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EVALUATION OF THE ADVANCED DEGASSING IN THE AFFECTED ZONES OF DEFORMATION PROCESSES

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Abstract. On the example of the results of experimental studies in the conditions of great depths of the mines of the Donetsk basin, the relationship between the parameters of advanced degassing and deformation processes in the roof rocks during the development of a coal seam is considered.

The purpose of the work is to establish the efficiency of advanced degassing depending on the location of degassing wells in the zones of tension and compression of rocks in the undermined geological stratum. This article deals with the influence of technogenic processes that occur in the rock massive in front of the mine face and along the pillar of the previously worked out longwall. It was established that the process of technogenic formation of cracks in the overhanging mass during the drivage of the mine face occurs up to a certain height with the rate of transition of tensile strains into compressive strains. Along the pillar and above it to the zone of manifestation of the supporting rock pressure (compression deformation zone), an area (band) of influence of the tensile deformation zone and rock stratification is formed. In this part of the massif, free methane accumulates, which flows through man-made cracks from the compression zone to the extension zone. Ahead of the mine face, similar man-made processes take place. The replacement of compression zones by extension zones leads to intense filtration of free methane and its accumulation in the separation zones. When caving the block of the main roof, gas from the stratification zone is released into the goaf, of longwall. Wells located in compression deformation zones do not provide effective degassing of roof rocks. The wells located in the tensile deformation zone of the undermined massif have the highest flow rate and high methane concentration. With the repeated underworking of such wells, their efficiency and service life increase.

It is recommended to apply advanced degassing of roof rocks by wells, which are located in rock tension zones on the border with goaf. The distance between degassing wells should be such that there is no or minimal technogenic and gas-dynamic connection between them. In the conditions we have considered, it should be 55-60 m.

Keywords: advanced degassing, dynamic shift trough (DST), deformation processes, zones of stratification.

Introduction. The development of coal seams in conditions of great depths is accompanied by complex of geomechanical processes in the undermined geological stratum. Changes in the massif occur from the excavated layer to the earth's surface. During the collapse of the rocks of the immediate roof and the cyclic subsidence of the blocks of the main roof, a dynamic shift trough (DST) is formed [1]. The drivage of rocks in the DST initiates technogenic transformations that affect the entire geological stratum. When the breakage face moves in the underworked space, deformation zones change, man-made cracks develop, and delamination zones are formed (Fig. 1).

The change of compression zones by tensile zones leads to intensive filtration of fluids, in particular methane. If above the main roof in the massif there are layers of rocks, which do not collapse during subsidence (do not lose their continuity), then in the thickness of the rocks are formed zones of stratification. The layers of these rocks become gas-resistant and prevent the filtration of methane to the earth's surface. Methane accumulates in the stratification zones, which flows from the compression zones to the tensile zones through man-caused cracks.

Displacement of the main roof blocks and subsidence of the underworked massif in the DST leads to redistribution of methane flows in the massif. Therefore, in conditions of great depths, the main gas evolution (75-80%) occurs in the mined-out space [2, 3]. If there are other gas-saturated geological objects in the roof of the

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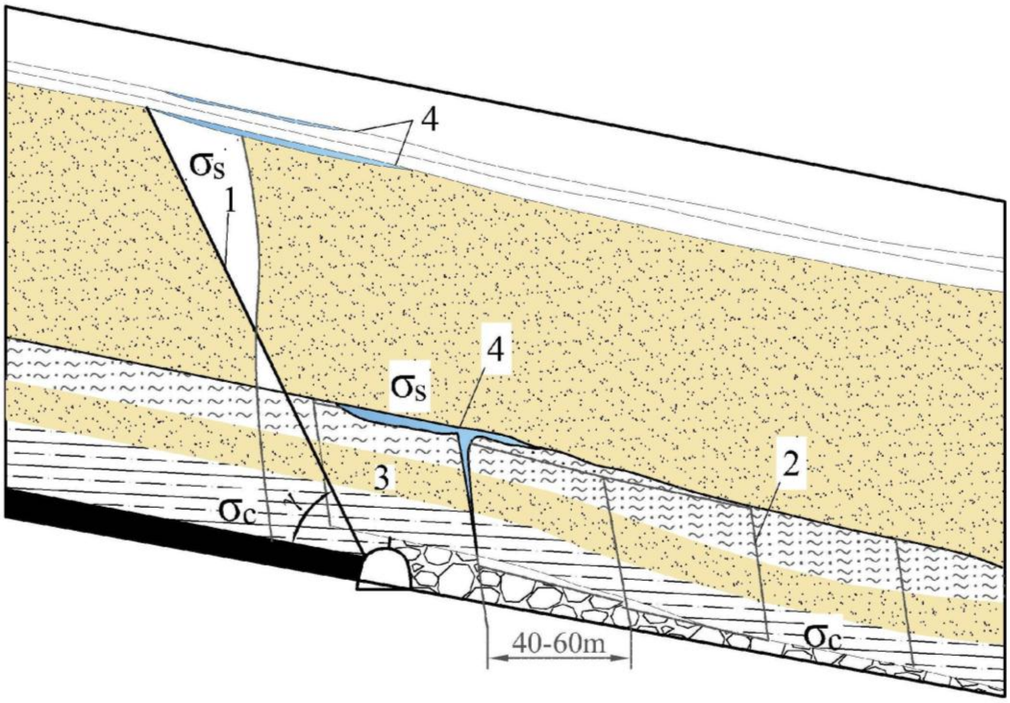
working layer, the concentration of CH4 in the source air flow of the site increases sharply. This leads to exceeding the permissible norms of CH4, violation of the ventilation regime and the creation of emergencies. To solve this problem, mines use different methods of degassing the coal massif and prevent gas-dynamic phenomena [4-9].



