Methane utilization in the Karaganda basin

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Abstract: The mines of the Karaganda basin develop coal seams that are very gas-rich in methane and liable to sudden emissions of coal and gas. The mining of one ton of coal is accompanied by the methane emission from 30 to 45 m$^3$ of into the mine workings, therefore, special attention is paid to the issues of reducing the methane content to safe values in the mining areas and its utilization. The gas content of mine working areas ranges from 30 to 100 m$^3$/min or more. The increase in air supply to the site is limited by the air speed limit and the rational, from an economic point of view, cross-section areas of the mine workings.

The methane of the developed coal seams is not only a source of danger, it can be used to generate heat and generate electricity.

The start of methane utilization in the Karaganda coal basin dates back to 1975, when methane was used at the mine named after the 50th anniversary of the October Revolution in the boiler ЂКВР-10/13 according to a project developed by the Donetsugileavtomatika Tr.

The prerequisites for the development of utilization were the development of degassing of coal seams. Methane removal by vacuum pumping stations in 1970-75 reached 200 mln.m$^3$ per year, and a significant part of the total amount was conditioned methane with a concentration above 25%. During these years, the degassing networks were reconstructed, and vertical slot burners for boilers were developed that made it possible to switch to methane combustion instead of coal and vice versa without any problems.

All methane utilization works are based on the economic feasibility of using recoverable methane as an additional energy resource.

The heat energy equivalent of 1 ton of coal is approximately 510m$^3$ of methane. The average daily consumption of coal in the boiler DKBR -6.5/13 is 22 tons, and in the boiler KBTC 10, with which almost all our boiler rooms are equipped - about 50 tons. Thus, in these boilers, 8,000 and 18,000 tons of coal are saved annually, using methane as an additional fuel. In addition, when burning 1 ton of coal, approximately 35 kg of dust, 4 kg of SO$_2$, 9 kg of CO, 1.5 kg of NO are emitted with a normally working cleaning system. Methane combustion products are water and carbon dioxide.

The process flowsheet for methane extraction is shown in figure 1. On average, 1.9 mln.m$^3$ of methane is extracted annually by the D$_6$ seam degassing in advance, in total about 130 mln.m$^3$ by means of degassing of which 20 mln.m$^3$ are disposed in the boiler rooms of mines. Main ventilation fans emit an average of 260 million m$^3$ of methane annually.
In the mines of the Coal Department, methane, extracted by means of degassing, was mainly used in boiler houses. At the end of 2011, a gas generator with a capacity of 1.4 MW was installed at the Lenin mine, which uses methane in admixture with a concentration of 30% or more. This methane is capped from the mined-out space of working areas using vertical wells drilled from the daylight surface.

The process flowsheet for the supply of coalmine methane to the consumer, regardless of the type and volume of equipment accepted in it, should be designed to ensure the following functions:

- supply of coalmine methane from the ANS gas collectors to the consumer, maintaining the gas pressure supplied to the consumer at a given level and protecting the ANS equipment and the consumer from excessive gas pressure;
- automatic shutdown of gas supply to the consumer and its discharge into the atmosphere when the controlled parameters of the equipment go beyond acceptable limits,
- gas dehydration;
- control, management, protection, automation.

**Figure 1.** Flowsheet of methane extraction in mines of the Coal Department of AMT JSC.

The general block diagram of the supply of coalmine methane to the consumer is presented in figure 2.

**Figure 2.** Block diagram of the methane supply.
The coalmine gas-methane is fed from a gas-emission sources to a vacuum pumping station. Then it enters the gas preparation plant, where moisture is separated from the methane-air mixture. Pre-dehydrated gas through the discharge gas pipeline enters the protection unit, where the gas supply to the consumer is automatically shut off when the methane-air mixture (pressure and methane concentration) deviates from the set parameters and is vented to the atmosphere. After the protection unit, coalmine methane is supplied to the consumer, where it is directly burned.

The process flowsheet of coalmine methane supply to the consumer is presented in figure 3, which shows:

- gas pipeline 1 from the ANS,
- gas pipeline 2 of the consumer,
- overpressure valve 3, which maintains the gas pressure at a predetermined level and protects against pressure increase. The upper pressure limit of the gas supplied to the consumer is determined by the setting of the overpressure valve,
- electrically-driven gate valve 4, which serves to discharge the gas-air mixture into the atmosphere in case of emergency violations of the operating mode of the equipment and protection operation (valves "per candle"), the same valve 9,
- moisture separators 5, used to remove droplet moisture carried away by the gas stream from the vacuum pumps. The same moisture separator 10,
- electrically-driven gate valve 6, which closes the gas supply to the consumer in case of emergency violations of the operating modes of the equipment (valve "per consumer"),
- high-speed locking device (shutoff valve) 7 and 11, which is the actuator of automatic protection. With a high-speed device 7, the valve 6 and the valve 4 are blocked. With the device 11, the valve 9 is blocked, the condensate drain line 3.

