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THE METHOD TO CALCULATE WATER CONSUMPTION FOR ANTI-SPARK SPRAYING OF A MINING COMBINE

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Abstract. The article presents the results of theoretical studies on water consumption by the internal spraying system of coal mining combines, which provides protection against ignition (explosion) of dust-methane-air environment during the coal extraction.

The evaluation of water consumption for preventing explosion due to heating of the mining combine cutter and cutting trace is based on the assumption that all the drive energy is spent solely on heating the cutter and cutting trace. This method is applicable only when the cutter and the spraying nozzle are located coaxially. This evaluation method, proposed herein for the first time, was previously published by the authors.

The evaluation of water consumption required to prevent explosion caused by incandescent sparks during the mining combine operation is based on the safe concentration of water vapor per cubic meter of air, which phlegmatizes the explosion from heated sparks. This value was determined in previous publications by standard regulatory methods of fire protection. The transition from a safe concentration of water vapor to a safe concentration of water droplets in a cubic meter of air was also described in previous publications. It is based on theoretical studies of the mass evaporation rate of a droplet during the induction period of the ignition delay. The resulting baseline value of the explosion-safe concentration of water droplets is applicable for any mutual location of the nozzle and the cutter. Its main determining parameter is the temperature of the heated medium surrounding the spark. In practice, the temperature of the heated medium cannot be determined theoretically with sufficient accuracy. Therefore, it is determined empirically. At this stage of the research, a widely used estimate of the limits of methane combustion in open space within the range of 850–900 °C was used. These limits may be refined in further studies.

The minute air flow rate for washing the longwall face in zone of operation of the combine drums is determined for the first time by the rate of methane release from the coal seam. This value is included in every project for comprehensive gas removal from the excavation zone, which is developed individually for each longwall. It is assumed that all methane is released only in zone of the drum operation. That is, the minute air flow rate in the zone of drum operation is calculated with a certain safety margin.

The results of this study, which for the first time make it possible to calculate the parameters of explosion-preventing spraying, are relevant for determining the water consumption for spraying layers with relatively low dust-generation capacity, but with essential wet softening of floors and roofs (as in Pavlohrad mines, Ukraine). For them, the nominal water consumption used by spraying systems of imported combine is too high and can cause great complications in moving the roof support sections and the face conveyor.

Keywords: explosion safety, dust-methane-air mixture, frictional sparking.

1. Introduction

During the recent years, the mining and technical conditions for developing coal deposits in Ukraine have undergone significant changes. The mining of highly dust-generating seams and host rocks has ceased. At the same time, host rocks have become more wetted. Wet softening of the seam floor leads to a noticeable decrease in their bearing capacity and causes heaving. This complicates the movement of sections of the longwall supports and the face conveyor, especially if the floor gets wetted.

There are two main reasons for the longwall floor wetting - natural water inflows and coal spraying during its extraction.

The water consumption of the spraying system in modern combines is comparable to natural water inflows and significantly worsens the condition of the longwall floor, hence, complicating mechanized coal extraction. But to justify a reduction of the wa-

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ter consumption for spraying, its comprehensive substantiation is required, since its rate is specified in the current regulatory document.

The requirements for the spraying parameters of mining machines were established about half a century ago, during the Soviet Union times [1], and have not undergone significant changes since then. In other coal-mining regions of the world, for example in the USA [2] and China, there are their own norms for specific water consumption [3]. They are based on the same sanitary and hygienic principles as the Soviet ones, and differ only in the values of dust generation of local seams.

The currently valid Ukraine regulatory documents НПАОП 10.0-5.23-04 [4, 5] contain only two requirements for spraying systems of mining combines - water pressure not lower than 1.2 MPa, and its specific consumption within the range of 30–40 liters of water per ton of extracted coal, which are the same as half a century ago. The M.S. Poliakov Institute of Geotechnical Mechanics of the National Academy of Sciences of Ukraine (IGTM, NASU) has recently substantiated [4, 6] the feasibility of reducing the specific consumption rate to the level of 20–27 liters of water per ton of broken coal without worsening the sanitary and hygienic working conditions for workers.

