RESEARCH ARTICLE OPEN ACCESS

The Role of Ventilation Schemes for Mining Areas in Ensuring Safe Conditions for the Development of Gas-Bearing Coal Seams

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Abstract:

Over the past more than fifty years, it has been experimentally established that gas release from sources undermined by treatment works can occur both in the workings and degassing wells of the exploited areas, and outside them into the worked-out space of worked longwalls. It is theoretically substantiated and confirmed by the practice of mining gas-bearing coal seams that the cause of gas release outside the exploited mining areas is the activation (repeated) movement of the undermined coal-rock strata. Additional gas release outside of the exploited mining areas during the activation of rock movement is not considered by modern regulatory documents when developing measures for the safe development of gas-bearing coal seams, which significantly reduces their efficiency. It is a great technical difficulty to single out two components of the gas balance within the boundaries of the exploited excavation area and outside it in mine conditions. The safe development of a coal deposit largely depends on the successful solution of this problem. Until now, the quantitative ratio of gas emission within the boundaries of the operated site and outside it, under the influence of the ventilation schemes used, has not yet been established. Based on experimental observations, a relationship was established between the level of gas release within the boundaries of excavation areas and beyond, depending on the ventilation schemes used.

Keywords **—** Underworking, Strata, Activation, Movement, Gas Release, Workings, Mine, Areas, Scheme, Ventilation.

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I. INTRODUCTION

Variants of ventilation schemes for coal mines in accordance with the regulatory document [1] during the development of gas-bearing seams are classified according to the degree of separate dilution of hazards by the sources of their entry into the mine atmosphere and the ratio between the directions of movement of outgoing and fresh ventilation air jets. The disadvantage of the classification [1] is the consideration of ventilation air jets only within the mine workings of the operated extraction area. Purification works can cause increased gas emission both within the mining area and beyond its boundaries [2-8].

Until now, the influence of ventilation schemes for mining areas on the distribution of gas release between local and general mine workings has not been sufficiently studied. The study of the processes of distribution of gas emission between local and general mine workings is relevant, since the creation of safe conditions for the development of coal seams in terms of the gas factor depends on them.

II. THEORETICAL PART

According to many researchers, one of the main reasons for gas release outside the mining areas is the activation of the movement of undermined rocks [2,5,8,9]. The available information in the literature on gas showings during the activation of rock displacement [8, 10] does not allow us to draw definite conclusions about the possible ways of combating such hazards in mines. The hypothetical schemes describing the processes of activation of rock displacement and gas release are somewhat different from each other, but they complement each other. According to [8], as a result of the extinguishing of the stratification cavities, gas release caused by the activation of rock displacement occurs behind the production face. Experimental data [10] indicate that gas release caused by repeated rock displacements can occur along the entire boundary of the goaf of worked-out mining areas. In both cases, gas spinning is the result of the activation of rock displacement. In the first, it occurs in the goaf behind the operated working face, in the second, as a rule, a significant part in the goaf of previously worked longwalls.

Experimentally distinguishing two components of the gas balance within the boundaries of the mining area is a great technical difficulty. One component is a consequence of the primary displacements of rocks, the second is the result of their activation.

The activation of the displacement of the rock mass and the earth's surface occurs during repeated underworking, when the underworking is located on another seam (above or below the initially worked out), or when developing one seam by adjacent workings. The main reason for the activation is the altered physical and mechanical properties and the destruction of rocks during their primary processing. The manifestation of the activation of rock displacement according to [11,12] can be divided according to the following conditions:

- development of one seam by adjacent workings;
- development of the formation suite;
- conducting mining operations in the zones of influence of coal pillars left on adjacent seams.

To establish the features of gas release during the activation of the movement of rocks, it is necessary to carry out long-term (throughout the entire time of mining the extraction areas and after their shutdown) monitoring the release of methane into mine workings and degassing wells of operated and spent lavas.

Currently, there is experimental data on gas release from the mined-out space of shut-in longwalls during the operation of mining areas in one layer. The manifestation of such gas release was established during the development of anthracite layers of the Torez-Shakhtyorsky [7] and Bokovo-Khrustalsky industrial regions [4,5,9,10]. The observations were carried out in particular during the development of anthracite seams by the mines named after newspapers Izvestia, Khrustalskaya, Almaznaya.

