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## Complex Extraction of Methane and Coal from Thick Coal Seams.

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### ABSTRACT

High methane content in coal seams and adjacent rocks influences negatively the efficiency and the safety of underground mining operations. Coalbed methane can be recovered with gas draining systems and then utilized as an additional energy feedstock. The problem although is present because modern mining methods do not provide sufficient technological capabilities to carry out full-scale coalmine methane recovery. We discuss the problem in this paper and propose technologies which can be used to separate processes of coal mining and coalbed methane extraction.

**Keywords:** coalbed methane, methane recovery, complex extraction, coal seams, Kuznetsk Basin.

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**INTRODUCTION**

The long experience of exploitation of gas-bearing coal deposits in Russia, Ukraine and Kazakhstan shows that coalbed methane release grows as mining depth increases at coalmines (figure 1). In recent decade, gas emission in coalmines has reached 30-40 m<sup>3</sup> per ton of withdrawable coal.

More than 95% of exhausted methane are discharged into the atmosphere during coal seams development. Total volume of methane emission in Russia is 2.5 billion m<sup>3</sup>/year; about 1 billion m<sup>3</sup>/year is discharged through gas-draining and degassing systems, and only small volume (about 70 million m<sup>3</sup>/year) is used as energy feedstock.

Kuznetsk Basin is one of the most perspective basins for production and industrial usage of coalbed methane. As estimated by long-term scientific research and geological surveys, methane resources at Kuznetsk Basin amount to 5-6 trillion m<sup>3</sup> to a depth of 1,200 m, and to 13 trillion m<sup>3</sup> to a depth of 1,800 m. The most considerable volumes of these resources are concentrated at Erunakovsky, Tom-Usinsky, Tersinsky and Leninsky deposits [1, 2, 3].

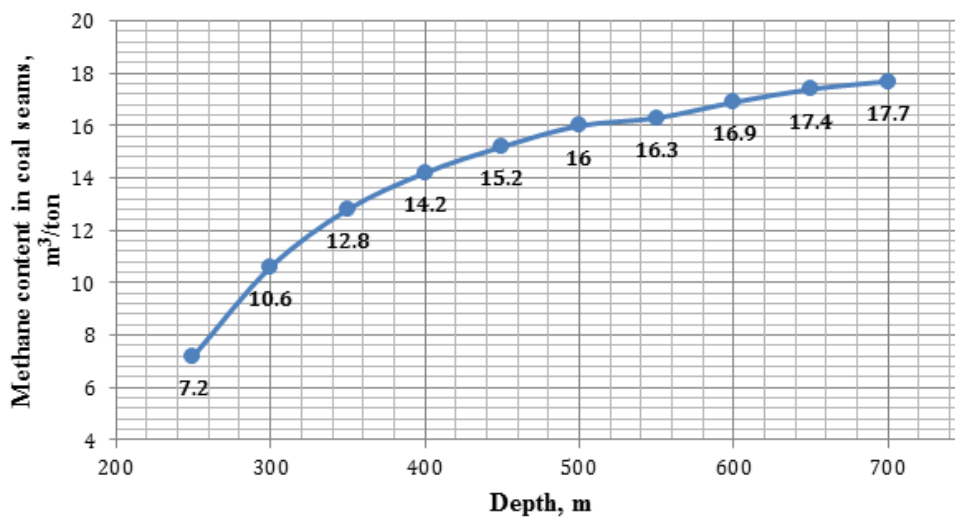


Figure 1: Increase of methane content in coal seams with depth (generalized graph for Kuznetsk Basin)