However, in addition to dust suppression, spraying prevents ignition and explosion of a mixture of air with methane and coal dust during the combine operation [7]. However, the regulatory documents do not specify the water consumption rate required for this purpose. In Ukraine, some recommendations on this issue are available [8], which are not officially approved, since they are based purely on the results of experiments for an irrational arrangement of spraying nozzles and do not take into account the conditions of specific coal mines and seams. Moreover, the current regulatory documents do not include any norms of spraying water consumption as regard to explosion safety factor. It may therefore turn out that the minimum specific water consumption [4–6] according to sanitary and hygienic requirements will not be enough to prevent explosion or ignition.

Purpose of this work is to create scientifically substantiated criteria for evaluating water consumption by spraying systems in mining combines in order to prevent ignition and explosion of a mixture of methane with air and coal dust.

2. Methods

There are two sources of ignition or explosion of the methane-dust-air mixture during the operation of mining machines [9–11] - heating of the cutter and cutting trace to a high temperature, and incandescent sparks from rocks.

The methods for calculating water consumption to prevent ignition or explosion from these two factors are considered in detail in works [12–14] for roadheaders and can be taken as the basis for calculations for mining combines.

In particular, the calculation of water consumption to prevent explosion due to heating of the cutter and cutting trace of the roadheader is based on the thermal balance model [12]. Drive energy of the actuator E_a is spent on the useful (work of rock destruction E_u and on heat losses – namely, heating of the cutter Q_c, the cutting trace Q_t and heating of the rock mass Q_m around the cutting trace. The first and last factors can be neglected, assuming that all the energy of the drive is spent only on heating the cutter and the cutting trace.

Then, the water consumption for internal spraying per one drum of the mining combine q_t (l/min) is determined by formula (11) from reference [12]. Taking into account the numerical values of general physical quantities, it can be expressed as

$$q_t = 0.093 k_o N_d \tag{1}$$

where N_d – nominal power of the drive of one drum (kW); k_o – coefficient of nozzle spray overlapping.

With coaxial location of the nozzle and the cutter, as well as the maximum spray cone angle, k_o = 3. If the nozzle axis is turned towards the leading furrow, and the spray cone angle is less than the maximum, but greater than the usual one, then k_o = 2. In the case of a nozzle with a standard spraying cone, which is located coaxially with the cutter, then k_o =1.

Calculation of water consumption to prevent explosion from incandescent sparks during the operation of excavation machines is based on the basic parameter – the required concentration of water vapor in a cubic meter of heated air around the incandescent spark, which can phlegmatize (suppress) the explosion. This value was determined in work [13] according to the standard fire protection method for determining the phlegmatizing concentration of water vapor in a methane-air mixture [14].

The transition from the phlegmatizing concentration of water vapor in heated air to the concentration of water droplets in air with a normal temperature q was carried out in [15] by estimating the amount of vapor formed from droplets during the induction period of the ignition delay, according to the relation

$$\begin{cases} q = \dfrac{8.2222}{10^8} t^3 - \dfrac{2.08285714}{10^4} t^2 + 0.176865873016t - 49.967619047635; d = 165 \mu m \\ q = \dfrac{6.0741}{10^8} t^3 - \dfrac{1.48809524}{10^4} + 0.121483862434t - 32.671587301609; \ d = 43 \mu m, \end{cases} \tag{2}$$

where t is the temperature of the heated medium, °C; d is the equivalent droplet diameter, μm.

The upper equation applies to conventional spraying nozzles, the lower one -to ejectors.

The required mass evaporation rate was calculated not according to the classical Sreznevsky formula [16], but according to modern data in [17].

If the indicator of the phlegmatizing concentration of water droplets in a cubic meter of air q is multiplied by the minute air flow rate V (m^3) for washing the drum of the mining combine, we obtain the water consumption for anti-spark spraying by one drum

$$q_s = qV. \tag{3}$$

That is, the problem reduces to determining the maximum air flow rate V in zone of operation of the mining combine drum, which is dangerous in terms of the explosion factor.