Gas emission from the mined-out area of stopped mining areas during the operation of adjacent longwalls was also observed during the development of gas-bearing formations for grades D and G by the Chaikino and Krasnolimanskaya mines [10], this indicates that gas emission caused by the activation of rock movement during the operation of adjacent longwalls typical for all gas-bearing strata containing coal of all grades from D to A.

For the case under consideration, the development of seams by adjacent longwalls is characterized by gas release not only into the mine workings of the shut-in and operated areas, but also into the degassing wells of the exhausted longwalls [3,13]. This is a direct experimental confirmation of gas release during the activation of rock movement outside the exploited mining areas.

During the development of adjacent seams, some features of gas release were established, due to the formation of different zones of activation of rock displacement. They depend on the relative position of the seams in the suite and coal pillars left during the development of adjacent seams [4, 14]. The formation of zones of activation of rock displacement and re-gas release from underworked rocks is also associated with the degree of their underworking, the size of the worked-out space and the order of lava mining in the wing of the mine field [15, 16].

The well-known theoretical schemes for the displacement of undermined rocks and experimental data on gas release from undermined sources indicate that gas release upon activation of rock displacement is manifested as a result of their primary and secondary displacements. During the development of the first longwall in the mine field, all gas release from the undermined sources occurs under the influence of primary rock displacements. The commissioning of the next longwall causes the activation of the movement of rocks and the formation of additional zones of gas release in front of and behind the working face, as well as along the contour of the boundaries of the worked-out space of the worked-out longwalls. In this case, gas release from undermined sources can occur both under the influence of primary rock displacements and during their activation. Depending on the ventilation schemes of the excavation areas and their location relative to the main air supply and air exhaust mines, gas emission can occur both in the development of the operating excavation area and beyond.

The effectiveness of the recommended [1] ventilation schemes for excavation areas, as practice has shown [2,17,18-20], did not always correspond to the mining-geological and mining conditions of their application. In addition, the requirements for the choice of ventilation schemes for gas-rich areas during the development of mine layers prone to spontaneous combustion are controversial [21].

The optimal choice of ventilation schemes for mining areas is one of the main factors ensuring the safety of mining operations. The solution to this problem is especially relevant in the presence of gas release under the influence of the activation of rock displacement, since until now the influence of ventilation schemes of exploited areas on the share of gas release in local and general mine workings has not been quantitatively established. An easy way to comply with the conference paper formatting requirements is to use this document as a template and simply type your text into it.

III. PURPOSE AND RESEARCH METHODOLOGY

Purpose - on the basis of experimental observations, to establish a possible relationship between the level of gas release within the boundaries of the excavation area and beyond, depending on the ventilation schemes used.

The analysis involved experimental data on gas release into mine workings and degassing wells during the development of seam l2 in the 8th and 9th western faces of the mine named after newspaper "Izvestia" State Enterprise "Donbassanthracite". The 0.9 m thick anthracite seam was mined by long pillars by uprising. The main gas release (more than 90%) occurred from the undermined coal-rock strata.

IV. RESEARCH RESULTS AND DISCUSSION

According to the classification [1], the operation of the excavation section of the 8th western longwall was carried out with a sequential dilution of hazards, a combined direction of an air jet outgoing from a longwall, dependent ventilation of a working mine, horizontal movement of an air jet in the face space, return flow direction of fresh and outgoing air jets.

Similar classification features were characteristic of the 9th western lava. The exception was the uncertainty in establishing the ventilation class of the mine working - independent or dependent ventilation. According to [1], the operation of a single longwall belongs to an independent class of ventilation. The development of the 9th western longwall in the wing of the mine field took place with an aimless excavation of the seam and the absence of cleaning work in other mining areas. In this regard, the question arose - "Is the 9th western lava single in the presence of gas release from the worked-out spaces of previously stopped lavas?" In this case, there is no unambiguity in the definition of the concept of a single longwall. There is no doubt about the term "single lava" if it is worked out first in the wing of the mine field. These criteria were met by the operating conditions of the 2nd western longwall. The analysis involved information on gas release into mine workings and degassing wells within the boundaries of this area. Methane release within the boundaries of the mining area corresponded to gas release in the wing of the mine field. According to the accepted classification, during the development of the 2nd western longwall, an isolated complete dilution of hazards, the issuance of an outgoing ventilation air stream to the worked out space, independent ventilation of the working mine, horizontal air movement along the bottomhole space, direct-flow direction of fresh and outgoing air jets.