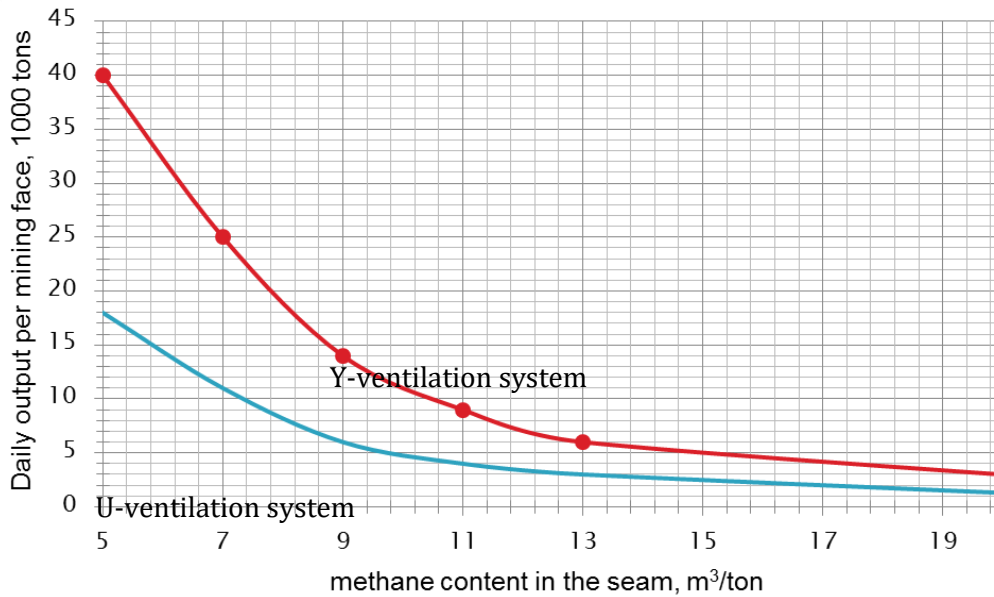
Table 1: Coal mines, extracting thick coal seams with high methane content (Kuznetsk Basin)

Mine	Year of construction	Operational depth, m	Seam thickness, m	Annual capacity	Mine rating of gas hazard (relative methane-bearing capacity)
“Polysaevskaya”	Reconstructed in 1987	430	2.4	1,71 million tons/year	Very Gassy Mine (more than 15 m <sup>3</sup> CH <sub>4</sub> /ton)
“Kirova”	Reconstructed in 1989	240-410	2.2	3,73 million tons/year	Very Gassy Mine (more than 15 m <sup>3</sup> CH <sub>4</sub> /ton)
“Kotinskaia”	2004	350	4.3	4,50 million tons/year	Third Category (10-15 m <sup>3</sup> CH <sub>4</sub> /ton)
“7 Noiabria”	1988	25-300	4.6	2,90 million tons/year	First Category (up to 5 m <sup>3</sup> CH <sub>4</sub> /ton)
“MUK-96”	1996	250-350	3.5	1,83 million tons/year	Very Gassy Mine (more than 15 m <sup>3</sup> CH <sub>4</sub> /ton)
“Komsomolets”	Reconstructed in 1987	300-400	2.8	2,45 million tons/year	Very Gassy Mine (more than 15 m <sup>3</sup> CH <sub>4</sub> /ton)

These deposits are characterized by relatively favorable geological and mining conditions, which ensure high production rates of operating mines (table 1). High-capacity extractive equipment used at these mines can provide the output per mining face up to 500,000 tons per month and more. However, mining

depth increases throughout the Kuznetsk Basin, so does the coalbed methane content. Increasing methane content constrains the output due to ventilation requirements (so called “gas factor”).

The dependence between output per mining face and methane content in a coal seam is shown on figure 2. U-ventilation system is typical for coalmines developing flat and thick seams. As seen from the graph, high mine capacity cannot be maintained without gas drainage operations if gas content is more than 8 m<sup>3</sup> per ton.



**Figure 2: The dependence between maximum output per mining face and methane content in the working seam (generalized graph for Kuznetsk Basin)**

Methane bleeding off from the coal into the underground excavations is one of the most dangerous production factors impairing efficiency significantly (table 2); on the other hand, it is lost irrevocably as an energy feedstock. In addition, methane pollutes the atmosphere severely as it is even more harmful than carbon dioxide in the context of greenhouse effect.