1 – line of DST of rocks in a geological stratum; 2 – the lines of separation of the main roof blocks; 3 – clamping console; 4 – zones of stratification of rocks; γ – dynamic angle in the shear of DST ; σ_s - stretching zone; σ_c – compression zone

Figure 1 – Scheme of formation of zones of stratification and displacement of rocks

One of the ways to solve this problem is to use of advanced degassing of roof rocks through underground wells. However, the degassing process will be inefficient if the method does not take into account the shear processes in the forged massif.

Methods. Geomechanical processes in the massif at the boundary of the mined-out space and coal seam. When solving the problems of advanced degassing of roof rocks, the zones of stratification in the massif along the boundary of the whole with collapsed rocks are of the greatest interest. These zones are formed in the DST due to the shift of the processed massif to the side of mined-out space.

The subsidence of the roof outside the DST is slower than in its central part. The difference in the subsidence velocity leads to the formation at a dynamic angle of the half-trough shear γ (see Fig. 1) of the shear line - 1. At the same time along the shear line are formed zones of stretching Ϭs and compression Ϭc During the separation and subsidence of the main roof blocks along the line of separation - 2 in the DST, a compression zone is formed Ϭc. After planting the main roof, along the preparatory work is formed lateral clamping console - 3. Between the clamping console and collapsed rocks in the DST is the subsidence of rock layers and the formation of stratification zones - 4. In the presence of gas-saturated sandstones in the geological stratum.

In the conditions of mines of the Donetsk basin such object is sandstone $m_4Sm^1_4$. It is located above the m_3 layer at a distance of 25 to 30 values of its capacity. Up to this height in the worked-out massif there is a shift of blocks and change of continuity of rocks. The rocks which located above the sandstone do not lose their continuity when shifted, so they become gas-resistant.

In the zones of stratification and fracturing, the permeability of rocks is much higher, and the gas pressure is lower than in the virgin massif. This facilitates the filtration of methane from the virgin mass into zones of stratification. The location of the bottom of the degassing wells in such areas allows for effective advanced degassing.

Location and parameters of degassing wells. Studies of the efficiency of advanced degassing of roof rocks were carried out during the development of the m_3 layer in the 15th and 16th western longwalls. There are 6 degassing wells were drilled in the rocks of the main roof (Table 1).

Table 1 – Parameters of experimental degassing wells

Well / date of construction / picket of wellhead/	The length of the well L, m	The angle of rise of the well to the horizon β, degrees	The angle of rotation of the well from the axis of production γ, degrees.	Azimuth directly to the well, degrees.	The distance from the bottom of the well to the target from the slope №7 l, m	The length of the well in the sandstone $m_4Sm^1_4$ $L_{san.}$, m
2e/7.08/$PK141_{west}$	232	26	90_{west}	292	224	94
3e/14.08/$PK142_{west}$	210	26	105_{west}	277	212	107
4e/20.08/$PK140_{west}$	204	24	35_{west}	347	77	82
5e/27.08/$PK140_{east}$	165	35	11_{east}	33	43	67
6e/2.09/$PK140_{east}$	168	35	35_{east}	57	84	73
7e/11.09/$PK141_{east}$	282	13	50_{east}	72	235	102

The peculiarity of these studies is that the wells were located in different zones of deformation. Initially, the parameters of the method in the zones of compression and stretching of DST from 15 longwall were investigated. Then, in the dynamics of deformation processes in the zones of compression and stretching, during the development of 16 longwall (Fig. 2).

Consider the location of wells in space (see Fig. 2, a). Well 3e is located in the compression zone of the massif, which shifted after working 15 longwall. Well 2e is located in the zone of stratification from the impact of compression deformations DST spent 15 longwall. When working off the longwall 16, it will be in the zone of stretching and in the zone of compression from the reference rock pressure. Well 4e is located above the excavation field 16 of the western longwall. When cleaning, it will be first in the zone of stretching, and then in the zone of compression. Wells 5e and 6e, as well as well 2e, are located in the strip of the zone of strain deformations formed as a result of shear of rocks 15 longwall. Well 7e is drilled at a small angle to the horizon, lined to a short length and flooded. According to its indicators, it is not typical, so it is not considered.