For drivage faces, the dangerous air flow rate V used for washing zone destructed with the cutting head was determined in [18] on the basis of three given values – the total minute air flow rate for the zone ventilation V_v, the level of safe methane concentration in the outgoing stream C_s =1% and the explosively dangerous concentration of methane in the air in the destruction zone $C_{e.d.}$ =4% . The methane flow rate into the destruction zone was not specified directly, it was determined from these three parameters. Such a calculated determination of the methane flow rate is possible due to two circumstances - firstly, the predominant localization of methane release near the face, and secondly, the absence of leaks and inflows into the outgoing air stream during drivage through the stable cross-section.

Neither of these circumstances applies to mining combines operating in a longwall. A mining combine operates simultaneously with two drums, the distance between which exceeds the cross-sectional size of the gate road. In addition, one of the drums (the leading one) cuts the coal by the full seam thickness, while the second (the trailing one) – cuts only partially, because the seam thickness is less than the total diameter of both drums.

Since the longwall has only one side wall, which is destroyed by the combine, and on the opposite side, a goaf is formed, the cross section of the air stream is neither stable nor constant along the longwall. Distribution of air velocity across the longwall cross-section is highly non-uniform. Part of the air moves outside the nominal cross section of the longwall through the goaf, that is, the actual cross section of the roadway exceeds the nominal. But even greater deviations from the uniform distribution of the air velocity are observed in the area of the combine body, and especially near its cutting drums. In past studies, the Makiyivka Research Institute thoroughly studied this issue. In its summary work [8], it was noted that in the zone of twin cutting drums, the minimum values of the air velocity are 0.15–0.3 of its maximum value, if the combine moves against the ventilation stream, and when moving in the opposite direction, this ratio increases to 0.7–0.8. For separated cutting drums, when the combine moves against the air flow, the minimum values of the air velocity near the leading drum are 0.2–0.3 of its maximum value, and for the trailing drum, they are 0.4–0.5. And when moving in the opposite direction, this ratio increases to 0.3–0.5 for the leading drum. The information provided well illustrates the complexity of determining the air flow rate in the zones of operation of the cutting drums of mining combines.

These circumstances invalidate the method for determining the methane flow rate in zones of rock destruction by the cutting drums, which was used for the roadheading.

Therefore, we adopted a different approach, which proposes to determine the maximum dangerous minute air flow rate for washing the longwall face in the drum operation zone by using the widely used indicator of methane release from the working face I_{wf} [19–22]. This value appears in every project of comprehensive gas removal from the extraction area, which is developed for each longwall.

The indicator of methane release from the coal seam I_{wf} consists of methane release in zone of the cutting drum operation and methane release from the rest of the seam surface and the goaf. Although not all the methane taken into account by the indicator $\bar{I}_{wf}$ is released in zone of the cutting drum operation, we neglect the methane release from the rest of the seam surface and the goaf and assume that I_{wf} is equal to the release of methane only in the drum operation zone. That is, with this approach, the indicator of the minute air flow rate in the drum operation zone will be calculated with a certain margin.

The maximum air flow rate V in the cutting drum operation zone in terms of the explosion danger factor was determined by I_{wf} using standard algebraic calculations.

4. Results and discussion

The total diameter of the cutting drums over the cutters of the mining combine is greater than the thickness of the coal seam, so the leading cutting drum works with a full seam thickness, while the trailing one – only with a part of the seam thickness. Accordingly, the methane release from the leading cutting drum is greater than from the trailing one. We assume that methane release from the leading front cutting drum I_{fd} correlates with the methane release from the trailing rear cutting drum I_{rd} as the thickness of the layers that are extracted by them. For the front cutting drum, the thickness of the layer being extracted is equal to its diameter over the cutters *D*, and for the rear drum, it equals the difference between the thickness of the seam and the thickness of the layer extracted by the front cutting drum *H-D*

$$\frac{I_{fd}}{I_{rd}} = \frac{D}{H - D} \tag{4}$$

and the sum of these values should be equal to the methane release from the coal seam

$$I_{fd} + I_{rd} = I_{wf} \ . \tag{5}$$

By solving the system of equations (4, 5), we obtain

$$\begin{cases} I_{fd} = I_{wf} \dfrac{D}{H}; \\ I_{rd} = I_{wf} \left(1 - \dfrac{D}{H} \right). \end{cases} \tag{6}$$

The analysis (6) shows that in the zone of action of the front cutting drum, the release of methane is noticeably greater than in the zone of the rear cutting drum.