**Table 2: Major methane explosions at Russian mines (Kuznetsk Basin)**

Date	Mine	Fatality
01.12.1992	Sheviakova	25
02.12.1997	Zyrianovskaya	67
21.03.2000	Komsomolets	12
16.06.2003	Ziminka	12
10.01.2004	Sibirskaya	6
10.04.2004	Taizhina	47
28.10.2004	Listviazhnaya	13
09.02.2005	Esaulskaya	25
19.03.2007	Ulianovskaya	110
24.05.2007	Ubileinaya	39
08.05.2010	Raspadskaya	91
20.01.2013	Shahta #7	8

**METHODS**

The problem can be solved if powerful gas drainage systems are introduced for both working seam and goaf areas [4]. Such systems should be designed to maximize methane debit and concentration. Captured methane should be later used as an independent energy feedstock. We discuss the specifics and present a conception of such gas drainage systems in the given paper.

## RESULTS AND DISCUSSION

Currently there is no long-term conception for designing and introducing gas drainage systems in Russia [5]. Coalmine methane is not considered an important natural resource as petroleum or natural gas. Adaptation of appropriate gas draining technology and proper industrial equipment as well as presence of ample resources would allow the coalmine methane to become an important part of Fuel & Energy Balance of coal-bearing regions in the near future. However, unlike in other countries, there is no legal basis for widescale commercial production of coalmine methane in Russia nowadays, and it hinders attraction of investments.

At the present moment, gas draining operations are carried out at several enterprises at the Kuznetsk Basin. They involve (figure 3) draining methane from the coal seam prior to mining (pre-drainage); removing gas from live goaf areas with vertical boreholes drilled from the surface; removal of the methane-air mixture through the pillar; draining methane from the goaf with boreholes drilled from the parallel drift (post-drainage).