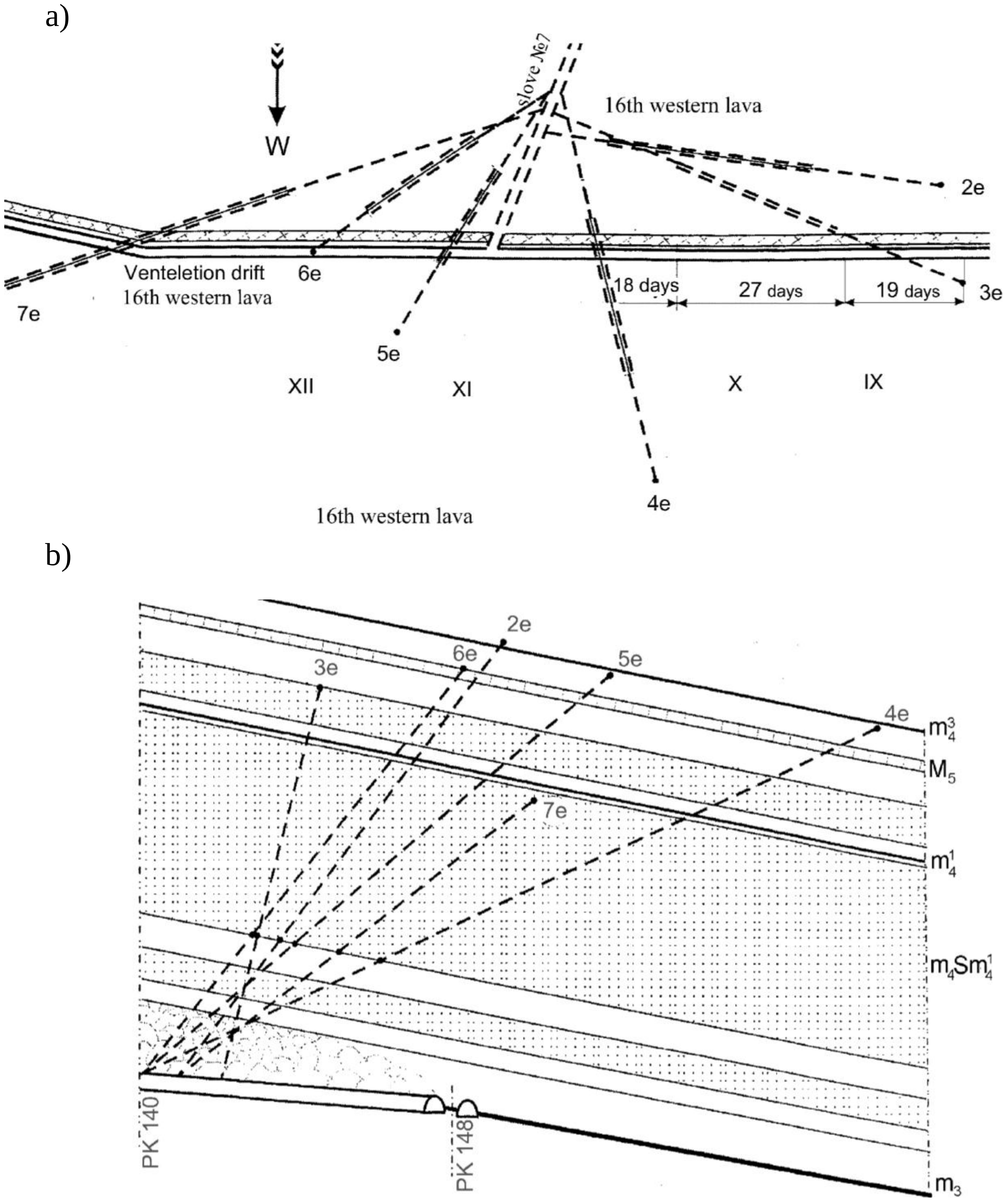


Figure 2 – Location of degassing wells in the plan - a (dotted line shows part of the wells in the sandstone) and in section - b

Thus, the experimental parameters 2e, 5e and 6e, which are located in the deformation zone of the DST tensile, will correspond to the technological parameters of advanced degassing during the operation of the 15 longwall.

For each well were determined: the level of vacuum at the wellhead and speed; flow rate and temperature of the gas-air mixture; concentration and flow rate of pure (in terms of 100%) methane. At the same time, the position of the bottom of the 16 longwall relative to the degassing wells was determined and the gas evolution in the goaf of the site was estimated.

Results and discussion. The results of experimental studies. Consider the results obtained during the operation of degassing wells that were in the compression zone. Well 3e is in the zone of compression of rocks that have already moved, as a result of excavation work 15 longwall, and well 4e in the zone of compression of rocks during their shift during the operation of 16 longwall.

Well 3e operated for 31 days with a flow rate of 0.1 to 0.3 m^3/min and a methane concentration of 10 to 48%. The reason for the low efficiency of the well is its location in the compression zone of sandstone $m_4Sm^1_4$.

The operation of well 4e before working on the bottom 16 of the longwall is characterized by two periods (Fig. 3). In the first period, at a distance of 110 m from the bottom, the well was in the zone of stretching. In the second, at a distance of 50 m from the face, in the compression zone of the reference rock pressure.