For each cutting drums, we write an obvious equation for determining the minute air flow rate at the lower limit of the methane explosive concentration $C_{e.d.}$

$$\begin{cases} V_{fd} \le 100\dfrac{I_{fd}}{C_{e.d}}; \\ V_{rd} \le 100\dfrac{I_{rd}}{C_{e.d}}. \end{cases} \qquad (7)$$

The obtained system of equations (7) determines the maximum air flow rate in zone of the coal mass destruction by the front V_{fd} and rear V_{rd} drums of the mining combine.

The second rows of the systems of equations (6, 7) are relevant only if the combine is equipped with drums of different diameters and with different numbers of spraying nozzles.

Here, a fundamental remark should be made. The values of V_{fd} , V_{rd} in equations (6, 7) should not be considered as the actual air flow rates in the zone of combine drum operation. These are the maximum calculated values of possible air flow used solely for determining the required water consumption for the spraying system. The actual air flow rate may be greater than the calculated one, but in this case the methane concentration will not reach the explosive level. Therein, it is not necessary to adhere to the content of water droplets in the air according to formulas (2), since neither an explosion nor an ignition will occur anyway. Conversely, if the actual air flow is less than the calculated one and the methane concentration reaches explosive levels, then the content of water droplets specified by (2) must be strictly adhered to. However, according to formula (3), the water consumption for phlegmatization will be less, because the air flow is less than for V_{fd} , V_{rd} in equations (6, 7).

Thus, although the calculated values of V_{fd} , V_{rd} in equations (6, 7) are not identical to reality, they make possible to reliably determine the required water consumption for explosion-preventing spraying of excavation machines (both mining and roadheading).

Knowing the maximum calculated value of the possible air flow rate in the zone of destruction by the leading cutting drum, it is possible to determine the water flow rate q_{fd} for this drum using formula (3) and the first row of (7)

$$q_{fd} = 100q\frac{I_{fd}}{C_{e.d}} \qquad (8)$$

and substituting the value of I_{fd} from formula (1.6) into the last expression, we obtain

$$q_{fd} = 100q\frac{I_{wf}}{C_{e.d}}\frac{D}{H}. \qquad (9)$$

The total water consumption for explosion-preventing spraying does not require the summing of the water consumption for spraying of the cutting trace qt according to formula (1) with the water consumption for phlegmatization of sparks for q_{fd} according to formula (9) because q_{fd} contains already the portion of water evaporated on the cutting trace q_t . This was substantiated in detail for roadheaders in the last year report on this topic.

Taking into account the possibility of some nozzles failing during a continuous coal mining cycle - handled in the same manner as it was done for the roadheader in the previous report - and the assumed explosion-preventing concentration of methane $C_{e.d.}$ = 4%, we obtain the final formula for the flow rate of internal anti-spark spraying of the leading cutting drum

$$q_{fd} = 25qI_{wf}\frac{D}{H}\frac{S_{nom}}{S_w}, \quad (10)$$

where q is the safe specific content of droplets in the air, l/m^3, determined by formulas (2); I_{wf} is the rate of methane release from the coal seam, m^3/min; D is the drum diameter by cutters, m; H is the seam thicknes, m; S_{nom} is the nominal number of nozzles on the auger; S_w is number of nozzles remaining operational at the end of the excavation cycle.

