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SHORT-TERM PREDICTIONS OF METHANE EMISSIONS DURING LONGWALL MINING

KRÓTKOTERMINOWE PROGNOZY WYDZIELANIA SIĘ METANU PODCZAS WYBIERANIA ŚCIAN

The prediction of methane emissions to the longwall environment carried out at the design stage may include subjective errors resulting from the underestimation of input values for calculations and in particular, methane saturation of underlying and overlying seams, their thickness and distance from the mined seam.

The method of a short-term prediction of methane emissions to the longwall environment during its excavation which is presented in this article and which was developed as a part of a strategic research project (Krause et al., 2013), allows for verification of discrepancies between the predicted methane emissions during excavation for the designed longwall and the actual one. The method of short-term prediction allows for variant pre-estimation of methane emissions for changing operational progress and changes in methane saturation of the mined seam and surrounding deposit at the panel length. It can be used by the Mine Ventilation Department continuously during the longwall mining.

Keywords: mining, methane hazard, longwall, prediction

Prognoza wydzielania się metanu do środowiska ściany, wykonana na etapie jej projektowania, może być obarczona błędami subiektywnymi wynikającymi z niedoszacowania wartości wyjściowych do obliczeń a w szczególności nasycenia metanem pokładów podebranych i nadebranych, ich miąższości oraz odległości od pokładu eksploatowanego.

Przedstawiona w artykule metoda prognozy krótkoterminowej wydzielania się metanu do środowiska ściany podczas jej eksploatacji, opracowana w ramach strategicznego projektu badawczego (Krause i in., 2013), pozwala na weryfikację występujących rozbieżności między prognozowanym dla projektowanej ściany a rzeczywistym wydzielaniem się metanu podczas eksploatacji. Metoda prognozowania krótkoterminowego pozwala na wyprzedzające wariantowe oszacowanie wydzielania się metanu dla zmieniających się postępów eksploatacyjnych oraz zmian nasycenia metanem pokładu eksploatowanego i otaczającego złoża na wybiegu ściany. Może być stosowana przez Dział Wentylacji Kopalni na bieżąco podczas eksploatacji ściany.

Słowa kluczowe: górnictwo, zagrożenie metanowe, ściana, prognoza

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1. Introduction

The predicted methane emissions to the designed longwall in Polish collieries is based on input assumptions which include: methane content distribution in the seam parcel at the panel length, parameters of the longwall (length, height, planned progress), location of the underlying and overlying seams as well as vertical distribution of their methane content within the operating relaxation.

The prognostic evaluation of methane emissions to the longwall environment may be subject to objective errors resulting from the application of the method as well as the subjective errors resulting from the adoption of imprecisely estimated values for the calculations and it may result in discrepancies between the predicted and actual methane emissions during the longwall mining.

The calculated prediction should be based on as accurate as possible identification of spatial deposition of underlying and overlying seams in relation to the mined seam together with gas conditions therein at the designed panel length. The predicted absolute methane content constitutes the basis for selection of methane prevention, including selection of the method of its ventilation and methane drainage.

In the event of technical and organizational changes, including another system of operation during the longwall mining or in case of discrepancies between the prediction and the actual methane emissions, it is recommended to verify the prediction based on the method presented in this publication.

The existing discrepancies enforce decisions to be made, aimed at increasing the air flow in the longwall, improvement of the efficiency of methane drainage and often at reducing an average daily operational progress and thus, the extraction.

In case of methane content in the mined seam above 4.5 m^3CH_4/Mg_{csw}, an increase of shearer cutting speed results in an increase of methane content in the air flux in the longwall working (Krause, 2009; Szlązak et al., 2014).

Implementation of organizational changes during mining operations consisting in reduction of cutting cycle time by increasing the operating speed of the shearer has a direct influence on the volume of methane emitted per unit time and thus, an increase of percentage methane content in the air in the longwall.

Moreover, an increase in the number of cycles in the longwall causes an increase of an average daily longwall advance and it contributes to an increase of the amount of methane flowing to workings from goaves as a result of degassing of underlying and overlying seams within the operating relaxation zone.