The main factors determining gas release include the development of cleaning works at the mining area (removal of the bottom hole from the split furnace) and an increase in coal production until the planned indicators are reached after the start of operation of the mining area [22].

The growth of coal production in the mining areas of the 2nd, 8th and 9th western longwalls after the start of their operation was characterized by one general equation (Fig. 1):

$$A = 1207(1 - e^{-0,02L}) \text{ , t/day,} \quad (1)$$

where 1207 is the planned level of coal production, t/day;

0.02 is an empirical coefficient characterizing an increase in production to planned indicators when removing (*L*) the working face from the split furnace.

The correlation ratio (*R*) for equation (1) was 0.92, which indicates the identity of the influence of coal mining and the removal of working faces from the open-cut furnaces on the level of gas emission during the operation of mining areas of the 2nd, 8th and 9th western longwalls. This assumption was confirmed for gas release in the wing of the mine field during the operation of the 8th and 9th western longwalls. It was described by the general equation:

$$I_{кр} = 53,1(1 - e^{-0,02L}) \text{ , m}^3\text{/min} \quad (2)$$

where 53.1 is the gas emission level corresponding to the planned coal production, m^3/min;

0.02 is an empirical coefficient characterizing the change in gas evolution with the distance (*L*) of the working face from the split furnace.

The tightness of the relationship between the parameters $I_{кр}$ and *L*, described by equation 2, was characterized by a high value of the correlation ratio ($R = 0.98$).

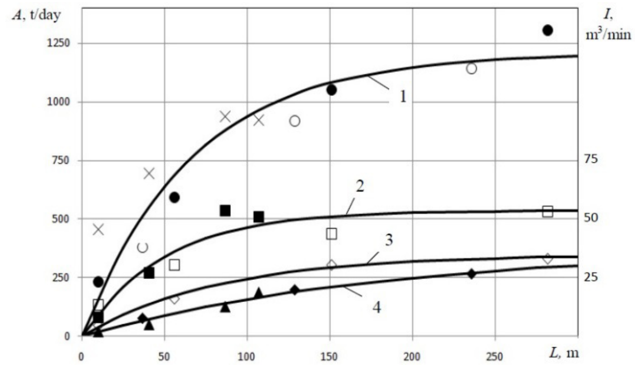

Figure 1 - The dependence of the change in coal production (*A*) and methane release in mine workings and degassing wells (*I*) on the removal (*L*) of the working faces from the split furnaces during the development of the seam by the mine. newspaper "Izvestia".1 - averaging curve of change in coal production; ○, ●, × - experimental data for the operation of the 2nd, 8th and 9th western lavas, respectively; 2 - curve of gas evolution in the wing of the mine field during the operation of the 8th and 9th western longwalls; □, ■ - experimental data; 3 - curve of gas evolution within the mining area of the 8th western longwall (point 4, Fig. 2); ◊ - experimental data; 4 - curve of gas evolution within the mining areas of the 2nd and 9th western lavas; ♦, ▲ - experimental data.

Gas release within the excavation area during the operation of the first (single) 2nd western longwall in the mine field was in essence equal to the methane release in the mine field wing. If we compare the gas release in the area of the 2nd western longwall with methane release within the cut areas of the 8th and 9th western longwalls with the same influence of A and L, then only two factors could affect their differences - the presence of mined-out spaces of stalled lavas and the use of different options for ventilation schemes.

Different variants of ventilation schemes for the 8th and 9th western longwalls, 1-K-Z-g-w and 1-K-N-g-w, respectively (Fig. 2), did not affect the level of gas release in the wing of the mine field.

