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DOI: 10.31643/2025/6445.33

Earth Sciences

Evaluation of modern methods and techniques for calculating parameters during coal bed degassing

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Received: *August 7, 2024*
Peer-reviewed: *August 8, 2024*
Accepted: *August 26, 2024*

ABSTRACT

The modern strategy for the development of underground coal mining in the Karaganda basin provides for the development of the concept of reforming the mining fund, ensuring a high level of concentration and intensification of mining operations with increasing the load on the treatment face to 5-6 thousand tons per day. At the same time, the main deterrent factor is the high methane content of the coal seams of the basin, which reaches 30-40 m3/t of coal. The high gas content of the coal seams being developed and their satellites is one of the main causes of methane explosions in mines, leading to violations of the technological regime and irretrievable loss of life. The problem of degassing minefields has always been and is among the priority areas that require prompt solutions. Gas dynamic phenomena and sudden methane emissions are accompanied by human casualties, and large material and financial losses, and are 25-30% of the cause of the total number of accidents that occurred in coal mines of the CIS countries in the last decade. The article evaluates progressive methods of degassing high-gas-bearing, explosive formations to reduce the methane content and ensure the safety of the operation of coal mines in the Karaganda region, taking into account modern experience and achievements in this field.

Keywords: *methane, gas flow rate, gas output, methane abundance, coal mines, degassing, mining technology, minefields, gas dynamic phenomena, formation.*

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Introduction

The mine gases of the coal seams of the Karaganda coal basin contain methane, carbon dioxide, nitrogen, hydrogen sulfide, hydrogen and heavy hydrocarbons. The Dolinskaya and Karaganda formations are characterized by the highest gas content. At depths of more than 400-500 m in the Karaganda basin in the developed formations of the Karaganda formation, the amount of gas reaches 22-25 m^3/t, increasing in the Sherubainurinsky and Tenteksky districts to 25-27 m^3/t. The methane content of coal seams increases with the depth of their occurrence [1].

Unlike oil and gas reservoirs, most coal seams are characterized by lower values of natural porosity, filtration and diffusion permeability. The natural permeability of coal seams is low and in the conditions of the Karaganda basin, it is (10-50)×10-4 milliDarsi (mDa) [2].

The deeper the coal seams sink into the subsurface, the more gas they contain, but at the same time, their gas permeability and methane flow rate from drilled degassing wells decrease. In this regard, there is a need for artificial directional effects on coal seams to intensify their gas recovery. These include such methods as hydraulic fracturing (sufficiently high methane production rates from hydraulic fracturing wells have been recorded – up to 5-7 m^3/min), hydraulic fracturing, hydrochloric acid treatment (a decrease in the gas content of mine workings by 30-70% has been achieved), torpedoing in wells, hydraulic pulse treatment, interval fracturing and several other modifications of the intensifying effect for the growth of coal gas recovery [3].

Currently, an integrated method of artificial degassing has been developed and implemented at the mines, including the simultaneous use of several methods and schemes of degassing from methane sources: preliminary degassing of the reservoir under development, degassing of under- and over-worked formations (satellites) and the developed space: underground wells drilled above the mounting chamber, counter wells, wells above collapse domes and vertical wells from the surface; gas extraction from a particularly explosive formation d6 through wells drilled from field unloading workings, etc. [4]. Currently, work is actively being carried out on advance degassing preparation from unloading field workings of a particularly explosive formation d6 is being carried out in the field of the Kazakhstanskaya mine, with drilling of ascending degassing wells through a particularly explosive coal pack.

Experimental part

In the mines of the Karaganda basin, degassing of converging coal seams, worked-out spaces and host gas-bearing rocks with the help of wells drilled from the surface is widely used. The location of the well is chosen in such a way that after the end of drilling and casing of the well, the area of its intersection with the reservoir under development is located in the coal massif at a distance of more than 30 m ahead of the lava. The well should cross the reservoir under development and go deeper into the soil rocks by 3-5 m. The casing of vertical wells is carried out with steel pipes with a diameter of at least 100 mm. The lower part of the casing is located 3 - 5 m above the roof of the formation. In the areas of intersection of the adjacent overlying layers, the casing pipes are perforated with holes with a diameter of 15-20 mm with a length of this pipe of 20 m for each of the layers.

The mouth of the vertical well is sealed to the first from the surface of the coal seam, but not less than 10 m long. At the same time, the methane flow rate through wells increases, and the service life of vertical and underground degassing wells increases. The gas is sucked out at a discharge of at least 150 mmHg. The efficiency of degassing the methane release source at a distance between wells of 60-70 m is 60-80% and at a distance of 70-100 m - 50-60%.

Analytical studies show that with an increase in the load on the lava to 3,000 - 4,000 tons per day or more, the optimal values of the lava length of at least 200-250 m and the excavation column up to 1,500-2,000 m increase [5].

One of the promising areas of improvement is the work on the early degassing of coal seams by hydro-pneumatic action through wells drilled from the earth's surface. The intensification of reservoir gas recovery is based on the methodology of B. Moscow State Mining University (now MISIS) (Figure 1). During the period of application of this method, 152 wells were processed at the mines of the Karaganda coal basin (Table 1) with subsequent hydraulic fracturing and more than were extracted 100 million tons m^3 of methane.