The developed short-term prediction method (Krause et al., 2013) allows to carry out variant estimates of the volume of methane emitted to the mined longwall environment divided into two streams: the first directly to the longwall cut with a shearer, the second to the longwall goaves depending on the longwall advance.

It should be noted that the results of researches which have been carried out in the longwalls for the last twenty years by Zakład Zwalczania Zagrożeń Gazowych (*the Centre of Combating Gas Hazards)* indicate a growing methane ratio (which amounts to ca. 60%) emitted to goaves as a result of degassing of overlying and underlying seams in relation to the total amount of methane emitted to the mined longwalls environment (Drzewiecki, 2004; Krause, 2009).

For this reason, methane hazard has increased especially in the longwalls ventilated using "U" method over the unmined coal. This ventilation method provides that methane desorbing to the longwall goaves from the underlying and overlying seams fills the goaves and then flows to the crossing of the longwall and ventilating gallery. It should be mentioned that 75% of all mined longwalls in collieries in Poland are ventilated using the "U" method over the unmined coal and about 20% using the "Y" method with a discharge of used air along the goaves and behind the longwall face.

In the light of applicable mining regulations, design of a longwall located in the seam where the methane saturation is greater than 2.5 m^3CH_4/Mg_{csw} requires the development of predictions concerning methane emissions which is the basis for determining the necessary air flow in the longwall and making a decision on the need to apply methane drainage. Determination of capacity of excavation ventilation within the mining area under high methane hazard requires calculations to be made with regard to predictions concerning convergence of galleries before and behind the longwall face. Adaptation of Budryk-Knothe theory to the prediction of longwall galleries deformation has been included in the publications (Prusek, 2010; Prusek & Jędrzejec, 2008).

The method of short-term prediction of methane emissions to the longwall area which eliminates the discrepancies between the prediction values calculated for further parcels of the designed panel length and the actual emission of methane during the longwall mining has been presented in the publication.

Short-term predictions allows for pre-estimation of the amount of methane which will be emitted to the workings from goaves in a subsequent period of operation based on the identified amount of methane emitted to the longwall environment during the current period.

The actual amount of methane emitted to workings from the longwall goaves during the current period allows to calculate with high accuracy the value of the short-term prediction related to the emission of methane for the subsequent period for the planned average daily longwall advance. The short-term predictions allows for variant calculations of the ventilation and methane balance in excavations within the longwall, and also the calculation of its production capacity.

2. Forecasting methane emissions at the panel length of the designed longwall – current conditions

Prediction of methane emissions to the designed operating area consists in the estimation of its amount, taking into account the parameters of the longwall, mining and geological as well as gas, technical and organizational conditions.

Methane emissions prediction which is prepared for the designed longwall should be based on as accurate verification of the operated seam and the surrounding deposit as possible. The adoption of input assumptions for the calculation of the prediction which differ from the actual conditions gives rise to discrepancies between the predicted values and the actual emission of methane during excavation.

The prediction method of methane emissions for the designed longwalls, developed in the Central Mining Institute in 2000 under the name "Dynamic prediction of absolute methane emissions on longwalls" (Krause & Łukowicz, 2000), removed the errors and mistakes made in the prediction method which has been applied since the seventies of the last century (Kozłowski, 1972), and it consisted in, among others, assuming *a priori* for all designed longwalls, irrespective of their length and inclination, a constant range of the relaxation and degassing zone, that is 120m from the roof and 60m from the floor of the mined seam. As far as the designed longwalls for which methane emissions is predicted are concerned, it is necessary to know the relaxation range and spatial deposition within this zone of seams and coal layers below and over the designed excavation.

The degassing range of layers where coal is extracted below and above them (Pawiński et al., 1995; Szlązak et al., 2014), depends on the length of the longwall and its inclination. The dependencies which allow for calculation of the size of the deposit relaxation range from the roof and floor of the longwall have been introduced to the method of dynamic prediction of absolute methane emissions on longwalls (Krause & Łukowicz, 2000). The range of relaxation and degassing of the deposit within the longwall depends on the length of the longwall L_s and its inclination α and it has been presented as a nomogram in Figure 1.