This formula determines the water consumption provided that all nozzles remain operational throughout the entire excavation cycle. In practice, this is not the case: during the excavation cycle, some of the nozzles become clogged. The minimum number of operational nozzles S_w, which still provides explosion protection, is determined by formula (10) by the nominal water consumption q_{nom} for internal spraying of one drum

$$S_w = 25qI_{wf}\frac{D}{H}\frac{S_{nom}}{q_{nom}}. \quad (11)$$

As an example, let's calculate the required water consumption for an explosion-preventing standard internal spraying system for the MB-630 combine using formula (10). The combine worked in the mines of the PJSC PJSC "Pokrovske Mine".

The combine with a drum diameter by the cutters D = 1.25 m and with a total number of internal spraying nozzles of 102 (S_{nom} = 51 nozzles.) was used in the 13th southern longwall of block 10, seam d4 with an average thickness of 1.42 m and a minimum thickness of 1.3 m. The average methane release from the layer is I_{wf}=5.23 m^3/min. The planned productivity P_k of the combine is 4500 t/day, or 5 t/min.

The safe specific content of droplets in the air determined at a temperature of the heated environment of 900 °C according to the above formula (2) for conventional nozzles is q = 0.43 l/m^3.

The required water flow rate of the leading cutting drum q_{fd} under the condition that no nozzle fails during the excavation cycle, $S_w = S_{nom} = 51$ nozzles, is calculated by the formula (10)

$$q_{fd} = 25 \times 0.43 \times 5.23 \times \frac{1.25}{1.3} \times \frac{51}{51} \approx 54 \ l/min \qquad (12)$$

The obtained minimum explosion-preventing consumption q_{fd} is lower than the nominal q_{nom} = 63 l/min for one drum of the MB-630 combine, so not all nozzles need to remain operational throughout the excavation cycle.

The maximum number of operating nozzles S_w, which still provides explosion protection, is determined by the formula (11)

$$S_w = 25 \times 0.43 \times 5.23 \times \frac{1.25}{1.3} \times \frac{51}{63} \approx 43 \, pieces \qquad (13)$$

That is, the reserve of the combine MB-630 for nonoperating nozzles is ≈ 18%.

Let's check the water consumption for explosion-preventing spraying of the cutting trace q_t by formula (1). The drive power of the drum of the combine MB-630 is N_d = 280 kW, the characteristic of the nozzle spray will be considered normal with k_o=1, so

$$q_t = 0.093 \times 1 \times 280 \approx 26 \ l/min \qquad (14)$$

As we can see, q_t is about twice lower than q_{fd}. Therefore, q_{fd} already contains q_t, and the minimum explosion-preventing flow rate for one spraying drum is determined by formula (12) and not by formula (1).

Thus, the nominal flow rate of the internal spraying system of the combine MB-630 ensures explosion safety during coal mining with a margin of at least 16%.

Finally, let's check whether the water consumption of the internal spraying system alone is sufficient to meet the sanitary and hygienic standards [3] by the dust factor. Total water consumption for internal spraying by both drums of the combine is

$$Q_t = 2q_{nom} = 2 \times 63 = 126 \ l/min \qquad (15)$$

And the specific nominal water consumption per ton of extracted coal for internal spraying system of the MB-630 combine is

$$q_{sc} = Q_t / P_к = 126/5 \approx 25 \ l/t \qquad (16)$$

It is 5 l/min less than the minimum limit (30–40 l/t) specified by requirements of the current regulatory document of Ukraine [5], but it is in the middle of the refined IGTM range (20–27 l/t) [6], as shown in figure 1.

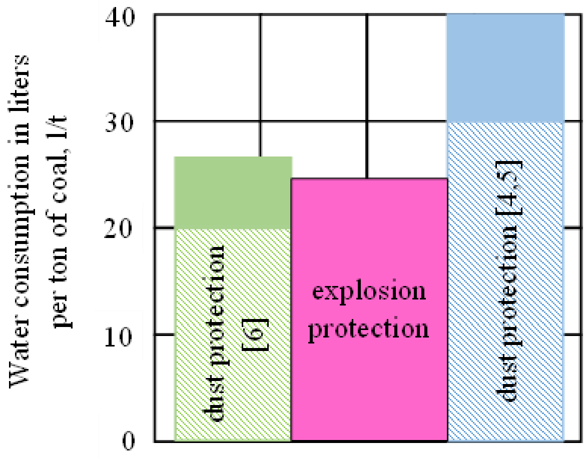

Figure 1 – Required specific water consumption by the spraying system of the MB-630 mining combine in the conditions of PJSC "Pokrovske Mine"