The time during which the zone of tensile deformations is replaced by compression deformations depends on the speed of drivage of the face and the step of collapse of the main roof [1]. Under the conditions under consideration, the estimated value of the time of change of tensile deformations by compression deformations is 40 days, according to the experiment - 34 days.

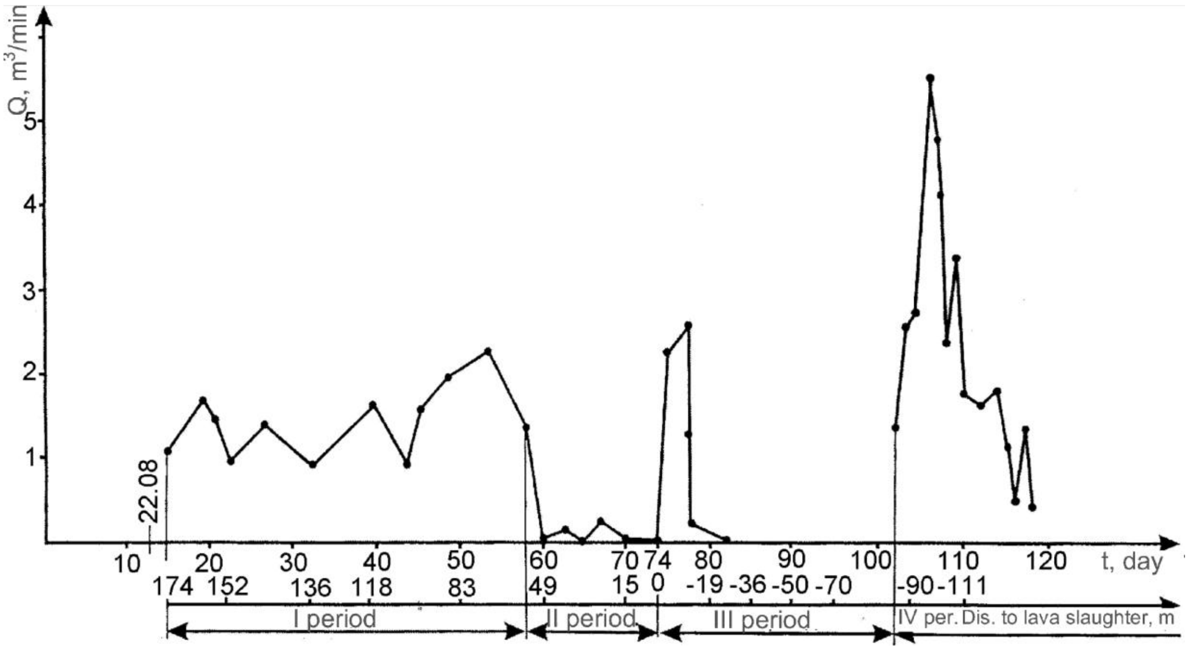


Figure 3 – Dynamics of methane flow through well 4e in the process of subcontracting

The above calculation confirms the data on the dynamics of methane flow through well 4e, which are also characterized by two periods (see Fig. 3). In the first period, 88.6 thousand m^3 of methane were extracted in 44 days. The average daily extraction was 2013 m^3 with an average flow rate of 1.4 m^3/min and a methane concentration of 31.7%. Such values of degassing parameters do not allow efficient methane utilization. In the second period, the concentration of methane in the gas mixture dropped to zero. After passing the longwall of the target with the bottom of the well, its flow rate increased to 2.25-2.63 m^3/min, the concentration of methane in the mixture was 50-78%. Then, two days later, gas emissions decreased sharply, the well was shut down.

The obtained results allow us to draw the following conclusions. The change of deformations in the working massif leads to the intensification of gas evolution into the well. Sedimentation of rocks leads to short-term, for a short time, the release of gas. This gives reason to assume that in the conditions considered by us in front of the breakage face at a distance of about 50 m in the sandstone $m_4Sm^1_4$ compression zone is formed. A stretch zone is formed in front of the compression zone for about 60 m.

Consider the release of gas through well 2e. The peculiarity of the well is that, in addition to the gas-bearing sandstone $m_4Sm^1_4$, it crosses the coal seam m^3_4 (0.6 m thick). In addition, part of the well drilled in the sandstone is already in the compression zone of the DST from 15 longwall.

When working well 16 with longwall in the DST there was a change in deformation in the sequence: compression-stretching-compression. Consider this process on the example of changes in the flow rate of the well (Fig. 4).