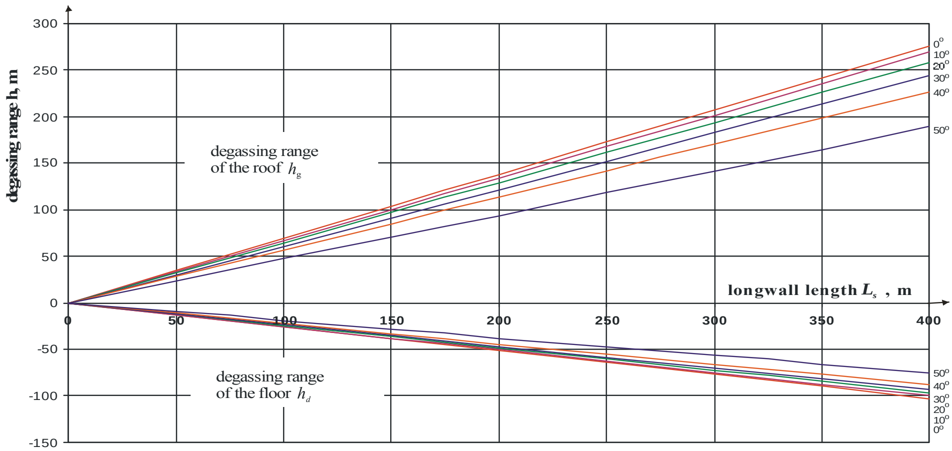

Fig. 1. The range of degassing of layers where coal is extracted below and above them depending on the length of the longwall L_s and its inclination α (Krause & Łukowicz, 2000)

The knowledge of the degassing range of the roof h_g and floor h_d of the longwall allows for identification of the seams and coal layers which have to be taken into consideration when applying of the dynamic prediction of absolute methane emissions on longwalls.

Currently, the knowledge concerning a post-critical deformation of rocks is used for the evaluation of the rock mass destruction resulting from mining operations and for determination of the range of destruction zones around the mine workings as well as for the assessment of the possibilities of occurrence of certain dynamic phenomena in the rock mass (Bukowska, 2012; Bukowska, 2013).

The dynamic prediction of absolute methane emissions on longwalls (Krause & Łukowicz, 2000) takes into account in its assumptions, a new method of calculation of methane content distribution in the parcel of the designed longwall, that is:

– distribution of methane content of the mined seam,
– vertical distribution of methane content in the overlying and underlying seams where coal is extracted below and above them and which are subject to relaxation and degassing.

The greatest value of methane content in the mined seam determined during researches was assumed in the method of predicting methane emissions to longwalls (Kozłowski, 1972) which was used between 1972-2000 and the value of methane content in the overlying and underlying seams was mostly assumed intuitively. Such assumptions overrated or underrated, even by 100%, the predicted value in relation to the actual methane emissions.

The previous experiences in the application of the predicting method (Krause & Łukowicz, 2000) allow to conclude that the discrepancies between the predicted methane content and the actual methane emissions to longwalls do not exceed 20% and are within the limits of tolerability. Implementation of technical and organizational changes to the longwalls with a high concentration of extraction, such as an average daily advance, where the methane content of the mined seam and the surrounding deposit is above 4,5 m^3CH_4/Mg_{csw}, should verify the prediction during mining operations, if the short-term method of methane emissions is applied.

3. Short-term prediction of methane emissions to longwall areas

Short-term predictions developed during longwall mining refer to two fluxes of emitted methane, that is:

- to the longwall working when the mined seam is cut by a shearer,
- to the workings within the longwall area from goaves as a function of a degassing deposit volume which depends on the operational progress.

The predicted methane emissions to the operating areas does not include an additional supply of methane as a result of an increased volume of the damaged deposit due to an increased seismic activity. Prediction of a seismic hazard within the operating areas (Kabiesz, 2010; Kabiesz et al., 2013) should provide information about the possibility of occurrence of an additional methane inflow to the longwall environment.

3.1. Short-term prediction of methane emissions to the longwall working during coal cutting

Methane contained in the mined seam is released to the longwall working during coal cutting with a shearer and much smaller amount is released from the exposed coal sidewall of the longwall face.