If the longwall where the combine was operating had a problem with the wet softening of the surrounding rocks, its external spraying system could be turned off. This would reduce the water inflow into the longwall from the spraying system by approximately 30%, without deteriorating the explosion safety of coal extraction.

It should be noted that the example of calculating the water consumption for explosion-preventing spraying system of the MB-630 combine is still approximate, because the actual temperature of the heated air near the incandescent spark is not precisely known. However, as equation (2) shows, this temperature strongly affects explosion-preventing water consumption. If it greatly exceeds the adopted value of 900 °C, then the required water consumption may be greater than the calculated one. And, conversely, if the actual temperature of heated air near an incandescent spark is lower than 900 °C, the required water consumption will be less than the calculated one.

4. Conclusions

The results of the presented study, as well as those previously published [15], made it possible to create a theoretically justified method for calculating the explosion-preventing water consumption for internal spraying systems of mining machines.

The scientific value of this work lies in integration of quite diverse physicochemical, heat-technical and aerological aspects of phlegmatization of ignition and explosion of dust-methane-air environment into a single parameter that determines the explosion-preventing water consumption for spraying a heated air near an incandescent spark at a given conditional temperature.

The practical significance of this work consists in the opportunity provided to assess the compliance of the spraying parameters of imported mining machines with the conditions of Ukrainian mines, which is particularly useful for specialists in the coal industry.

Conflict of interest

Authors state no conflict of interest.

REFERENCES

1. Ministry of Coal Industry (1990), 1.1.30-6.03-90. *Rucovodstvo po bor'be s pyl'yu v ugol'nykh shakhtakh:Normativnyy document Minuhleprova SU. Standart* [1.1.30-6.03-90, Guide to Coal Mine Dust Control: Regulatory document of SU Ministry of Coal Industry. Standart], Ministry of Coal Industry, Moscow, SU.

2. Kissell, F.N. (2003), *Mining Publication: Handbook for Dust Control in Mining,* National Institute for Occupational Safety and Health (NIOSH), U.S., available at: https://www.cdc.gov/niosh/docs/mining/works/coversheet1041.html (accessed 01 August 2025.)

3. Chunmiao, Y., Chang, L. and Gang, L. (2011), "Coal dust explosion prevention and protection based on inherent safety", *Journal Procedia Engineering*, vol. 26, pp.1517–1525. http://doi.org/10.1016/j.proeng.2011.11.2333

4. Ukraine Ministry of Coal Industry (2003), *KND t.1. Zbirnik instruktsiy do pravil bezpeki u vugil'nikh shakhtakh. Instruktsiya po kompleksnomu znepilyuvannyu povitrya. Normatyvnyy dokument Minvuhlepromu Ukraïny. Standart* [KND t.1. Collection of instructions on safety rules in coal mines. Instructions for comprehensive air dust removal. Regulatory Document of Ukraine Ministry of Coal. Standard], Ukraine Ministry of Coal Industry, Kiev, Ukraine.

5. Ukraine Ministry of Coal Industry (2005), *NPAOP 10.0-5.07-04. Instruktsiya z kompleksnoho znepylennya povitrya. Normatyvnyy dokument Minvuhlepromu Ukraïny. Standart* [NPAOP 10.0-5.07-04 Instructions for integrated dust removal air. Regulatory Document of Ministry of Coal Industry of Ukraine. Standart], Ukraine Ministry of Coal Industry, Kiev, Ukraine.