When processing the d6 formation in the field of the Kazakhstanskaya mine (Figure 2), the following technological schemes for early degassing of coal seams have been developed and implemented: pneumohydraulic action; hydrodynamic action using the effect of self-sustaining destruction of coal; pneumohydraulic action with exposure to working fluid; exposure using foaming substances, pneumohydraulic action using the effect of aeration of working fluid; hydro-impact using a water hammer [[6], [7]].

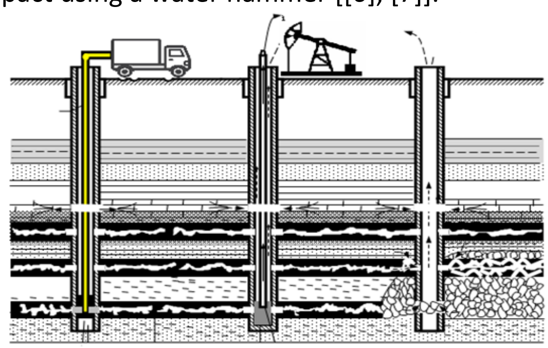


Figure 1 - Advance degassing of coal seams by hydro-pneumatic action through wells drilled from the surface

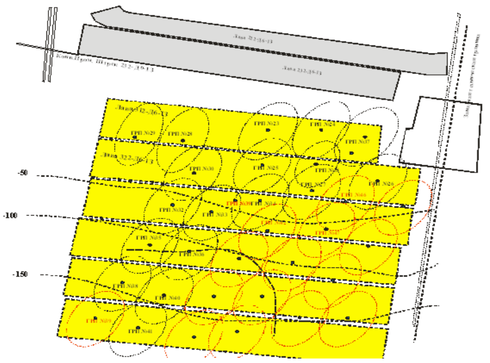


Figure 2 - The scheme of early degassing of the d6 formation in the field of the Kazakhstanskaya mine

The increase in the depth of coal seam mining determines the need to improve the technology of early degassing of minefields and methane extraction through wells drilled from the surface. At the same time, along with the positive aspects, such as separation in time and space of mining and degassing operations; the possibility of processing significant coal reserves through a well; achieving stable methane flows with a concentration of over 90%, there are also several negative factors and manifestations [8]. These include insufficient reliability of the method (with the same parameters of impact on the formation, the volumes of methane extraction from the treated areas vary significantly); lack of technical means to control the process of hydraulic impact on the formation and subsequent opening of natural cracks; no reliable relationship has been revealed between the parameters of reservoir treatment, its characteristics and methane extraction indicators [9].

To increase the reliability and efficiency of the method, it is necessary to change the approach to carrying out work on the early degassing preparation of minefields by methodically substantiating the parameters of artificial impact on the coal seam from the earth's surface. It is most advisable to improve the method of pneumohydro-separation of a coal seam, which is the most technologically advanced and effective method of exposure, using powerful high-performance compressors that provide a rate of injection of a gaseous working agent of more than 80 m3/min. A feature of the pneumatic hydroelectric effect on the coal seam is an increase in the phase permeability of the formation for gas, regardless of the mode of air introduction into the array, and a decrease in the sorption capacity of coal for methane when heating the formation, due to the chemical reaction of oxygen in the air with coal, when compressed air is injected into the coal seam at a rate exceeding the natural intake of the formation. The main parameters of pneumatic hydraulic separation include: the number of injection cycles; injection volume; injection rate; expected pressure, distance between wells.

The effectiveness of the impact of the method of pneumohydro separation of a coal seam from the earth's surface is estimated by the coefficient of pick-up:

$$K_n = \frac{q \cdot P_{at}}{\delta \cdot P_3} \qquad (1)$$

where q - is the rate of air injection into the reservoir, m^3/sec;

P_{at} - atmospheric pressure, MPa;

δ - is a coefficient that takes into account the conditions of opening the formation, the properties of the formation and the injected air, δ = 0.05-0.15;

P_3 - is the pressure at the bottom of the well, MPa.

Pneumohydro separation is carried out in cycles with an increase in the rate by 20-25% and an increase in the volume of injection of the gaseous agent by 10-15% in each subsequent cycle.

At the end of each cycle, the air is kept in the reservoir until the pressure stabilizes, and then the gas mixture is released until the pressure drops at the wellhead of the Py = 0.1 MPa. The number of cycles is assumed to be equal to the number of natural crack systems (n).

With an assumed radius of pneumatic separation of the R_{pd}, equal to 125 m, the total amount of air injected into the coal seam Q is determined by the formula:

$$Q = \frac{\pi \cdot R_{э}^{n^2} \cdot h \cdot m_e \cdot K \cdot P_c^p}{z \cdot P_\delta \cdot P_б \cdot \dfrac{T_{ai}}{T_{form}}} \qquad (2)$$

where h - is the reservoir capacity, m;

m_e - is the effective porosity of the formation, %;

K - is a coefficient that takes into account the filtration and reservoir properties of the coal seam and host rocks, K = 1.8 - 3.2;

R_{cp} - the expected average pressure of compressed air in the pneumatic separation zone:

$$P_c^n = \frac{P_p + P_{form}}{2} \qquad (3)$$

where P_p - is the pressure of the pneumatic separation of the formation, MPa; $P_p = \sigma_1 - P_{form} + \sigma_p$, here σ_1 is the vertical rock pressure, MPa;

P_{form} - reservoir pressure, MPa;

σ_p - is the tensile strength of coal, MPa;

z - is the coefficient of super-compressibility of air;

P_b - barometric pressure, MPa;

T_{ai} - the temperature of the injected air, Co;

T_{pl} - reservoir temperature, Co.