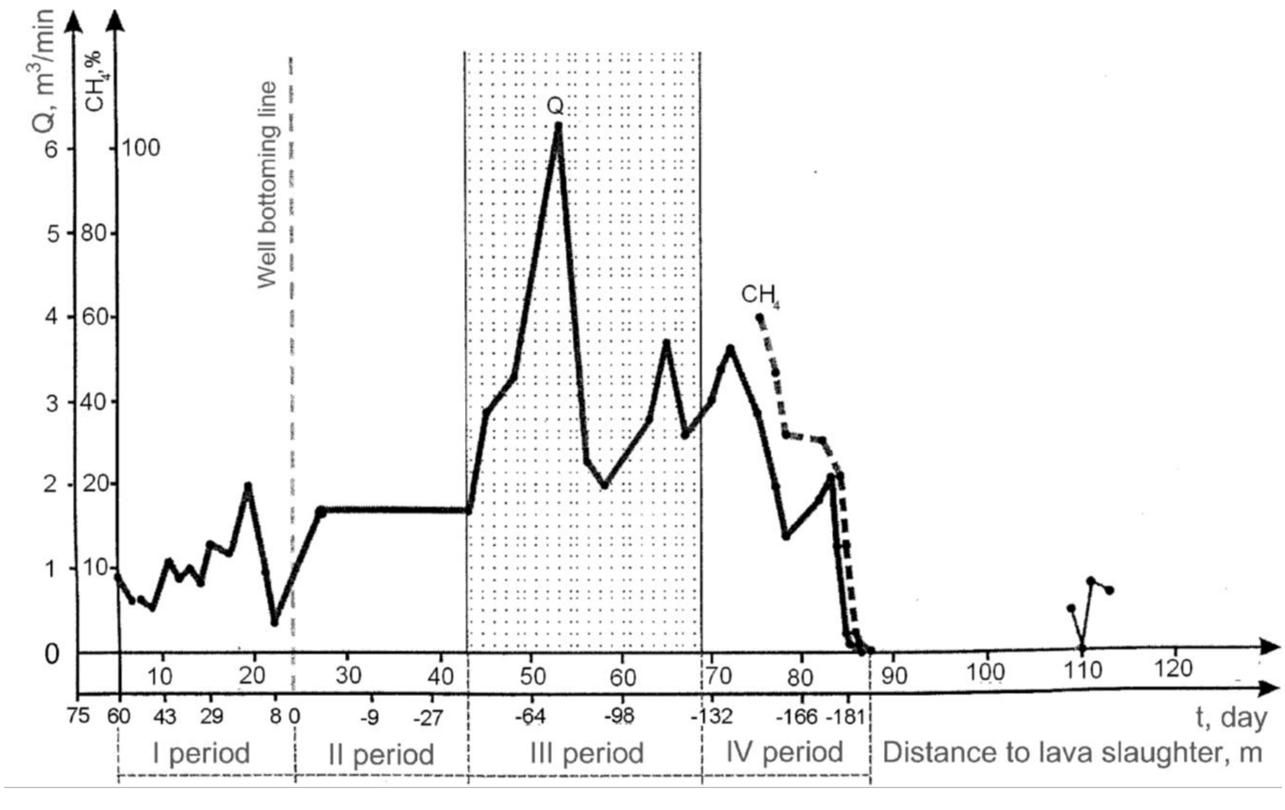


Figure 4 – Dynamics of methane flow through well 2e

The dynamics of gas evolution through the well is divided into several periods. In the first period (before the longwall approached the wellhead), well 2e worked for 19 days with an average flow rate of 1.05 m^3/min. During this time, about 29 thousand m^3 of pure methane was extracted (in terms of 100% CH_4), the average daily production of CH_4 was 1520 m^3. The concentration of methane in the gas mixture ranged from 14 to 72% (average - 40%). The main source of gas emissions during this period was sandstone $m_4Sm^1{}_4$, worked by 15 western longwall.

The second period was the next 19 days. During this time, the bottom 16 of the longwall moved from the bottom of the well (the intersection of the well of the coal seam, mined $m^3{}_4$) to the wellhead from the roof of sandstone $m_4Sm_4{}^1$. 43.7 thousand were withdrawn m^3 of methane, the average daily production was 2300 m^3/day, the average flow rate was 1.6 m^3/min. The concentration of methane in the mixture was about 40%. The average flow rate of methane from the $m_4{}^3$ layer being worked on was 0.55 m^3/min.

The third period lasted 27 days. During this time, the bottom 16 of the longwall moved from the point of exit of the well from the sandstone $m_4Sm_4{}^1$ to the point of entry of the well into the sandstone soil. The dynamics of methane flow in the well increased sharply and exceeded 6 m^3/min. (see Fig. 4). During this period, about 140 thousand m^3 of methane were extracted. The average daily extraction from the well, at a flow rate of 3.52 m^3/min, amounted to 5.1 thousand m^3. The concentration of methane in the gas mixture doubled, the average value was 80.4%. The value of the vacuum at the wellhead ranged from 20 to 85 mm Hg. The reason for the intensification of gas evolution (more than 2 times) was the secondary underwork of sandstone $m_4Sm_4{}^1$ 16 longwall and the change of deformation zones in the DST (compression-stretching-compression). In this area there was a part of well 2e with a length of 94 m.