6. Mineev, S.P. and Usov, O.A. (2023), "Criterion for assessment of compliance of water consumption by the spraying system of imported roadheaders with the requirements of Ukrainian regulations", *Geo-Technical Mechanics*, no. 165, pp. 27–36, http://doi.org/10.15407/geotm2023.165.027

7. Ukraine Ministry of Coal Industry (2023), *Pravyla bezpeky u vuhilnykh shakhtakh. Normatyvnyy dokument Minvuhlepromu Ukraïny. Standart* [Safety rules in coal mines. Regulatory Document of Ukraine Ministry of Coal], Ukraine Ministry of Coal Industry, Kharkiv, *Ukraine.*

8. Briukhanov, A.M., Berezhinskiy, V.I., Busygin, K.K., Kolosyuk, V.P. and Koptikov, V.P. (2004), *Rassledovaniye i predotvrashcheniye avariy na ugol'nykh shakhtakh* [Investigation and prevention of accidents in coal mines], vol. 2, Nord-Press, Donetsk, Ukraine.

9. Shevtsov, N.R. (2002), *Metodicheskiye ukazaniya k vypolneniyu raschetno-graficheskikh rabot po vzryvozashchite gornykh vyrabotok.Posobiye dlya studentov* [Guidelines for the implementation of calculation and graphic work on explosion protection of mine workings. Handbook for students], DonNTU, Donetsk, Ukraine, available at: https://ea.donntu.edu.ua/jspui/handle/123456789/17798 (accessed 01 August 2025).

10. Golin'ko, V.I., Lebedev, Ya.Ya., Litvinenko, A.A. and Mukha, O.A. (2015), *Aerologiya gornykh predpriyatiy: uchebnoye posobiye* [Aerology of Mining Enterprises: A Textbook], Dnipro, Ukraine.

11. Botvenko, D.V. (2020), Methodological foundations for forecasting and localizing explosive combustion of firedamp during rock destruction in coal mines, Abstract of D.Sc. Thesis, Fire and industrial safety, AO «NTS VostNII», Kemerovo, Russian Federation.

12. Minieiev, S.P., Usov, O.O., Yanjula, A.S. and Horodkov, Ye.V. (2023), "Estimation of water consumption for explosion-proof irrigation of underground excavation machines' cutting track", *Scientific Bulletin of DonNTU*, no 1(29), pp.76–82, https://doi.org/10.31474/2073-9575-2023-1(29)-76-82

13. Mineyev, S., Usov O. (2023), Mechanisms of methane-air mixture capture from a friction spark and methods for calculating its phlegmization, *Proc. of the International scientific conference "Safe, comfortable, capable territorial community",* Dnipro, Ukraine, 11–13 October 2023, pp. 115–118.

14. Korolchenko, A.Ya. (2002), "Calculation of the main fire and explosion safety indicators of substances and materials", *Pozharovzryvoopasnost'* [Fire and explosion safety], vol.11, no 6, pp. 29–31.

15. Minieiev, S.P., Usov, O.O., Yanjula, A.S. and Miroshnichenko, V.V. (2024), "Assessment of the concentration of water drops near the point for anti-spark falling of underground victory machines", *Scientific Bulletin of DonNTU*, no 1–2(31–32), pp.63– 69, https://doi.org/10.31474/2073-9575-2024-1(31)-2(32)-63-69

16. Sreznevskiy, B. (1882), *Zhurnal Russkogo fiziko-khimicheskogo obshchestva* [Journal of the Russian Physical-Chemical Society], no 14, p. 420.

17. Volkov, R.S., Kuznetsov, G.V. and Strizhak, P.A. (2012), "Numerical evaluation of optimal water droplet sizes under conditions of gas spraying by fire extinguishing agents in premises", *Pozharovzryvoopasnost'* [Fire and explosion safety], vol. 21, no 5, pp.74–78. https://doi.org/10.18322/PVB.2012.21.05.74-78

18. Minieiev, S.P., Usov, O.O., Yanjula, A.S., Bodnar, A.A. and Chaban, O.V. (2024), "Method of calculating water consumption for anti-spark spraying road header", *Physical and technical problems of mining production*, no (26), pp.106–116, https://doi.org/10.37101/ftpgv26.01.008

19. Minieiev, S.P. (2018), "On the prevention of accidents related to methane explosions in coal mines", *Geo-Technical Me*chanics, no 138, pp.115–136. https://doi.org/10.15407/geotm2018.01.115

20. Sofiyskiy, K.K., Stasevich, B.V., Bokiy, B.V., Sheyko, A.V., Gavrilov, V.I., Moskovskiy, O.V. and Dudlya, Ye.Ye. (2017), *Bezopasnost I efektivnost metanougolnykh shakht* [Safety and Efficacy of Methane-Coal Mines], FLP Khalikov, Kyiv, Ukraine.