R_{cp} is the expected average pressure of compressed air in the area of pneumatic dismemberment.

During pneumohydroaction, sequential processes of hydraulic fracturing of the reservoir with a working fluid with compressed air injection occur. The technology provides for the separation of the formation by aerated working fluid due to the simultaneous injection of liquid and gaseous agents at a rate exceeding the natural permeability of the formation. In this case, the injection of aerated liquid is carried out according to the pressure, injection, which must be at least:

$$P_н = 0{,}025H + \sigma_p \qquad (4)$$

where H - is the depth of the formation, m;

σ_p - is the tensile strength of coal, MPa.

At the end of the injection cycle, the degassing well is kept hermetically closed for 3 to 7 days. until the pressure drops at the wellhead to the value of reservoir pressure. Then the well is opened and a cyclic self-discharge of water occurs. At the same time, air bubbles contribute to the removal of the working fluid from the filter pores and cracks [[10], [11]].

In order to increase the efficiency of methane extraction from the formation of coal seams, the treatment of each formation of the formation begins with a hydropneumatic rupture of the downhole zone, which is then washed and strengthened with a solid filler, and the treatment of the formation continues in the mode of hydropneumatic separation, while the treatment of the subsequent formation of the formation begins after the output of the treated formation to a stable water and gas flow mode, and the processing parameters are determined by the following calculation formulas:

- in case of hydro-pneumatic rupture of the downhole zone of the formation, the volume of injection of the working fluid:

$$Q_{wf} = K \cdot R_{dz}^2 \cdot h \cdot n_e; \; м^3; \qquad (5)$$

- the volume of injection of solid filler to secure the downhole area:

$$V_3 = 2\pi R_{da}^2 \cdot h \cdot d \cdot L_{bl} \cdot K_p, \; м^3 \qquad (6)$$

where K - is a coefficient that takes into account the degree of filling of fracturing cracks with solid filler, K = 0.4 - 0.8; K = 0.4 - with maximum filling of cracks, K = 0.8 - with no or minimal filling of cracks;

R_{dz} - is the radius of the downhole zone of the formation, m;

h - is the reservoir capacity, m;

n - is the effective porosity of the formation, in fractions of a unit;

d - is the effect of a hydraulic fracturing crack, m;

L_{bl} - the size of the coal block in the downhole zone, m;

K_l - is the coefficient of loosening of the solid filler;

H - is the depth of the formation, m;

σ - is the tensile strength of coal, MPa;

R_e - is the effective radius of hydraulic action, m.

Calculated parameters were obtained for the possible absolute volume of drained methane from the depth of vertical degassing wells at different distances between them (from 50 to 250 m).

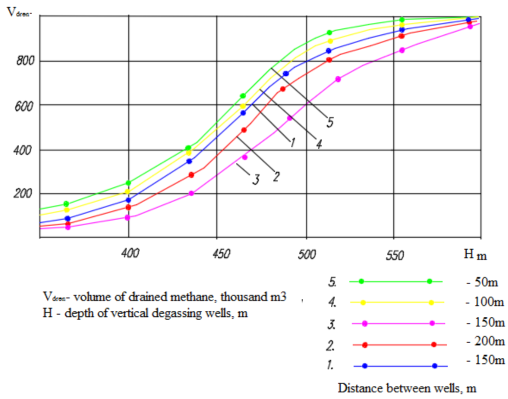


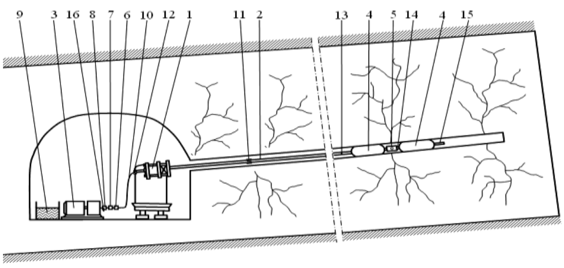
Figure 3 - Calculated parameters for the possible absolute volume of drained methane from the depth of vertical degassing wells at different distances between them (from 50 to 250 m)

It is known from world practice that in some cases, various intensifying methods of influencing the coal seam are used to increase the efficiency of degassing in underground mines [[12], [13], [14]].

One of the methods of progressive intensification of gas release during reservoir degassing is the point-to-point hydraulic fracturing of a coal seam, in which the formation is processed in fixed sections along the length of the well (Figure 4, a).

For the production of hydraulic fracturing, the machine drills degassing wells to a predetermined depth. After the end of drilling and flushing (no screw drilling) before drilling the well with the drilling machine 1, a sealing device consisting of two (or several) sealers 4 is introduced using rods 2.

The ratio of the lengths of the sealers is selected taking into account that water breaks into the well and occur in the direction of its bottom. A valve device 5 is placed between the sealers to supply water to the well (Figure 4, b).