The amount of cut coal per unit time as well as methane content in the mined seam affect the volume of methane emitted to the longwall working during the cutting cycle. The degassing degree of coal cut by a shearer depends on the value of its methane content M_o.

The results of researches carried out by the Central Mining Institute related to methane emissions to longwalls while cutting mined seams with different methane content (Krause, 2009) made it possible to determine its degassing degree η_s depending on the initial methane content M_o, according to the formula (1) and graphical interpretation presented in Figure 2

$$\eta_s = 8{,}354 \times M_o^{0{,}67} \tag{1}$$

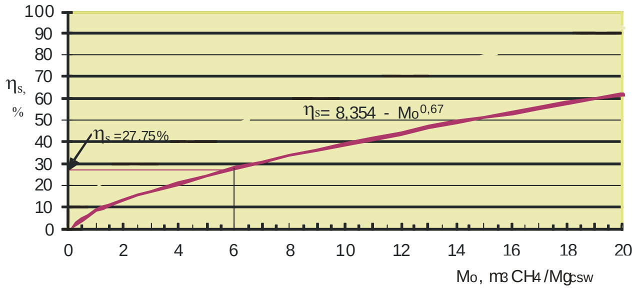

Fig. 2. Coal degassing degree η_s of the mined seam while being cut with a shearer depending on its methane content M_o (Krause, 2009)

Short-term prediction of methane emissions to the longwall working for time t of one cutting cycle with the initial methane content on the seam M_o for the location of the longwall face is calculated according to the formula

$$V_{CH_4}^{sc} = \frac{L_s\, m_e\, \gamma\, z\, M_o\, \eta_s}{100\, t} \tag{2}$$

where:

- V_{CH4}^{sc} — predicted volume of methane emitted to the longwall working per 1 minute during the cycle of cutting with a shearer with time t, m^3CH_4/min;
- L_s — length of the longwall, m;
- m_e — height of the mined longwall, m;
- γ — coal density, Mg/m^3;
- z — shearer web depth, m;
- M_o — initial methane content of the cut seam in the longwall, m^3CH_4/Mg_{csw};
- η_s — degassing degree of the mined seam, %;
- t — duration of cutting cycle, min;

Short-term prediction of methane emissions to the longwall working during cutting allows to estimate the amount of emitted methane for different times t of cycle duration. An example of prediction of methane emissions to the longwall working for 4 times t of a cutting cycle has been presented below.

Short-terms predictions have been made for the longwall with a length of L_s = 250 m, height of m_e = 3 m and web of z = 0,8 m, for the initial methane content of coal cut of M_o = 6 m^3CH_4/Mg_{csw} and for four times t of a cutting cycle: 60 min, 90 min, 120 min and 150 min.

Degassing degree η_s of coal of the mined seam with a methane content of M_o = 6 m^3CH_4/Mg_{csw}, during cutting, according to the formula (1), amounts to 27,75%, and it has been presented on the ordinate axis (Fig. 2).

The predicted amounts of the emitted methane have been calculated based on the formula (2), comparing the results in column 3 Table 1. The calculated methane content in air at the outlet from the longwall during shearer cutting has been compared in column 4 Table 1 for the predicted amounts of emitted methane (column 3) with the flow rate of air in the longwall of 1500 m^3/min.

TABLE 1

No.	Duration of cutting cycle t, min	Predicted amount of emitted methane while cutting $V_{CH_4}^{sc}$, m^3CH_4/min	CH_4 content at the outlet from the longwall, with air flow rate of 1500 m^3/min, %
1	2	3	4
1	60	21.65	1.44
2	90	14.43	0.96
3	120	10.82	0.72
4	150	8.66	0.57

The short-term prediction results for changing speed of cutting confirm the possibility of an increase or decrease of methane hazard within the longwall working.

The duration of the technological cycle in the longwall includes cutting and breaks during which other operations and maintenance activities are performed. The total duration of cycles t does not reflect the interim maximum operating speed of the shearer in the calculated short-term predictions.

