses of unrecovered resources. They depend on the formation of fine sludge and dust, scattering of individual pieces of rocks and dilution. For coal, these losses have not been determined. But data on cement can be cited. Thus, losses of 0-0.5 % of balance reserves are permissible for it, when in some cases this value reaches 0.79 % [3].
In this regard, it is necessary to analyse the ways to reduce the negative impact of coal gas ignition on the industrial safety of mining operations and the ecological state of the environment. The purpose of this study is to systematize the main scientific works in this area and determine the most effective ways to reduce the negative impact on the environment of blast-cleaning processes.

2. Methods
For the research, theoretical methods of cognition were used. At all stages, the accumulated theoretical base in the field of studying the flammability of coal mine methane, reducing its negative impact on the environment, mainly during DBO, was analysed. The data obtained were united into a single system. In addition, abstraction was used in a few cases. Some works were focused on slightly different issues. This required a distraction of some parameters that were considered secondary in this study.

To obtain data on the concentration of methane in the mixture released from drilling and blasting wells, an experiment was carried out directly on the territory of a coal mine.

3. Results
During DBO, a network of wells is drilled. Explosives are laid in them, which subsequently explode. These explosions should be viewed as a single source. They form a dust and gas cloud (DGC). When assessing the damage to the environment, the blasted rock mass (BRM) and DGC are calculated separately [4]. The amount of pollution depends on: 1) the amount of explosives, taking into account the types used, 2) volume of BRM, and 3) type of rocks [5].

The lack of extraction of rocks and coal occurs for geological, mining, technological, and economic reasons. The amount of losses depends on the structure of the field, the conditions of occurrence, the strength and stability of rocks, and other qualitative features of the formation [6].

During DBO, there are several main factors affecting the losses. Formation of fine dust during drilling pollutes the atmosphere in the form of DGC. During the explosion, individual pieces of rock are scattered by 300-400 m [4]. Moreover, part of the rock is over-crushed and fine particles are formed. Loss or dilution occurs also while contacting with solid waste rock.

3.1. Analysis of the concentration of gases in the mixture emitted from the blasthole wells and its intensity
To determine the absolute indicators of gas release from the wells, measurements were taken in a number of blast holes drilled through the coal seams. The experiment was carried out using a device to estimate the volume of gas released from the massif through the well. This rig was designed for wells with diameters of 276 mm and 216 mm (while changing the size of the cone on the casing pipe with a diameter of 200 mm).

![Figure 1. Intensity of gas release from the well, l/m.](image-url)
The intensity of gas release in the cased hole was measured using a flow meter. The specific consumption of the gas mixture has increased (Fig. 1). This refutes the initial assumption that immediately after the explosion of the block in the wells located in the immediate vicinity, the inflow should sharply increase, and then gradually decrease, due to a fairly rapid process of natural degassing of the rock mass.

The concentration of methane and carbon dioxide in the mixture released from the massif was estimated by the express method using a gas analyser. As shown by field experiments, for the complete displacement of air from the well in the case of installing a 1.5-meter casing, it takes about 2 hours, after which fluctuations in the concentration of methane and carbon dioxide are not observed (Fig. 2). Field measurements show that the following composition is characteristic of the emitted gas: methane – 94.1 %, carbon dioxide – 0.06 %, the rest is nitrogen.

![Figure 2. Change in the concentration of methane in the gas mixture, %.

3.2. Analysis of ways to reduce the risk of methane ignition during blasting

International experience shows [7] that control of methane concentration in the immediate vicinity of the wellhead is the most important condition for ensuring the safety and environmental friendliness of mining operations. The control schematic diagram should include a gas analyser sensor that transmits information to the analytical system at the rig. The drilling operator, receiving concentration data near the well, will be able to change the rate of penetration of the well and the intensity of the blowdown to prevent the risk of methane ignition.

Explosives with protective properties, such as ugenites, can be used to reduce the risk of methane fires [8]. New explosives should provide a reduction in the risk of ignition of the gas mixture through the use of safety capabilities and the release of borehole charges, as well as high detonation ability.

It is important to note that safety is specific and requires certain conditions. In addition, different substances provide different characteristics. Powdered explosives provide better stemming. Water-based explosives give stable detonation. And the elimination of TNT increases the environmental friendliness of the blast-hole.

To increase the recovery of methane and reduce its amount involved in an explosive mixture, it is necessary to use degassing [9]. All methane recovery methods have different efficiency and applicability at different stages of mining operations.

4. Conclusion

In the course of the study, it has been found that the flow rate of gas coming out of coal and rock is unstable and cannot be predicted. At the same time, there is a risk of interaction between explosion products and coalbed methane. Given the instability of the explosive mixture, there is a possibility of methane ignition.
The process of BRM expansion is also accidental. The only way to reduce the amount of BRM is the rational use of explosives. It is important also to use individual schemes of location and detonation of charges for each field [10].

A dust-gas-air mixture is formed in the well, which creates additional costs when calculating the blasthole parameters [11]. To reduce the adsorption of gases, it is proposed to use moistening of coal and surrounding rocks, as well as to carry out degassing.

Another equally effective way to reduce the risk of methane ignition is the use of safety explosives. It can be concluded that the use of uglenite has a greater effect in reducing the risk of methane ignition. However, the use of various explosives of substances is not always suitable in specific situations. Whereas moistening the coal seam and host rocks is a universal technique and should be applied on a regular basis.

To account for methane emissions from the surface, it is important to note some uncertainty in this direction. There are no clearly declared methods to perform this operation. At the same time, relatively little gas is released from the blasthole well, which means that the instruments usually used in these cases in the oil and gas sector are not suitable. The use of an Orifice instrument or an outburst forecast one is recommended [12].

Thus, it should be concluded that further research is needed in the field of reducing resource losses during blasting and accounting for gas emission from the surface. In the area of reducing the risk of methane ignition, there are several methods, but they are specific and require individual analysis at a specific location for blasting.

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