1 – drilling rig (SBG-1m); 2 – drilling rods; 3 – high–pressure pumping unit; 4 – sealers; 5 – valve device; 6 – pressure gauges; 7 – flow meter; 8 – three-way tap; 9 – water tank; 10 - high-pressure hose; 11 - seal ring; 12 – adapter to the drill rods; 13 – adapter from the drill rods to the sealer; 14 – adapter from the sealer to the valve device; 15 – plug to the sealer; 16 – adapter from the three-way tap to the hoses

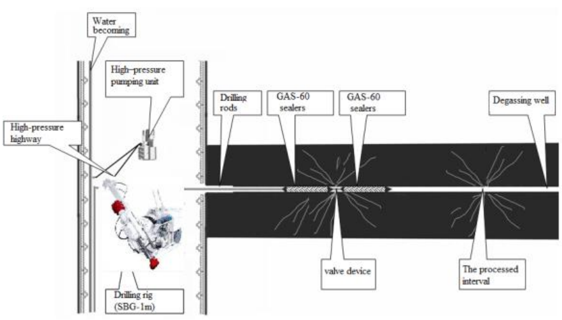
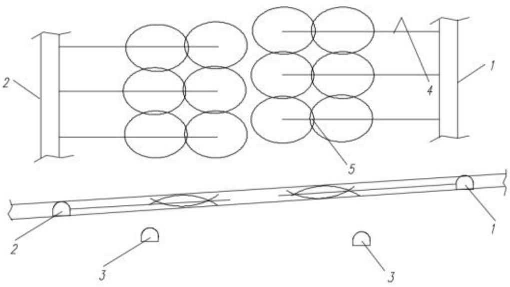


Figure 4 - The scheme of conducting inter-interval hydraulic fracturing of a coal massif through reservoir wells

After installing the sealing device in a given area, a high-pressure pump 3 is turned on and waterfalls along the rods at a rate of 20-50 l/min, which expands the sealers. When the maximum liquid pressure is exceeded (at least 2-3 MPa), the valve opens automatically in the valve device, and water enters the well cavity located between adjacent sealers. The pressure and flow of water are constantly monitored with a pressure gauge and a water meter. After supplying the calculated amount of water or a drop in liquid pressure, the pump is stopped and the water is lowered from the rods and sealers using a three-way crane, carrying out depressurization of the well (Figure 5).



1 – conveyor belt of overlying lava;
2 – conveyor belt of prepared lava;
3 – field production; 4 – hydraulic fracturing wells;
5 – Overlaying adjacent zones of interval hydraulic fracturing.

Figure 5 - The scheme of hydraulic fracturing using two seals

Then, the sealing device is moved with the help of rods and a drilling machine in the direction of the wellhead and installed in such a way that the end of the sealer closest to the bottom of the well is located at the boundary of the rupture zone with the movement of sealing elements along the well to a length equal to the length of both sealers and the valve device.

After installing the sealing device on a new section of the well, the processing process is repeated. In this sequence, sections of the coal massif are processed along the entire length of the well until the near end of the sealer approaches the wellhead at a distance of up to 15 m.

Despite the low pump performance in case of intermittent hydraulic fracturing (2.4 - 5.0 m3/min) compared with hydraulic fracturing from the surface (270 m3/min), hydraulic fracturing of the coal massif, as shown by the positive results of work in mine conditions, occurs within a radius of up to 10 m from the treated well. Calculations show that with intermittent hydraulic fracturing, the specific injection rate per 1 ton of processed coal reserves is 1.5 times higher than with hydraulic fracturing, and therefore, at this rate of fluid supply, hydraulic fracturing can occur within a radius of up to 10 m from the fracturing well (Figure 5, Table 1) [15].

Table 1 – Comparative parameters and indicators for different modes of hydraulic action on the formation

Type of action	The weight of the equipment used	Pressure, MPa	Injection rate, m3/h	The radius of the hydraulic action, m	Total volume of liquid, m3	Processed stocks in the specified radius,t	Specific injection rate per 1 ton of reserves, 10-4m3/(h*t)
Hydropneumor separation of a coal seam from the surface	Over 10	20-25	270	130	10000	297.3	9.1
Hydraulic fracturing from underground workings	3.0	20-25	40	30	200	28.1	14.2
Point-to-point hydraulic fracturing	0.4-0.6	20-25	2.4	10	2	1.8	13.0