21. Minieiev, S.P. (2009), *Svoystva gazonasyshchennogo uglya* [Properties of Gas-saturated Coal], NGU, Dnepropetrovsk, Ukraine.

22. Ukraine Ministry of Energy (2023*), NAOP* Proektuvannya degazatsii vuhilnykh shakht I expluatatsii degazatsiinykh system. Pravyla [NAOP Design of degassing of coal mines and operation of degassing systems. Rules], Ukraine Ministry of Energy, Dnipro, Ukraine.

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МЕТОД РОЗРАХУНКУ ВИТРАТИ ВОДИ НА АНТИ ІСКРОВЕ ЗРОШЕННЯ ВИДОБУВНОГО КОМБАЙНУ

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Анотація. У статті наведені результати теоретичних досліджень витрати води системою внутрішнього зрошення видобувних вугільних комбайнів, яка забезпечує захист від спалаху (вибуху) пил метан повітряного середовища під час видобутку вугілля.

Оцінка витрати води на запобігання вибуху внаслідок розігріву різця та сліду різання виїмкового комбайну базується на припущенні, що вся енергія приводу витрачається тільки на розігрів різця та сліду різання. Вона придатна тільки для співвісного розташування різця та зрошувальної форсунки. Цей метод оцінки, запропонований вперше, опублікований авторами раніше.

Оцінка витрати води на запобігання вибуху від розпечених іскор при роботі видобувних комбайнів ґрунтується на безпечній концентрації водяної пари в кубометрі повітря, яка флегматизує вибух від розпечених іскор. Ця величина визначена в попередніх публікаціях стандартними нормативними методами пожежної справи. Перехід від безпечної концентрації водяної пари до безпечної концентрації водяних крапель в кубометрі повітря був також викладений в попередніх публікаціях. Він ґрунтується на теоретичних дослідженнях масової швидкості випаровування краплини протягом індукційного періоду затримки спалаху. Отримана таким чином базова величина вибухобезпечної концентрації водяних крапель придатна для будь-якого взаємного розташування форсунки і різця. Головним її визначальним параметром є температура розігрітого середовища навколо іскри. Температуру нагрітого середовища практично не можливо визначити теоретичним шляхом з прийнятною для практики точністю. Тому, температуру нагрітого середовища визначається емпіричним шляхом. На даному етапі досліджень використана широко розповсюджена оцінка меж горіння метану у відкритому просторі в діапазоні 850–900 °С. В подальших дослідженнях ці межі можуть бути скориговані.

Хвилинна витрата повітря на омивання вибою лави в зоні роботи шнеків вперше визначається за показником виділення метану із вугільного пласта. Ця величина фігурує в кожному проекті комплексної дегазації виїмкової дільниці, який розробляється на кожну лаву. Приймається, що весь метан виділяється тільки в зоні роботи шнеків. Тобто показник хвилинної витрати повітря в зоні роботи шнеків обчислений з певним запасом.

Результати досліджень, які вперше дозволяють розрахувати параметри вибухобезпечного зрошення, актуальні для визначення витрати води на зрошення пластів з порівняно не великою пило утворюючою здатністю, але з підошвою та покрівлею, що розмокають (Павлоградські шахти України). Для них номінальні витрати води системами зрошення імпортних комбайнів є завеликими і можуть привести до великих ускладнень при пересувці секцій кріплення та вибійного конвеєру.

Ключові слова: вибух безпека, пил метан повітряна суміш, іскріння від тертя.