Figure 3. Process flowsheet of gas-methane supply to the consumer.

Pressure regulator 3, gate valve 4 "per candle", valve 6 "per consumer", moisture separator 5, shutoff valve 7 and gas pipelines and condensate lines connecting them form gas preparation plants PP. The gate valve 9, the moisture separator 10, the shutoff valve 11 and the gas pipelines and condensate lines connecting them form a protection unit (PU).

It should be noted that conditioned methane with a concentration in the methane-air mixture of more than 30% is obtained mainly from the mined-out space, where methane from the unapproachable part of the developed seam, from the grists and from the host rocks comes as a result of discharge. In rare cases, it is possible to use methane extracted by preliminary degassing wells. For example, at the Lenin
mine in 2013, for a long time it was possible to supply the boiler room with gas-methane with a concentration of about 30% in the mixture extracted by embedded wells drilled along D6 seam. However, maintaining such a concentration in the gas pipeline to embedded wells is an extremely laborious task.

The use of methane of the vertical wells or gas drains is much preferable since it is contained in the mined-out space much more in a free state.

The materials of table 7 show that when mining the southern block of the K10 seam at the Abayskaya mine, the main part of the conditioned methane 82.1 m³/min accounted for vertical wells and gas drainage. When mining the northern block, the methane rate by vertical wells and gas drainage averaged 88.9 m³/min.

The KVTS-10 boiler is installed at the Abayskaya mine. The boiler room was converted to gas-methane in 2003. The gas consumption of the boiler is 20 m³/min. The boiler room is supplied with a methane-air mixture through a central vacuum pumping station equipped with gas preparation equipment (figure 4). Gas pipelines are installed behind the brattishes of gas drainage drifts, passed along the K11 seam. Methane removal is carried out from the mined-out space of working longwalls along the K10 seam.

In total, about 29 mln.m³ of methane was utilized during the operation of the boiler room, which is equivalent to 59 thousand tons of coal, CO₂ emissions were reduced by 0.5 mln.t.

Despite the fact that, as a whole, in the AMT JSC, the volumes of utilization of methane extracted by means of degassing do not decrease, having reached a certain level since 2003, while only about 30-35% of all methane mined is used.

For example, at the Abayskaya mine, on average only about 25% of conditioned methane is used for utilization during the work of working areas along the K10 seam.

However, increasing the volumes of utilization is associated with a number of difficulties, namely:

- dispersion of vacuum pumping units with different concentrations of methane in the mixture over the wide area;
- lack of means for transporting methane-air mixture over a distance of more than 1.5 km;
- the absence of gas compressors for supplying methane through the network, since vacuum pumps have a low ability to discharge (0.3 - 0.4 atm);
- lack of the possibility of stable gas supply in view of the periodicity of the work of gas longwalls in mines.

A wide range of mining-and-geological and mining-engineering conditions of occurrence of coal seams, their sorption ability, and gas permeability inhibit large-scale commercial mining of gas-methane without the use of special technologies for activating embedded gas recovery.
The use of conditioned methane in the mines of the coal department to generate electricity has so far been not economically viable in its pure form due to the high cost of the plants, the low price of electricity in Kazakhstan and the payback period of 10 years or more. However, lately much attention has been paid to reducing methane emissions into the atmosphere, and the implementation of carbon quotas will allow economically recouping some methane utilization projects.

Given the specific conditions of gas supply and analyzing the proposed technologies and equipment, preference should be given to technologies and equipment, which are mobile, block-modular designs, equipped with rotary vacuum pumps and a gas preparation system for supplying gas to methane utilization plants. It is advisable to use gas generators of small capacities up to 3 MW, because the generated electricity and heat will be used locally inside the facilities of mines [1].

So, at the Lenin mine in 2011 a gas generator with a capacity of 1.4 MW was installed, which is included in the mine network. Its gas supply is carried out through the methane removal from vertical wells in the working areas of the mines named after Lenin and "Kazakhstanskaya". The generator has a block-modular design and can be easily moved to the desired point in the mine field.