The fourth period of the well was 18 days. It began with the passage of longwall at the point of entry of the well into the sandstone $m_4Sm_4{}^1$ and lasted until the cessation of gas evolution into the well. The release of gas into the well stopped after the planting of the main roof rocks and the formation of a compression zone in the DST (see Fig. 1). During this period, 52.15 thousand m^3 were withdrawn (average daily production - 2.9 thousand m^3, average flow - 2.01 m^3/min.). At change of deformations (compression) concentration of methane reached 80%. During the transition of tensile deformations in the compression deformation, the gas evolution from the massif to the well decreased and stopped in the compression zone. Then well 2e was disconnected from the degassing chain. Thus, about 265 thousand m^3 of methane with a concentration suitable for its utilization was extracted through the well.

The results of experimental studies on degassing of the main roof rocks by well 2e indicate the following. The main sources of gas in the well were sandstone $m_4Sm^1{}_4$ and coal seam $m^3{}_4$. The density of methane reserves of them is 79.89 and 9.02 m^3 of methane per m^2, respectively. The stock ratio is 8.85. According to the results of gas evolution, this ratio is (3.52-0.55): 0.55 = 5.4. The coal seam $m^3{}_4$ in the area of the well was worked with 16 longwalls, and the sandstone $m_4Sm^1{}_4$ was worked twice - with 15 and 16 longwalls. Assume that the gas evolution stopped due to gas depletion of rocks. Then, based on the obtained ratios, in the first part-time sandstone $m_4Sm^1{}_4$ was degassed by 40%, and the second by 60%.

Consider the efficiency of advanced degassing wells 5e and 6e. The peculiarity of these wells is that they are located in the deformation zone of the DST tensile from

15 longwall. The distance between the wells is about 40 meters. In the process of working off the longwall 16, they were in different zones of deformation. First in the zone of "stretching-compression" from 15 longwall, then "compression-stretching-compression" DST 16 longwall. At change of deformations in the massif around wells there were processes of technogenic crack formation. This led to the formation of a new degassing zone and the flow of gas from the massif, mainly to well 5e.

High efficiency of degassing of roof rocks through wells 5e and 6e is characterized by two factors. The first is gas evolution through wells, with approximately the same flow rate. Gas evolution began 220-230 m before the approach of the clearing face 16 of the longwall to the wells (Figs. 5, 6). Second, high methane flow and concentration were observed in both wells.

The graphs show that the dynamics of the gas evolution process can be divided into two periods. The first period is the time of man-made processes associated with the formation of the degassing zone (40-45 days). The second period is the time of methane extraction from the massif before the intersection of 16 longwall wells with sandstone and after their intersection.

750 thousand m^3 of methane (average daily production - 13.6 thousand m^3) was extracted before the longwall crossed the point of entry of wells into the sandstone (≈35 days). The concentration of methane in wells at an average flow rate of 9.44 m^3/min ranged from 49 to 100% (daily average - 70%). Such indicators characterize the high efficiency of degassing and satisfy the quality of the gas mixture for methane utilization.

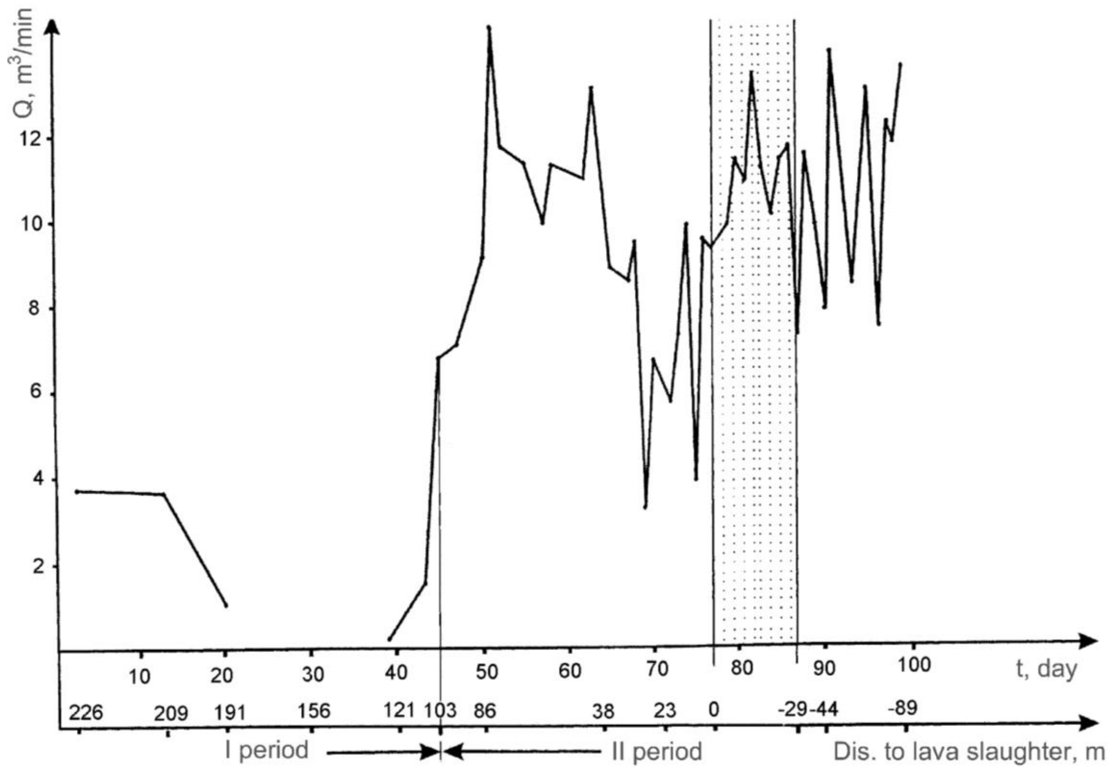


Figure 5 – Dynamics of methane flow through well 5e in the process of its subcontracting