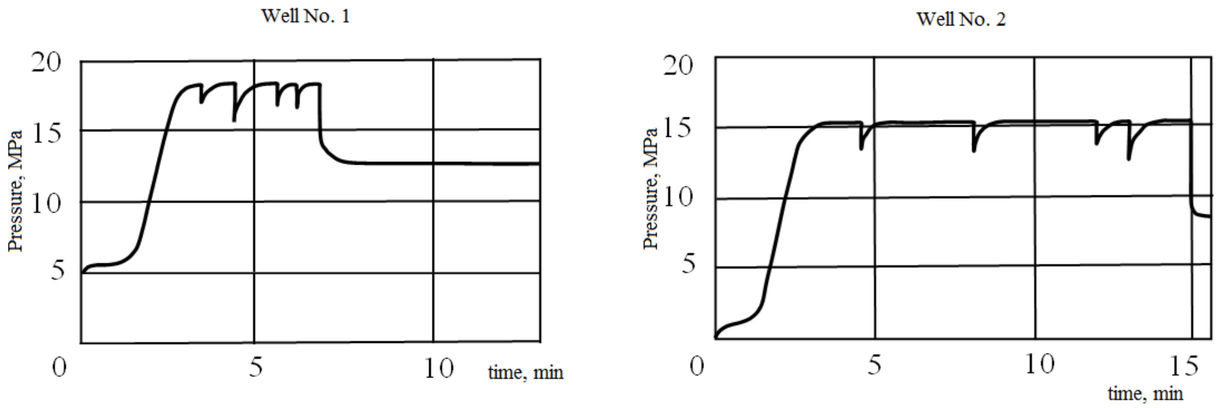


Figure 6 - Change in fluid pressure during well interval processing

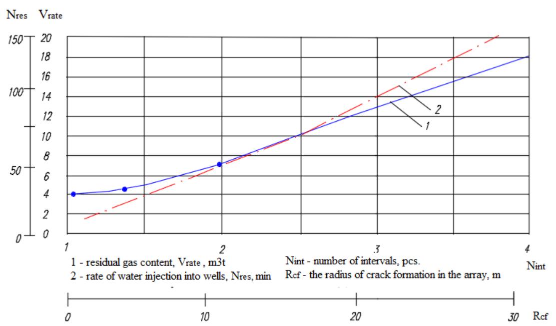


Figure 7 - The change in the rate of water injection into wells and the residual gas content of the coal seam, depending on the amount of applied hydraulic fracturing at the radius of crack formation in the massif

The main controlled parameter for the process of hydraulic fracturing of a coal massif is the liquid pressure according to the readings of a pressure gauge mounted on the discharge side of a high-pressure pump (Figure 6). High liquid pressure and its sharp drop indicate the formation of hydraulic fracturing cracks in the coal massif. The time spent on processing the formation in one interval is 7-15 minutes.

The rate of water injection into wells and, accordingly, the residual gas content of the coal seam is determined depending on the number of hydraulic fractures at the radius of formation (propagation) of cracks in the massif – Figure 7.

When choosing the type of pump for hydraulic fracturing, it is necessary that existing cracks open and new cracks form during its operation.

The formation of a tearing force by is performed according to the formula 16]:

$$P_r=(1-v)\,(2q_{\infty}+\sigma_s) \qquad (7)$$

where Pr - is the liquid pressure required for the formation of vertical cracks during hydraulic fracturing of a coal seam, MPa;

v - is the Poisson's ratio;

q_{∞} - lateral mountain pressure, MPa;

σ_s - is the tensile stress of coal, MPa.

In mine conditions, hydraulic fracturing was performed at the mine named after Lenin of the Karaganda coal basin from conveyor and ventilation bremsbergs 4.05 d6-1b (depth from the surface 672.7 - 822.2 m).

The conducted studies have established that for the conditions of the Karaganda coal basin, the lateral mountain pressure does not exceed 15-20% of the vertical pressure and it can be determined by the formula [17]

$$q_{\infty}=0,2\gamma H \quad (8)$$

where γ - is the volume weight of the overlying rocks, t/m^3;

H - is the depth of the formation, m.

After being reduced to a single measurement system (with an average density of carbon-bearing rocks γ = 2.5 t/m^3), formula (8) will take the form:

$$q_{\infty}=0,005H \quad (9)$$

At a depth of 700 m, the lateral mountain pressure value will be q_{∞} = 3.5 MPa.

For the d6 formation, the value of the Poisson's ratio is in the range ν = 0.1 - 0.3, and the breaking force for coal is σ_s =9.1 - 40 MPa. Substituting the initial data into formula (7), it turns out that the value of the liquid pressure for hydraulic fracturing at a depth of 700 m (mining operations will be carried out at this depth) is in the range of 16-20 MPa [18].

The rate of liquid supply to the coal seam is a very important parameter of hydraulic fracturing, since the higher the injection rate, the greater the radius of influence of hydraulic fracturing, and vice versa. In the case of underground hydraulic fracturing with an injection rate of 30-40 m^3/h through a reservoir well with a length of 70-100 m (with a sealing length of 40 m), the specific flow rate is 0.5 - 0.8 m^3/h. m.

In the mode of intermittent hydraulic fracturing with a rate of 2.4 m^3/h at a well interval of 0.3 - 0.4 m, the specific flow rate of liquid is 6 - 8 m^3/hr. m, i.e., an order of magnitude higher.

Therefore, at low flow rates (about 2.4 m^3/h), it is also possible to get cracks in the coal mass if the liquid acts on a small interval of the well [[19], [20]].

The injection rate and the fracking radius are interrelated parameters. At a water flow rate of 0.5 - 2 m^3/h or less through reservoir wells, natural cracks do not open, but only water is filtered into the reservoir with its humidification. Therefore, for the formation of non-closing cracks during hydraulic fracturing at a considerable distance from the well, it is advisable to use pumps with the highest possible performance.

In case of intermittent underground hydraulic fracturing in the Karaganda basin, when liquid is supplied to the reservoir at a rate of 30-50 l/min, the opening of existing and the formation of new cracks in the coal massif occurs within a radius of up to 10 m from the place where the liquid exits the valve device of the treated well. For hydraulic fracturing within a radius of 20 m, it will be necessary to increase the injection rate by 4 times and bring it to 60-100 liters/min.

In case of underground hydraulic fracturing, when a large amount of water is supplied to the coal mass per unit of time, first of all, the liquid also moves through large cracks. Under the influence of the "water wedge" there is an increase in the gaping of large cracks with simultaneous closure of cracks with a small gape due to movements and compaction of the coal mass between the cracks.

At the initial moment of water supply in the coal massif adjacent directly to the bottom of the well, the zone through which the liquid moves in the coal will generally represent a spherical radial flow resembling an ellipsoid. After the liquid reaches the roof and soil, the impact zone takes the form of a truncated ellipsoid. With the further movement of liquid from the well, the radial flow takes the form of a cylinder of a certain radius with a generator equal to the reservoir capacity.