Short-term predictions of methane emissions to the longwall working while cutting allows to calculate the allowable safe extraction capacity of the longwall. At this point it should be noted that the methane content of seams increases along with the depth and thus, the amount of released methane from 1 Mg of coal cut. Moreover, the increasing distance of operating regions from the personnel transport shaft extends the travel time of the mining crew to the regions and thus, the effective operating time in the longwall is shortened. The performance of mining activities with a shortened effective working time during a shift inspires to increase the shearer operating speed and thus, to shorten the time t of the technological cycle performance in the longwall. It improves methane emissions to longwalls during the cutting cycle. Changes in technical and organizational conditions in the mined longwalls prove the practical suitability of short-term predictions for variant calculations of the admissible production capacity.

Shortening the time t of the shearer cutting cycle reflects in an increase of the longwall operating progress which in turns affects the volume of the relaxed deposit within the longwall and the volume of methane released from the underlying and overlying seams. Depending on the longwall advance, the flux of methane emitted from goaves to workings within the longwall constitutes a part of short-term predicting.

3.2. Short-term predictions of methane emissions to workings from mined longwalls goaves

Short-term predictions of methane emissions to the longwall working during coal cutting with a shearer do not include methane flux emitted to longwall workings from goaves. The operational progress of the longwall results in degassing of relaxed underlying and overlying seams, and free methane which desorbs from them fills goaves and then migrates to active workings. Methane fills goaves of direct caving and migrates according to the field of aerodynamic potentials. During methane drainage from longwall goaves, methane is partially captured and discharged through pipelines to the surface.

The direction of escaping air and methane migration in the longwall goaves depends also on the adopted ventilation method and air flow rate in the longwall. Figure 3 presents as a visual

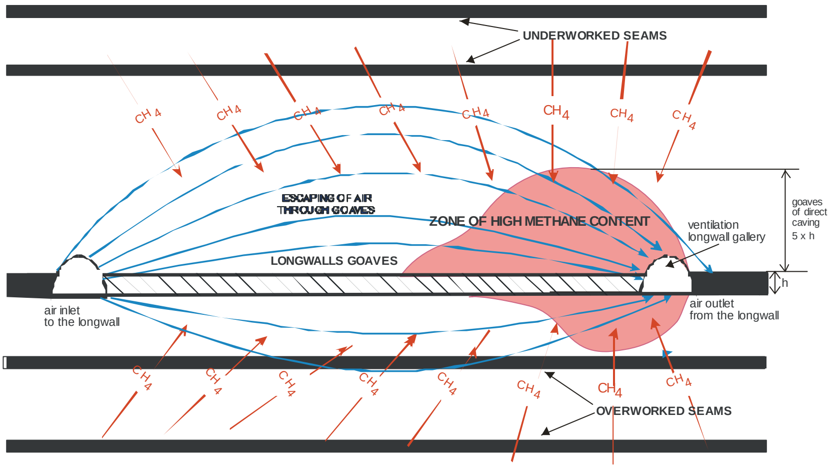

Fig. 3. Migration of air and methane through longwall goaves

reference, migration of air and methane in goaves. Escaping of air through goaves depends on the flow rate of air supplied to the longwall and the method of their sealing mainly at the side of air inlet to the longwall.

Implementation of changes in the average daily operational progress of the longwall affects the volume of degassing seam and it has a direct impact on the amount of released methane from relaxed underlying and overlying seams.

Relaxed volume of the rock mass within the longwall is affected by the following parameters: length and inclination of the longwall as well as operational progress. Length and inclination of the longwall usually do not change at the operational panel length and thus, the volume of the relaxed zone over and below the mined longwall shapes its operational progress. At constant operational progress and unchanging methane saturation of the surrounding deposit, a similar methane volume flows to goaves. The longwall advance should be referred to: day, week, month, quarter. At similar mining and geological as well as gas conditions of the deposit surrounding the longwall, the volume of released methane is correlated with an average daily longwall advance within a certain time period.

Statistical studies (Badura, 2013) confirmed the existence of a strong relation between average methane concentration in the subsequent days of the working week and the average daily output.

During longwall mining in a 5-day working week, it can be noted that an absolute methane amount emitted to workings from the longwall goaves in the subsequent days (from Monday to Friday) increases and afterwards it decreases during days off.