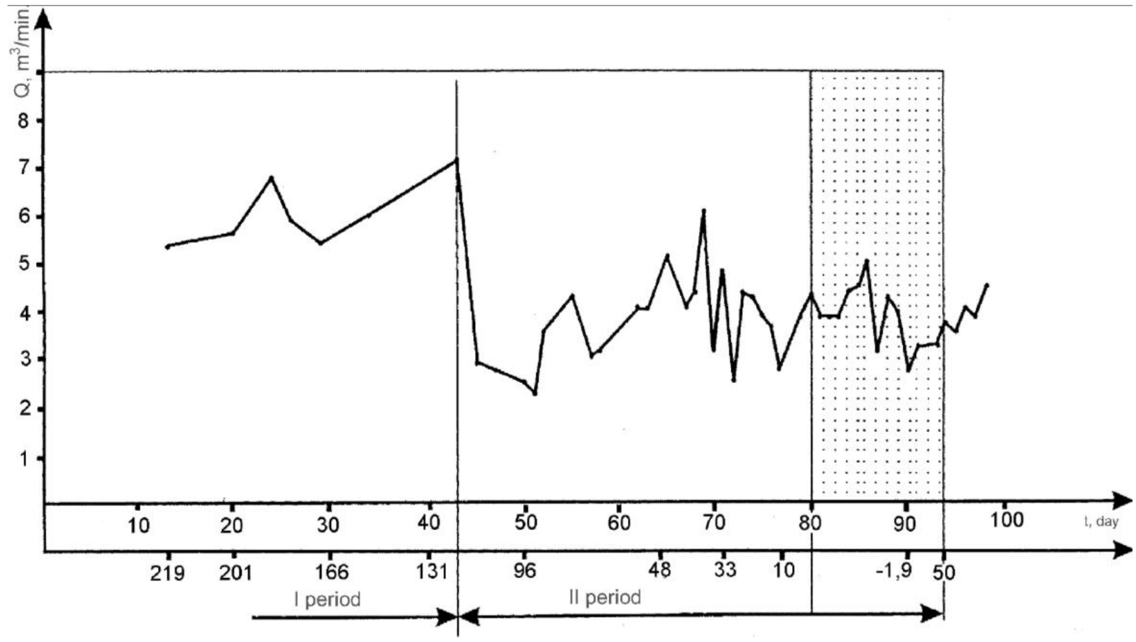


Figure 6 – Dynamics of methane flow through well 6e in the process of its subcontracting

As the longwall passes through the point of entry of well 5e into the sandstone soil (see Fig. 5), the flow rate of the well increased. When working with longwall on the entire section of sandstone drilled by a well (distance 0-29 m), the average methane flow rate did not change. Changes in the flow rate of the well began at a distance of 103 m from the bottom of the longwall to the point of entry of the well into the sandstone $m_4Sm_4^1$.

After connecting well 6e to the degassing system, 100% methane concentration was recorded at its head. During the 85 days of operation, about 600 thousand m^3 of methane were extracted, the average daily production was 7.1 thousand m^3, and the average flow rate was 4.93 m^3/min. Then the concentration of methane in the gas mixture varied from 50 to 100% (daily average - 70.1%).

The change in the flow rate of well 6e, as well as well 5e, can be divided into two periods of its operation (see Fig. 6). The first period was about 40 days with an average daily flow rate of 6.0 m^3/min, the second - 55 days with an average daily flow rate of 4.21 m^3/min. The nature of the change in the flow rate of well 6e confirms the conclusion that as a result of man-made cracking between wells 5e and 6e formed a new degassing zone.

Consider the dynamics of methane flow in well 4e, which is located in the compression zone 16 of the longwall (see Fig. 2, 3) and in well 5e, which is located in the tensile zone (see Fig. 2, 5) in front of the treatment face. In the dynamics of the process there is a general pattern - the change in the flow rate of wells occurs with changes in deformation in the DST. Before the zone of reference rock pressure, the change in the flow rate of wells is associated with the change in tensile strains by compression strains. The length of the tensile zone (increase in gas evolution) before the treatment face on wells 4e and 5e is about 60 m. The length of the compression zone (decrease in gas emission) is from 40 to 50 m (see Fig. 2 and Fig. 5). The duration of the period of change of tensile deformations by compression deformations is 33 days and is close to its calculated value [1].