The total amount of injected liquid QB (m^3) in each well interval is calculated using the formula:

$$Q_B = \frac{2}{3}\pi R_G^2 \; m_P K_{cap}, \quad (10)$$

where R_G - is the radius of propagation of hydraulic fracturing cracks, m;

m_P - full capacity of the coal seam;

K_{cap} - the coefficient of filling the coal massif with liquid, during hydraulic fracturing, is assumed to be in the range of 0.001 - 0.002.

Processing time of one interval - the estimated operating time of the t_r pump for processing is defined as the ratio of the calculated amount of water QB to the pumping rate q_p, assumed to be equal to the pump capacity

$$t_Г = \frac{Q_B}{q_H}, \quad (11)$$

For wells drilled through the reservoir, the distance between the treatment intervals is selected so that the zones do not overlap, i.e. the sealing device after the completion of the injection cycle must be moved at least the full length of the two sealers. In this case, the number of processing intervals is determined by the formula:

$$N = \frac{L_{well} - 20}{L_G}, \qquad (12)$$

where N - is the number of processing intervals;
L_{well} - the length of the well, m;
L_G is the length of the sealing device, m.

The number 20 indicates the extent of the degassing zone near the reservoir preparatory work for the rise or fall of the formation.

The experimental installation for hydraulic fracturing was tested in the landfill conditions of the Special Mine Installation and Degassing Department, and experimental work in underground conditions was carried out at the Abayskaya mine along the k10 formation at a depth of 510 m. The calculated fluid pressure at which the opening of existing fractures and the formation of new fractures for this depth should occur is 16.5 MPa. Hydraulic fracturing occurs at a liquid pressure of 15-18 MPa, close to the design pressure. To determine the methane flow rate from the treated wells, a packer (a device designed to separate 2 zones of the borehole and isolate the inner space of the production column from the impact of the borehole environment) and a measuring device were used, with the help of which it was established that the productivity of 1 cubic meter of the well as a result of interval treatment increased from 0.1-0.3 to 1.031.5 m^3/day *m, i.e. an average of 7 times [17].

Results and Discussions

The increase in the depth of coal seam mining determines the need to improve the technology of early degassing of mine fields and methane extraction through wells drilled from the surface. Along with the positive aspects: separation in time and space of mining and degassing operations; the possibility of processing significant coal reserves through a well; achieving stable methane production rates with a concentration of over 90%, there are also a number of negative factors. These include: insufficient reliability of the method (with the same parameters of impact on the formation, the volumes of methane extraction from the treated areas vary significantly); lack of technical means to control the process of hydraulic impact on the formation and subsequent opening of natural cracks; no reliable relationship between the parameters of formation treatment, its characteristics and methane extraction indicators has been revealed.

When pneumohydrogenation acts on a coal seam, the phase permeability of the formation for gas increases, regardless of the mode of air introduction into the array, and the sorption capacity of coal for methane decreases when the formation is heated, due to the chemical reaction of oxygen in the air with coal. A method for calculating the parameters of pneumohydro-separation of a coal seam from the surface is presented.

Conclusion

To increase the reliability and efficiency of the method, it is necessary to change the approach to carrying out work on the advance degassing of mine fields from the earth's surface. It is most advisable to improve the method of pneumohydro-separation of a coal seam, which is the most technologically advanced and effective method of exposure, using powerful high-performance compressors that provide a rate of injection of a gaseous working agent of more than 80 m^3 / min. During pneumohydrogenation, successive processes of hydraulic fracturing of the reservoir with a working fluid and subsequent air injection occur. The technology provides for the separation of the formation by aerated working fluid due to the simultaneous injection of liquid and gaseous agents at a rate exceeding the natural permeability of the formation.

Intensification of gas release during reservoir degassing in underground conditions is recommended to be carried out by inter-interval hydraulic fracturing of a coal seam, in which the formation is processed on fixed sections of the well. The calculation method, operational parameters and indicators are recommended for various modes of hydroelectric action on the coal seam in underground conditions during intermittent hydraulic fracturing of the coal seam. The article discusses the characteristics of the mine gases of the coal seams of the Karaganda coal basin, the features of their gas content and methods of artificial degassing. Studies show that with an increase in the depth of coal seams, the gas content increases, but their natural permeability and methane flow rate decrease, which requires the use of various technologies to intensify gas recovery, such as hydraulic fracturing, hydraulic fracturing and other methods. The article also presents data on the effectiveness of various methods of artificial impact on coal seams, which emphasizes the need for further improvement of these technologies to increase methane production and ensure the safety of mining operations.

CRediT author statement: **M. Rabatuly**: Conceptualization, Methodology, Software. **V. Demin**: Data curation, Writing-Original draft preparation. **A. Kenetaeva**: Visualization, Investigation. **Yu. Steflyuk**: Supervision. **J. Toshov**: Software, Validation.