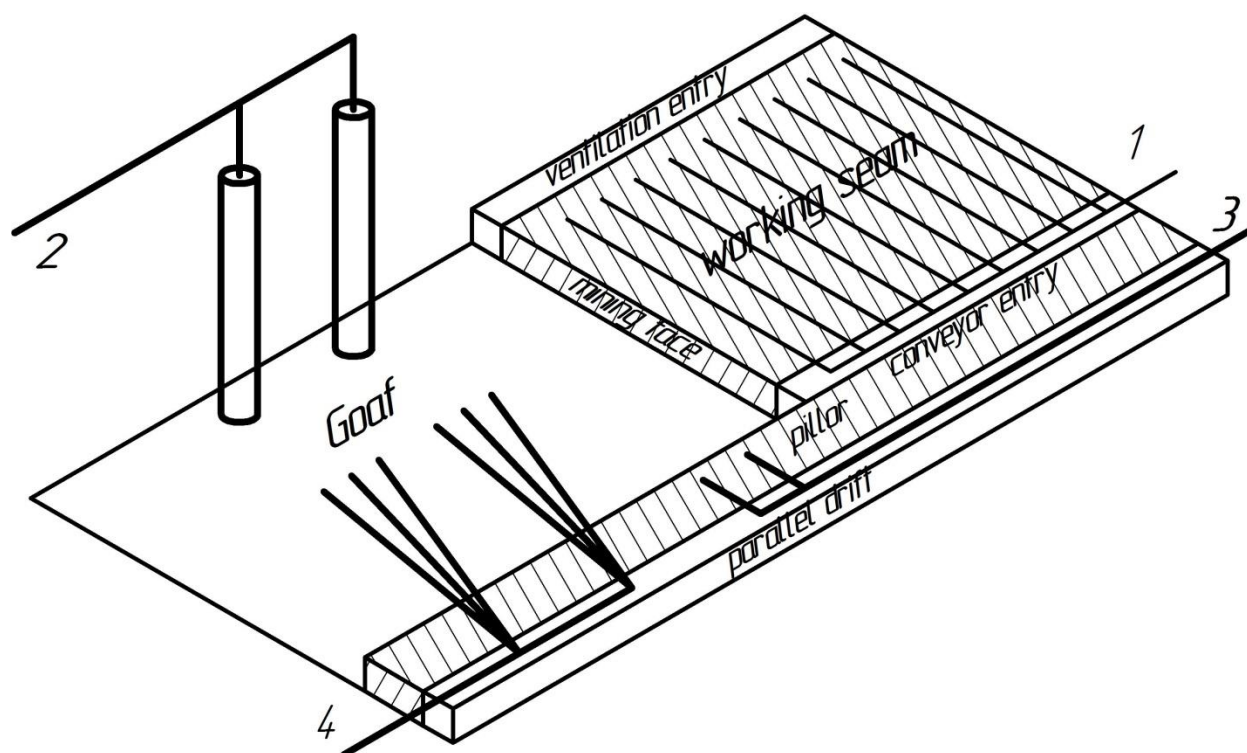
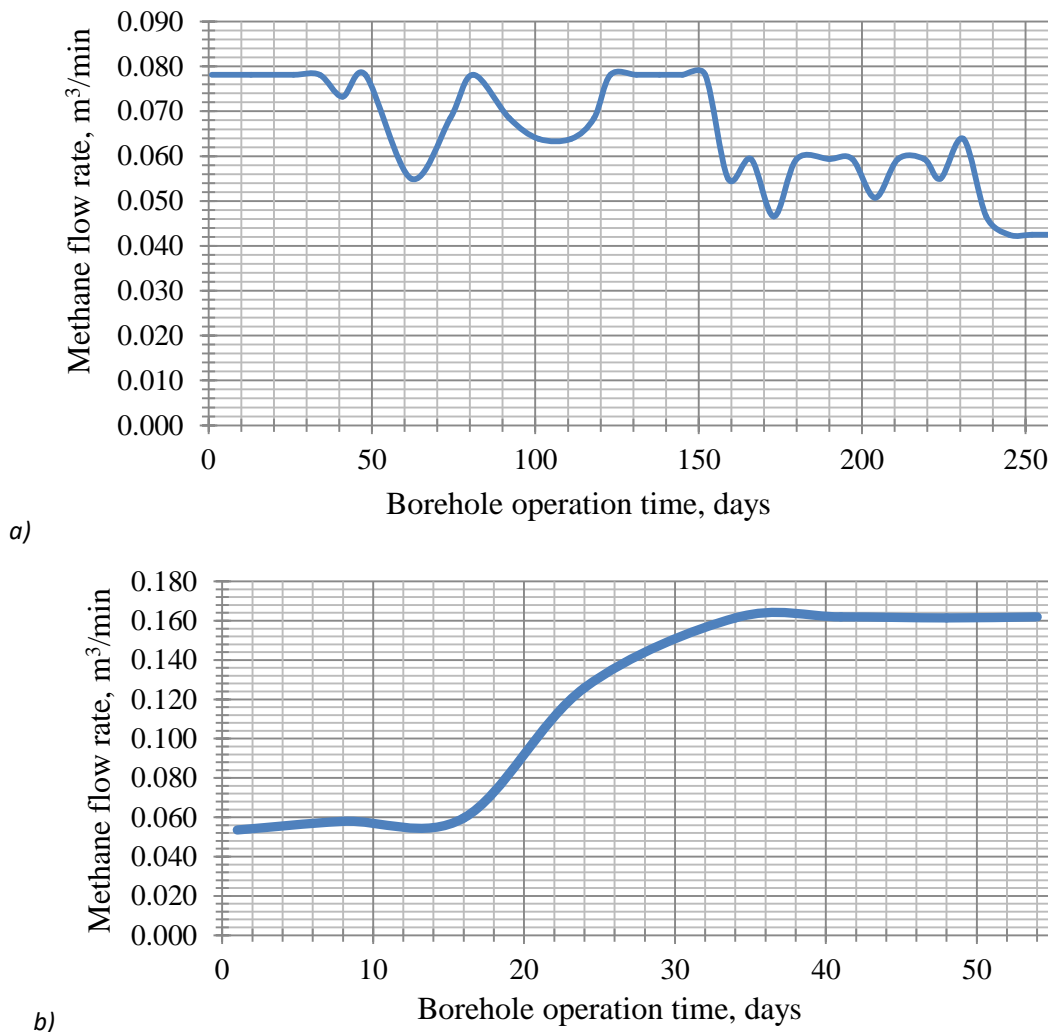


Figure 3: Complex gas drainage system of a longwall panel

1– working seam degassing, 2 – goaf drainage with surface boreholes; 3 – removal of methane-air mixture through pillar, 4 – goaf drainage with boreholes drilled from the parallel drift.