If the longwall is mined 7 days a week, the methane content of the longwall is maintained at a similar level. The operational progress during a week affects the total volume of methane emitted to goaves and the working system affects the distribution of the amount of methane emitted during the subsequent days of the week. Short-term predictions of methane emissions to workings from goaves allow to estimate, for the subsequent period of longwall mining, the amount of emitted methane depending on the planned operational progress. Short-term predictions of methane emissions to workings from goaves are performed for the planned change in the organization of works in the longwall, mainly to reduce or increase the advance of the longwall.

The methodology of short-term predictions of methane emissions to workings from goaves of longwalls mined using "U" method over the unmined coal and also "Y" method has been presented in the following part of the publication.

The short-term predictions developed for the subsequent mining period are based on the current emission of methane to workings from goaves.

The calculation of methane emissions should be made based on the values of automatic methanometry and anemometry readings in the measurement stations where methane and air speed sensors are installed in the longwall workings.

Recently, the amount of methane which is emitted to workings (absolute ventilation methane content) is determined on the last working day of the week when the emission is the highest. This method of determining ventilation methane content includes a safety margin for the calculation of short-term predictions.

The ratio of methane emitted from goaves to longwall workings W in the total ventilation methane content of the longwall area is calculated using the following formula:

$$W = \frac{\dot{V}_{\mathrm{CH_4}}^{zr}}{\dot{V}_{\mathrm{CH_4}}} \cdot 100\% \tag{3}$$

where:

- $\dot{V}_{\mathrm{CH_4}}^{zr}$ — amount of methane emitted to the longwall workings from goaves is calculated using the formula (7) or the formula (10);
- $\dot{V}_{\mathrm{CH_4}}$ — ventilation methane content within the longwall area is calculated using the formula (6) or (9) depending on the ventilation method „U" over the unmined coal or method „Y".

If the value of ratio W increases, the hazard also increases during ventilation of the longwall using the method "U" over the unmined coal and in case of method "Y", the hazard decreases.

The amount of methane emitted from goaves to longwall workings per 1 mb of an average daily longwall advance during the working week preceding the forecasted period is calculated using the following formula:

$$\dot{V}_{\mathrm{CH_4}}^{zr/1m} = \frac{\dot{V}_{\mathrm{CH_4}}^{zr}}{p_{sr}} \tag{4}$$

where: p_{sr} — an average daily longwall advance during the working days of the week preceding the short-term prediction.

The short-term prediction of methane emissions from goaves to workings with the planned increase or decrease of an average daily longwall advance for the following working week is calculated using the formula:

$$\dot{V}_{\mathrm{CH_4}}^{zrprog} = \dot{V}_{\mathrm{CH_4}}^{zr} + (p_{pl} - p_{sr})\dot{V}_{\mathrm{CH_4}}^{zr/1mb} \tag{5}$$

where: p_{pl} — planned average daily operational progress of the longwall for the following working week for which the short-term prediction is developed.

The method for calculation of the amount of methane emitted to workings from the longwall goaves for the ventilation method "U" over the unmined coal (Fig. 4) and method "Y" (Fig. 5) has been presented below.

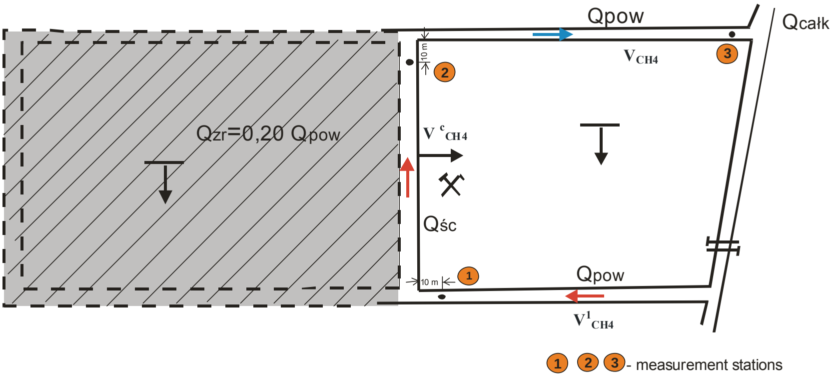

Fig. 4. Determination of ventilation methane content and the amount of methane emitted from goaves to workings during ventilation using "U" method over unmined coal

The longwall ventilated using the "U" method over the unmined coal.