Cite this article as: Rabatuly M, Demin VF, Kenetaeva AA, Steflyuk YuYu, Toshov JB. Evaluation of modern methods and techniques for calculating parameters during coal bed degassing. Kompleksnoe Ispolzovanie Mineralnogo Syra = Complex Use of Mineral Resources. 2025; 334(3):110-120. https://doi.org/10.31643/2025/6445.33

Көмір қабаттарын газсыздандыру кезінде параметрлерді есептеудің заманауи тәсілдері мен әдістерін бағалау

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Мақала келді: *7 тамыз 2024*
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ТҮЙІНДЕМЕ
Қарағанды бассейнінде жерасты көмір өндіруді дамытудың заманауи стратегиясы шахта қорын реформалау тұжырымдамасын әзірлеуді, тау-кен жұмыстарын шоғырландырудың және қарқындатудың жоғары деңгейін қамтамасыз етуді, жүктемені тәулігіне 5-6 мың тоннаға дейін жеткізуді көздейді. Бұл жағдайда негізгі шектеуші фактор бассейндегі көмір қабаттарының метанының жоғары болуы болып табылады, ол критикалық түрде 30 - 40 м3/т көмірге (орта есеппен 18 - 25 м3/т) жетеді. Өндірілетін көмір қабаттары мен олардың серіктерінің жоғары газдылығы кеніштердегі метан жарылысының негізгі себептерінің бірі болып, технологиялық режимнің бұзылуына және адам өліміне әкеліп соқтырады. Кен орындарын газсыздандыру мәселесі әрқашан жедел шешуді талап ететін басым бағыттардың бірі болды және болып қала береді. Газ-динамикалық құбылыстар мен метанның кенеттен бөлінуі адам өлімімен, үлкен материалдық және қаржылық шығындарға әкеледі және соңғы онжылдықта ТМД елдерінің көмір шахталарында орын алған апаттардың жалпы санының 25-30% құрайды. Мақалада осы саладағы заманауи тәжірибе мен жетістіктерді ескере отырып, метанды азайту және Қарағанды облысындағы көмір шахталарының қауіпсіз жұмысын қамтамасыз ету үшін жоғары газды, жарылу қаупі бар түзілімдерді газсыздандырудың прогрессивті тәсілдеріне баға берілді.

Түйін сөздер: метан, газ дебиті, газ бөліну, метанның көп болуы, көмір шахталары, газсыздандыру, тау-кен технологиясы, шахта алаңдары, газ-динамикалық құбылыстар, қабат.

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Оценка современных способов и методик расчета параметров при дегазации угольных пластов

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Поступила: *7 августа 2024*
Рецензирование: *8 августа 2024*
Принята в печать: *26 августа 2024*

АННОТАЦИЯ
Современная стратегия развития подземной добычи угля в Карагандинском бассейне предусматривает развитие концепции реформирование шахтного фонда, обеспечения высокого уровня концентрации и интенсификации горных работ с доведением нагрузки на очистной забой до 5 - 6 тыс. тонн в сутки. При этом основным сдерживающим фактором является высокая метаноносность угольных пластов бассейна, которая критически достигает 30 - 40 м^3/т (в среднем 18 - 25 м^3/т) угля. Высокая газоносность разрабатываемых угольных пластов и их спутников является одной из главных причин взрывов метана на шахтах, приводящих к нарушениям технологического режима и безвозвратным человеческим жертвам. Проблема дегазации шахтных полей всегда была и стоит в ряду первоочередных направлений, требующих оперативного решения. Газодинамические явления и внезапные выделения метана сопровождаются человеческими жертвами, большими материальными и финансовыми потерями, являются на 25-30 % причиной общего числа аварий, произошедших на угольных шахтах стран СНГ в последнее десятилетие. В статье произведена оценка прогрессивных способов дегазации высокогазоносных, выбросоопасных пластов для снижения метаноносности обеспечения безопасности эксплуатации угольных шахт Карагандинского региона с учетом современного опыта и достижений в этой области.

Ключевые слова: метан, дебит газа, газоотдача, метанообильность, угольные шахты, дегазация, технология горных работ, шахтные поля, газодинамические явления, пласт.

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References

[1] Rabatuly M, Musin RA, Demin VF, Usupaev ShE, Kenetaeva AA. Improving the efficiency of methane extraction from coal seams. Kompleksnoe Ispolzovanie Mineralnogo Syra = Complex Use of Mineral Resources. 2023; 324(1):5-11. https://doi.org/10.31643/2023/6445.01

[2] Drizhd NA, Rabatuly M, Aleksandrov AYu, Balniyazova G, Zhunis G. The results of the development of pilot wells in the sherubainurinsky site of the Karaganda coal Basin. Ugol. 2020; 6:36-40. http://dx.doi.org/10.18796/0041-5790-2020-6-36-40

[3] Demin V, Khalikova E, Rabatuly M. Research into mine working fastening technology in the zones of increased rock pressure behind the longwall face to ensure safe mining operations. Mining of Mineral Deposits. 2024; 18(1). https://doi.org/10.33271/mining18.01.027

[4] Zepeng W, Zhaolong G, Ruihui L, Haoming W, Shihui G. Effects of acid-based fracturing fluids with variable hydrochloric acid contents on the microstructure of bituminous coal: An experimental study. Energy. 2022; 244(PA):122621. https://doi.org/10.1016/j.energy.2021.122621

[5] Zou G, Zhang Q, Peng SJin C, Che Y. Influence of geological factors on coal permeability in the Sihe coal mine. 2022; 9. International Journal of Coal Science and Technology. https://doi.org/10.1007/s40789-022-00475-3

[6] Imashev A, Suimbayeva A, Zhunusbekova G, Zeitinova Sh, Kuttybayev A, Mussin A. Research into stress-strain state of the mass under open pit with a change in the open-pit bottom width. Mining of Mineral Deposits. 2022; 16(3):61-66. https://doi.org/10.33271/mining16.03.061