The bulk of the coalbed methane is extracted through the holes drilled from the surface and the parallel drift, which are connected to the pipe range behind the longwall face. However, concentration of methane extracted by such means is much lower than during seam degassing. This factor creates additional problems in terms of captured methane utilization.

Methane flow rate through individual boreholes is shown on figure 4. Two graphs show methane release rates through the borehole for a coal seam drainage (figure 4, *a*) and through the borehole for a goaf drainage (figure 4, *b*). The first borehole operates approximately 255 days; the total amount of captured methane is about 24 thousand cubic meters, which is nearly 20% of initial amount of gas contained in the coal seam. The second borehole operates only 55 days, but the total amount of captured methane is about 11 thousand cubic meters, which accounts for much larger volumes of captured pure methane. However, the concentration of methane in the methane-air mixture in the second case is 10-15 times less than in the first case and is unsuitable for use at power stations.



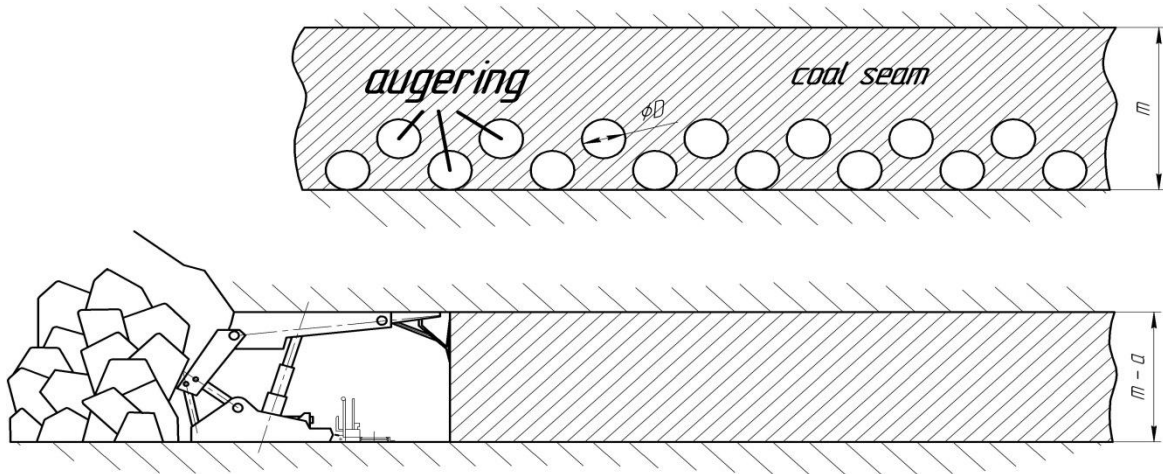
**Figure 4: Methane flow rate through individual boreholes at the “Kirova” mine  
a) coal seam drainage borehole; b) borehole for goaf drainage drilled from parallel drift**

Operational experience of gas-draining systems has shown that there are two main problems of implementing widescale commercial methane recovery. The first is low gas-recovery ratio for coal-bearing massifs and the second is “subordination” of the process of methane recovery to the process of coal mining. In other words, gas-draining technologies are adapted under coal mining technologies [6]. Besides, there are other problems such as the absence of proper amounts of gas-draining equipment, insufficient pipelines and limited lead-time and operation period of installed gas drainage systems due to technological requirements of a particular mining method being implemented at a coalmine. Operational parameters of a gas drainage system also depend on a mining method (concentration and debit of a methane-air mixture, boreholes exploitation periods, their connection and shutdown time, etc.)

One of the ways to address the discussed problem is to allocate the gas drainage process into a separate process of extraction of coalbed methane. But since coalbed methane extraction is deeply connected with coal seams mining, it is more appropriate to consider an integrated (not separated) mining of these types of fuel (as well as their complex design). In this case, extraction of coalbed methane still will be subordinated to the coal mining; however, if sufficient operational time is provided, gas drainage processes will become an independent cost-effective production [7, 8, 9].