Ventilation methane content of the longwall ventilated using "U" method over unmined coal is calculated by the formula

$$\dot{V}_{CH_4} = 0{,}01\ (K_3 - K_1)\ Q_{pow}, \quad m^3/min \tag{6}$$

where:

- K_1 — methane content in the longwall gallery supplying fresh air to the longwall (measurement station 1);
- K_3 — methane content in the ventilation longwall gallery discharging air from the longwall (measurement station 3);
- Q_{pow} — flow rate of fresh air supplied to the longwall, m^3/min.

The amount of methane emitted to workings from the longwall goaves is calculated by the formula

$$\dot{V}^{zr}_{CH_4} = 0{,}01\ (K_3\ Q_{pow} - K_2\ Q_{\acute{s}c}), \quad m^3/min \tag{7}$$

where:

- K_2 — methane content at the outlet from the longwall at a distance of 2m from the ventilation gallery (measurement station 2);
- $Q_{\acute{s}c}$ — flow rate of air in the longwall at the measurement station 2 at the outlet from the longwall, m^3/min.

Using the formulas (7), (4) and (5) it is possible to calculate the short-term prediction of methane emissions from goaves to workings of the longwall ventilated using the method "U" at the planned changes in the average daily operational progress in the subsequent week.

An example of calculation of the short-term prediction for the longwall with a total advance of 28 mb during the preceding week has been presented below.

The values of automatic methanometry and anemometry readings at the measurement stations 1, 2 and 3 allowed for calculation of the amount of methane emitted to workings within the long-wall. Assuming that the calculated ventilation methane content within the longwall area amounts to 25 m^3CH_4/min, according to the formula (6) and the amount of methane emitted from goaves to workings amounts to 15 m^3CH_4/min, according to the formula (7), the percentage amount of methane emitted to workings from the longwall goaves *W* in the ventilation methane content within the longwall amounts to 60%. If we apply the above to the formula (4), $V_{CH_4}^{zr/1mb} = 3{,}75$ m^3CH_4/min is emitted per 1m of the longwall advance from goaves to the longwall workings.

An increase of the average daily longwall advance from 4 mb/day to 6 mb/day, that is from 28 mb/week to 42 mb/week will result in an increase of the amount of methane emitted from goaves to the longwall workings.

If we apply the above to the formula (5), it is possible to calculate the value of the short-term prediction of methane emissions from goaves to the longwall workings and it will amount to $V_{CH_4}^{zr\,prog} = 22{,}5$ m^3CH_4/min. For the planned increase of an average daily operational progress of the longwall in the subsequent week up to 6 mb/day, the predicted amount of methane emitted from goaves to workings will increase from 15 m^3CH_4/min to 22,5 m^3CH_4/min and the ventilation methane content within the longwall area from 25 m^3CH_4/min to 37,5 m^3CH_4/min.

The presented-above example proves that the short-term predictions of methane emissions from goaves to longwall workings become particularly important in the longwalls with a high value of ratio *W* ventilated using "U" method over the unmined coal.

<u>A longwall ventilated using the method "Y" with a fresh air flow supplied to the air outlet from the longwall</u>

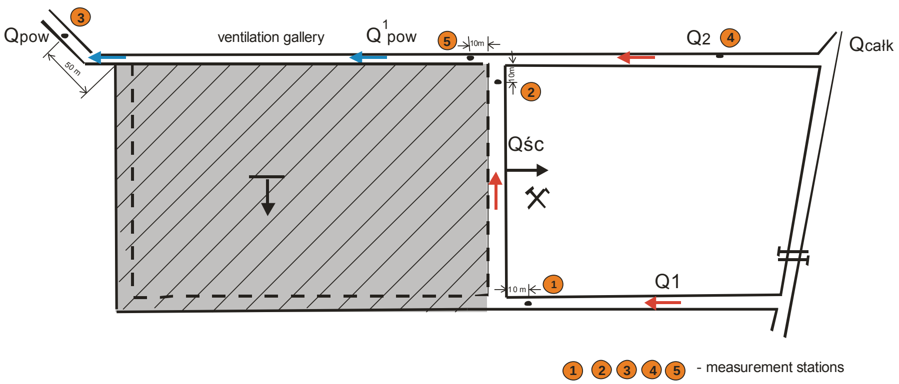

Fig. 5. Determination of ventilation methane content and the amount of methane emitted from goaves to workings during ventilation using "Y" method with a fresh air flow

The fresh air flow rate Q_{pow} is supplied to the longwall with two galleries where Q_1 is the main flow rate and Q_2 is the air flow which supplies fresh air to the outlet longwall air flux.