[7] Kenetayeva AA, Kenetayeva ZhK, Tokusheva ZhT, Rabatuly M. Methane content of coal seams of Karaganda basin. Mater. 3th internat. conf. Cognitive Robotics. Tomsk. 2018, 1-5. https://doi.org/10.1088/1757-899X/516/1/012020

[8] Petrov AA, Nikolayev NI. Rezultaty issledovaniya vliyaniya zhidkostey-razrushiteley na polimermineralnuyu filtratsionnuyu korku [Results of the study of the effect of liquid destroyers on the polymer-mineral filter cake]. Nedropolzovaniye [Subsoil use]. 2021; 21(2):58-63. (in Russ.). https://doi.org/10.15593/2712-8008/2021.2.2

[9] Solar J. Sizing the thickness of the coated insulation against methane leakage coming out of bedrock. Applied Mechanics and Materials. 2014. https://doi.org/10.4028/www.scientific.net/AMM.501-504.2327

[10] Drizhd NA, Rabatuly M, Kenetayeva AA, Steflyuk YuYu. Metody intensifikatsii gazootdachi ugolnykh plastov Gornyy zhurnal Kazakhstana. 2021; 10:8-12. https://doi.org/10.48498/minmag.2021.198.10.001

[11] Plaksin M S, Rodin R I. Improvement of degasification efficiency by pulsed injection of water in coal seam. IOP Conf. Ser.: Earth Environ. Sci. 2019; 377:012052. https://doi.org/10.1088/1755-1315/377/1/012052

[12] Maussymbayeva AD, Yurov VM, Rabatuly M, Rakhimova GM. Assessment Of The Influence Of The Surface Layer Of Coals On Gas-Dynamic Phenomena In The Coal Seam. Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu. 2024; 2. https://doi.org/10.33271/nvngu/2024-2/005

[13] Inkin O, Tishkov V, Dereviahina N, Sotskov V. Integrated analysis of geofiltrational parameters in the context of underground coal gasification relying upon calculations and modeling. Ukrainian School of Mining Engineering. 2018. https://doi.org/10.1051/e3sconf/20186000035

[14] Pat. 2022/0131.2 KZ. Sposob otsenki absolyutnoy pronitsayemosti v protsesse pri burenii skvazhin [A method for assessing absolute penetration in the process of well drilling]. Rabatuly M. Opubl. 17.02.2022, bull. 7212. (in Russ.). https://cloud.mail.ru/attaches/16554580951242976274%3B0%3B1?folder-id=0&x-email=mukhammedrakhym%40mail.ru&cvg=f

[15] Bodden WR, Ehrlichb R. Permeability of coals and characteristics of desorption tests: Implications for coalbed methane production. International Journal of Coal Geology. 1998; 1-4:333-347. https://doi.org/10.1016/S0166-5162(97)00039-6

[16] Zhang S, Tang S, Zhang D, Fan G, & Wang Z. Determination of the Height of the Water-Conducting Fractured Zone in Difficult Geological Structures: A Case Study in Zhao Gu No. 1 Coal Seam. Sustainability. 2017; 9(7):1077. https://doi.org/10.3390/su9071077

[17] Tutak M, & Brodny J. Predicting Methane Concentration in Longwall Regions Using Artificial Neural Networks. International Journal of Environmental Research and Public Health. 2019; 16(8):1406. https://doi.org/10.3390/ijerph16081406

[18] Portnov VS, Filimonov EN, Mausymbayeva AD. et al. Otsenka gazonosnosti plasta k10 v usloviyakh Sherubaynurinskogo uchastka na osnove dannykh fakticheskogo gazovydeleniya [Assessment of gas content of the K10 formation in the conditions of the Sherubaynurinsky site based on actual gas emission data]. Kompleksnoe Ispolzovanie Mineralnogo Syra = Complex Use of Mineral Resources. 2016; 2:3-10. (in Russ.). https://kims-imio.kz/wp-content/uploads/2018/03/ilovepdf_com-3-10.pdf

[19] Ma Y, Nie B, He X, Li X, Meng J, & Song D. Mechanism investigation on coal and gas outburst: An overview. International Journal of Minerals, Metallurgy and Materials. 2020; 27(7):872-887. https://doi.org/10.1007/s12613-019-1956-9

[20] Cun Zhang, Shihao Tu, Min Chen, Lei Zhang. Pressure-relief and methane production performance of pressure relief gas extraction technology in the longwall mining. Journal of Geophysics and Engineering. 2019; 14(1):77-89. https://doi.org/10.1088/1742-2140/14/1/77

[21] Kamarov RK, Akhmatnurov DR, Mussin RA, Zamaliyev NM. Setting the volume and location of the gas collectors of abandoned coal mines. Naukovyi Visnyk Natsionalnogo Hirnychoho Universytetu, Dnepropetrovsk. 2018; 2:5-11. http://www.nvngu.in.ua/jdownloads/pdf/2018/02/NVNGU02_2018_Kamarov-1.pdf

[22] Drizhd NA, Mussin RA, Alexandrov A Ju. Improving the Technology of Hydraulic Impact Based on Accounting Previously Treated Wells. International science and technology conference Earth science. IOP Conf. Series: Earth and Environmental Science. 2019; 272:022031. https://iopscience.iop.org/article/10.1088/1755-1315/272/2/022031/pdf