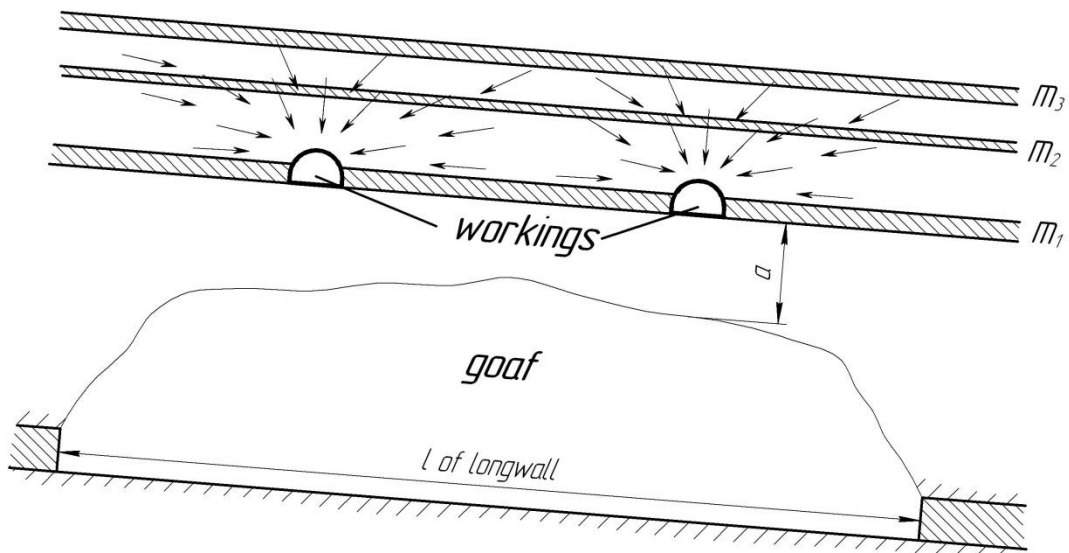
One of the possible schemes for the maximum extraction of coalbed methane is presented on figure 5. The panel is developed in advance before longwall mining starts. The boreholes with a diameter of 500-700 mm are drilled parallel to the seam bottom in a “chessboard manner” by an augering machine positioned in a

panel entry. As a result, coal seam starts to break down under rock pressure, and numerous fissures and pores begin to open and widen. The degassing of the distorted coal seam should then be started. It is estimated, that this would allow extracting up to 90% of methane contained within it [10]. After a period of time, the coal seam will “settle down”, and its extraction by a conventional longwall mining method will become technologically feasible again.



**Figure 5: Softening thick coal seam with large-size holes to intensify gas recovery**  
 $m$  – seam thickness;  $a$  – shrinkage of the seam after a period of time.

Another scheme is designed to recover methane from adjacent seams (figure 6). One or more roadways are developed in the underworked adjacent seam in advance of mining works. The distance  $a$  between the entries and the working seam must be long enough to prevent aerodynamic connection between entries and the goaf. Before mining starts, the entries are sealed and depressurized. Undermining of the rock strata would drastically increase rocks filtration capacity, and methane would start to leak into the entries. As an alternative variant, boreholes can be drilled from the entries to the mined-out space and then sealed, while the entries stay unsealed.



**Figure 6: Gas drainage from undermined adjacent seams.**  
 $a$  – distance between the entries and the working seam;  $l$  – longwall length.

**CONCLUSION**

We considered a few possible technologies to improve coalbed methane recovery at the operating or planned coalmines. It is necessary to point out that if new legislative framework is created and coalbed

methane is included in All-Russia Classifier of Products as a separate useful mineral, large-scale implementation of gas drainage technological schemes will be greatly accelerated. Pre-drainage of coalbed methane will not only provide additional energy feedstock, but also will increase effectiveness of underground coal mining (in terms of production rates) and reduce environmental impact in mining areas.

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