The total air flow rate Q_{pow} within the mined area is the sum of fresh air flow rates Q_1 and Q_2 supplied to the longwall, according to the formula

$$Q_{pow} = Q_1 + Q_2 \tag{8}$$

where:

Q_1 — flow rate of the main fresh air flux supplied to the longwall, m^3/min,
Q_2 — flow rate at the fresh air flux.

The difference between the air flow rates Q_{pow} at the measurement station (3) and Q^1_{pow} at the measurement station (5) determines the amount of air escaping through the longwall goaves from the side of the longwall gallery which supplies the main fresh air flux Q_1.

Ventilation methane content of the longwall ventilated using "Y" method with a fresh air flux Q_2 supplied to the air outlet from the longwall is calculated by the formula

$$\dot{V}_{CH_4} = 0{,}01\,(K_3\,Q_{pow} - K_1\,Q_1 - K_4\,Q_2), \quad m^3/min \tag{9}$$

where:

K_3 — methane content in the flux of used air Q_{pow} discharged from the operating area (measurement station 3);
K_1 — methane content in the main fresh air flux Q_1 supplied to the longwall (measurement station 1);
K_4 — methane content in the fresh air flux Q_2 (measurement station 4);

Amount of methane emitted from the longwall goaves to the ventilation gallery is calculated by the formula

$$\dot{V}^{zr}_{CH_4} = 0{,}01\,(K_3\,Q_{pow} - K_5\,Q^1_{pow}), \quad m^3/min \tag{10}$$

where:

K_5 — methane content in the flux of used air in the ventilation gallery at a distance of up to 10m behind the longwall face (measurement station 5);
Q^1_{pow} — otal used air flow rate discharged from the longwall $Q_{śc}$ together with the fresh air flux flow rate Q_2, m^3/min is calculated by the formula

$$Q^1_{pow} = Q_{śc} + Q_2 \tag{11}$$

Applying the above to the formulas (10), (4) and (5), it is possible to calculate the short-term prediction of methane emissions from the longwall goaves to the ventilation gallery using the "Y" ventilation method.

Short-term predictions estimate the amount of released methane exclusively for ventilation air discharged from the longwall area, assuming that during methane drainage from goaves, its constant efficiency is maintained.

Short-term predictions of methane emissions to the longwall working, along with the changes in the shearer cutting speed and in the prediction of methane emissions from goaves to workings for the changing average daily progresses, constitute a helpful tool to verify the discrepancies which may occur during mining operations. Under the conditions of the planned change in the organization of the working system within the longwall, they allow to predict methane emissions more precisely.

For the planned changes in the organization of works in the longwall, the calculated values of short-term predictions of methane emissions to the longwall working during cutting and to workings from goaves can be analysed both separately and together when assessing methane hazard.

4. Summary

Under the conditions of increasing output concentration and with the implementation of organizational and technical changes during mining operations, concerning the cutting speed and operational progress, the analysis of methane emissions to the longwall environment based on the calculations of short-term predictions becomes more and more important for improving the conditions of safe mining operations.

Shortening the time during which a shearer cutting cycle is performed by increasing its speed, results in an increase of methane emissions to the longwall. Short-term predictions of methane emissions to the longwall working allow for verification of safety of the planned changes in the organization of working system in the longwall.

Short-term predictions of methane emissions to workings from goaves of longwalls ventilated using "U" method over the unmined coal becomes significantly important during the assessment of safety conditions for the planned changes in an average daily longwall advance.

Short-term predictions of methane emissions during longwall mining may constitute a helpful tool in the operations of collieries both for the pre-estimation of methane emissions to the longwall workings and for variant assessment of methane hazard.

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