The mines of the Karaganda basin develop coal seams that are very gas-rich in methane and liable to sudden emissions of coal and gas. The mining of one ton of coal is accompanied by the methane emission from 30 to 45 m³ of into the mine workings, therefore, special attention is paid to the issues of reducing the methane content to safe values in the mining areas and its utilization [2].

The gas content of mine working areas ranges from 30 to 100 m³/min or more.

The increase in air supply to the site is limited by the air speed limit and the rational, from an economic point of view, cross-section areas of the mine workings.

In this regard, measures aimed at preventing, reducing or redistributing methane emissions within mine workings are and will be increasingly used in coal mines.

Gas emission control is based on the use of ventilation and degassing, the ratio between which is determined by the gas content of mine workings and the mined-out space.

It should be noted that in accordance with the structure of the gas balance at the mines, practically all known methods of degassing are used in the industry, which made it possible to increase the productivity of coal mining.

Over the past few years, the load on the working faces, which was unprecedented for the Karaganda basin, of the order of 5–7 or more, up to 17.5 thousand tons per day, made it possible to organize work in the coal department according to the mine – longwall scheme. Today, longwalls with a millionth load are operating at each mine, and 8 working faces provide 70% of the coal department's output [3].

At the same time, the concentration of mining operations led to 2–5 times increase in the absolute gas content of the working areas, reaching 100–150 m³/min. This problem can be solved by using a complex of degassing methods with a stable efficiency of 65-80%, accompanied by the reconstruction of mine degassing systems and an increase in the volume of work on drilling wells and installing large diameter gas pipelines. At the same time, the volume of methane recovered by means of degassing in comparison with 1997 increased 2.5 times. So, at the mine “Shakhtinskaya” during mining of 32 Д6-у longwall with mining up to 7 thousand tons per day, gas content of the longwall was 120 m³/min. This required the use of the following degassing methods: preliminary embedded, advanced embedded, wells above the collapse domes, vertical wells from the surface, isolated methane removal due to a brattish with a total methane removal by degassing of 90 m³/min. About 5 km of a 325 mm diameter gas pipeline was laid, 600 embedded wells and wells above the collapse domes were drilled. Seven vacuum pumps worked for the working area.

At the Abayskaya mine, during mining of the Кb10 seam with 321K10-9о, 33K10-c longwalls, the gas content of the working areas reached 155 m³/min. To ensure safe operation by the gas factor, 4 degassing methods, 6 vacuum pumping stations, about 4.5 km of gas pipelines were used, and the degassing efficiency reached 82-87%.

The coal department is working on the utilization of methane recovered by means of degassing. Gas use volumes increased from 1.5 million m³ in 1996 to 15 million m³ in 2014. During this period, in addition to the Kostenko mine, boiler houses were commissioned at the Lenin, Shakhtinskaya and
Abayskaya mines. In 2011, a gas generator operating on coalmine methane was installed at the Lenin mine.

The coal department of AMT JSC makes significant efforts to increase the growth of methane utilization volumes and reduce its emissions into the atmosphere, as well as consider other modern technologies that can be a solution to the problem of using gas extracted by ventilation means, the annual volume of which is about 300 million m$^3$ or 3.6 million tons in carbon equivalent [4].

The main scientific points:

- regularities of changes in gas content (methane) of the K$_{10}$ seam with a depth of occurrence through the wells drilled in the seam;
- developed the principle of interpretation of the regularities of change in the gas content of coal seams depending on the pressure of overlying rocks acting on them;
- the factors determining the gas content of the coal-bearing stratum (sorption capacity, gas pressure and gas permeability) were determined [5].

Research Methods. The solution of the allotted task was carried out by experimental observations of the gas content of coal based on the results of measurements in samples; statistical processing; and studies of the regularities of changes in gas content at different points in the seam, relative to the mine workings, as well as from the seam depth [6].

The scientific novelty of the work is as follows:

- the regularities of changes in the gas content of coals from the stress-strain state of the seam are determined;
- a higher gas content of the northern wing of the K$_{10}$ seam of the Abayskaya mine field (18-19 m$^3$/t) was determined, compared with the southern section (14.5 m$^3$/t), while the gas recovery of the K$_{10}$ seam of the southern wing significantly exceeds that on the northern wing;
- On the basis of the “Classifier of methane content of coal seams of the Karaganda basin”, a methodology for determining is developed [7].

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