From the graphs of changes in methane flow through wells 2e, 4e, 5e, 6e, we have that the highest flow was observed in the zones of tensile deformation. The most efficient was the well 5e, which was first located in the stretching zone of the DST rocks 15 longwall, which shifted, and then in the stretching zone 16 longwall. These stretching zones were formed under the influence of the formed clamping console at the boundary of the mined-out space along the preparatory work (see Fig. 1). The maximum flow rate (14 m^3/min) was obtained at well 5e at a distance of 86 m from the treatment face as it approached the well.

During the period of experimental research, 2.5 million m^3 of pure methane were extracted through degassing wells 2e, 4e, 5e and 6e. Comparison of the results of control of CH_4 content in the outlet air flow of 15 longwall and with the use of advanced degassing in 16 longwall showed a decrease in methane concentration from 1.3% to 0.5-0.7%.

Conclusions. According to the results of the research, the following has been established: advanced degassing of the main roof rocks at great depths should be carried out in areas adjacent to the mined-out space along the preparatory work. It is necessary to take into account the patterns of rock shear in the DST:

- the process of man-made cracking in the overhanging massif, when moving the clearing face at this speed, occurs to a certain height;
- along the whole and above it to the zone of manifestation of the reference rock pressure (zone of compression deformations) under the influence of tensile deformations a strip of the zone of stratification of rocks is formed. Free methane accumulates in this zone, which flows from the massif by man-made cracks;
- in front of the zone of reference rock pressure from cleaning works, similar processes take place in the roof of the formation.

Rocks that lie above the main roof (the main geological object, sandstone $m_4Sm_4^1$, which contains methane), do not lose their continuity during shear, are gas-resistant and contribute to the accumulation of free methane. The accumulation of free methane occurs in the zones of tensile deformations (stratification of rocks), both already worked and the mass of rocks that are worked.

Wells located in the zone of tensile deformations of the DST of the worked-up massif, and then in the zone of its re-working have the highest productivity and duration of gas evolution. Wells drilled in the zone of compression deformation do not provide the efficiency of degassing of the main roof rocks. The distance between the degassing wells should be such that there is no or minimal man-made and gas-dynamic connection between them. In the conditions considered by us it should make 55-60 m.

The use of advanced degassing of $m_4Sm_4^1$ sandstone containing methane by wells allowed to reduce the methane content in the output air flow of the site from 1.3% to 0.5%, to remove and dispose of 2.5 million m^3.

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ОЦІНКА ЕФЕКТИВНОСТІ ВИПЕРЕДЖАЮЧОЇ ДЕГАЗАЦІЇ У ЗОНАХ ВПЛИВУ ДЕФОРМАЦІЙНИХ ПРОЦЕСІВ

Зберовський В.В., Четверик М.С., Власенко В.В., Змієвська К.О., Дудля К.Є.

Анотація. На прикладі результатів експериментальних досліджень в умовах великих глибин шахт Донецького басейну розглянуто взаємозв'язок параметрів випереджувальної дегазації та деформаційних процесів в породах покрівлі при відпрацюванні вугільного пласта.

Мета роботи - встановити ефективність випереджувальної дегазації в залежності від розташування дегазаційних свердловин у зонах розтягування та стискання гірських порід у геологічній товщі, що підпрацьовується.

У роботі розглянуто вплив техногенних процесів, що відбуваються у масиві гірських порід попереду очисного вибою та вздовж цілика раніше відпрацьованої лави. Встановлено, що процес техногенного утворення тріщин у нависаючому масиві при переміщенні очисного вибою відбувається до певної висоти зі швидкістю переходу деформацій розтягувань у деформації стиснення. Уздовж цілика і над ним до зони прояву опорного гірського тиску (зони деформацій стиснення) формується область (смуга) впливу зони деформацій розтягувань та розшарування гірських порід. У цій частині масиву відбувається акумулювання вільного метану, який техногенними тріщинками перетікає із зони стиснення в зону розтягування. Попереду очисного вибою відбуваються аналогічні техногенні процеси. Зміна зон стиснення зонами розтягування призводить до інтенсивної фільтрації вільного метану та його накопичення у зонах розшарування. При посадці блоку основної покрівлі газ із зони розшарування виділяється у вироблений простір лави. Свердловини, що розташовано в зонах деформацій стискання, не забезпечують ефективну дегазацію порід покрівлі. Свердловини, які розташовані в зоні деформацій розтягування підпрацьованого масиву, мають найвищий дебіт та високу концентрацію метану. При повторному підпрацюванні таких свердловин їх ефективність та термін служби зростають.

Рекомендується застосовувати випереджальну дегазацію порід покрівлі свердловинами, які розміщуються в зонах розтягування гірських порід на межі з виробленим простором. Відстань між дегазаційними свердловинами має бути такою, щоб між ними був відсутній або був мінімальний техногенний та газодинамічний зв'язок. У розглянутих нами умовах вона має становити 55-60 м.

Ключові слова: випереджаюча дегазація, динамічна мульда зсування (ДМЗ), деформаційні процеси, зони нашарування.

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