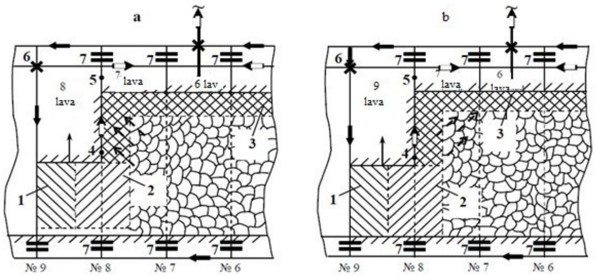

Figure 2 - Ventilation of the excavation areas of the 8th and 9th western longwalls of the seam at the mine named after newspaper "Izvestia" SE "Donbassanthracite". a) - according to the scheme 1-M-Z-g-W with the direction of air leaks through the worked-out space of the worked-out longwalls to the section working; b) - according to the scheme 1-M-N-g-W with the direction of air leaks through the worked-out space of the worked-out longwalls from the section working; ⬅ - fresh ventilation air stream; ➡ - outgoing ventilation stream of exhaust air; ↑ - direction of moving faces; – – ► - direction of air leaks through the goaf; 1 - zone of gas release from adjacent layers and enclosing rocks during their primary processing; 2, 3 - zones of gas release during the activation of rock movement, respectively, after the passage of the working face and in front of it; 4, 5 - points for measuring gas emission in mine workings; 6 - crossing; 7 - ventilation doors; No. 6 - No. 9 - slope numbers, respectively, from 6th to 9th.

The different direction of air leaks through the worked-out space of the stopped longwalls influenced the level of gas release in the workings of the exploited sections. With the ventilation scheme 1-K-Z-g-w in the local outgoing ventilation air stream of the 8th western longwall at point 4, gas came from the worked-out space of the exploited longwall and partially from the worked-out space of the stopped longwalls (Fig. 2, a). The main share of gas release from the worked-out space of the stopped longwalls occurred dispersed along the length of the ventilation tunnel between points 4 and 5. The gas release in point 5 corresponded to gas release in the mine field wing and was described by equation 2.

When ventilating the excavation section of the 9th western longwall according to the 1-K-N-g-t scheme and the direction of air leaks from the section, point 4 (Fig. 2, b) received the main amount of gas from the worked-out area of the operated longwall. The methane coming from the mined-out space of the shut-in longwalls was almost completely removed by air leaks outside the operating area. This is confirmed by the general dependence (curve 4, Fig. 1) of gas release within the mining areas of the 9th and 2nd western lavas:

$$I_{уч} = 28,9 \cdot (1 - e^{-0,01L}) \text{ , m}^3\text{/min,} \quad (3)$$

where 28.9 - gas release within the mining areas of the 2nd and 9th western longwalls when removing (L) working faces from the split furnaces and reaching the planned loads;

0.01 is an empirical coefficient characterizing gas release within the boundaries of mining areas.

Equation 3 corresponds to a high correlation ratio (R = 0.99), which indicates the absence of gas release into the section workings from the mined-out spaces of stopped longwalls when using the 1-K-N-g-W scheme.

When applying the ventilation scheme of the 8th western longwall 1-К-З-г-т at point 4 (Fig. 2, a), additional gas was released from the worked-out area of the worked-out longwalls. This is confirmed by statistical processing of experimental data (curve 3, Fig. 1):

$$I_{уч} = 35,0 \cdot (1 - e^{-0,01L}) \text{ , m}^3\text{/min,} \quad (4)$$

where 35.0 - gas release at point 4 (Fig. 2, a) upon reaching the planned loads and applying the ventilation scheme 1-K-Z-g-w;

0.01 is an empirical coefficient characterizing the change in gas evolution in point 4 (Fig. 2, a).

Empirical equation 4 (curve 3, Fig. 1) is characterized by a high correlation ratio (R = 0.99), which is a confirmation of the flow of gas from the worked-out space to point 4, both operated and worked-out longwalls.

Comparison of the empirical coefficients of equations 3 and 4 (28.9 and 35.0, respectively) indicates that by changing the direction of air leaks through the mined-out space of stopped longwalls, it is possible to reduce gas release at point 4 (Fig. 2), as well as to exclude the diffuse inflow of methane into a local mine with an outgoing ventilation air stream along its entire length.

V. CONCLUSIONS

Based on the research carried out, the following conclusions were made:

- the ventilation scheme of excavation areas, all other things being equal, does not affect the level of gas emission in the wing of the mine field;

- the ventilation scheme of the mining area affects the distribution of methane release between local and general mine workings. The minimum gas release within the mining area is observed when the action of the general mine depression is directed from the worked-out space of the exploited longwall towards the worked-out spaces of the worked-out longwalls;

- the presence of mined-out spaces of previously stopped longwalls during the operation of a separate extraction area activates the processes of displacement of underworked rocks and can lead to a significant increase in gas release (more than 2 times) in the wing of the mine field;

- depending on the options for ventilation of the excavation area, from 50 to 100% of the amount of gas released in the wing of the mine field is released within its boundaries.

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