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INFLUENCE OF THE FIELD OF AERODYNAMIC POTENTIALS AND SURROUNDINGS OF GOAF ON METHANE HAZARD IN LONGWALL N-12 IN SEAM 329/1, 329/1-2 IN "KRUPIŃSKI" COAL MINE

WPŁYW POLA POTENCJAŁÓW AERODYNAMICZNYCH ORAZ OTOCZENIA ZROBÓW NA ZAGROŻENIE METANOWE W ŚCIANIE N-12 W POKŁADZIE 329/1, 329/1-2 W KWK „KRUPIŃSKI"

Designing exploitation in seams in surroundings of strongly methane bearing seam assumes particular importance in conditions of the growing concentration of output. While planning exploitation, calculations results of predictions of methane emission to longwalls form a basis for selection of a mode of ventilation scope of utilized prevention, including methane drainage, as well as planned volume of coal output.

Performed in the article, systematic analysis of methane hazard in longwall N-12 in seam 329/1, 329/1-2 in 'Krupiński' Coal Mine, in which on 5.05.2011 took place methane ignition, allowed to determine factors forming methane hazard in this longwall while taking into consideration location of longwall parcel relative to previous mining in this seam. Occurring discrepancies between total amount of methane emitted to longwall N-12 and forecast value indicate circumstances of additional inflow of methane from outside of its environment. Confirmation of such methane flow are results of calculations of distribution of the field of aerodynamic potentials in workings contouring mined out longwall N-14 and mining of longwall N-12, as well as, being a relevant particularity, results of methane bearing determination on coal pillar separating post-exploitation goaf of both longwalls. The article emphasizes the necessity of taking into account, at the stage of designing longwalls, ventilation conditions and the influence of the field of aerodynamic potentials on the possibility of goaf gases flow which may contribute to the increase of methane hazard.

Keywords: methane hazard, field of potential, forecasting of safe ventilation

Projektowanie eksploatacji w pokładach w otoczeniu silnie metanowego złoża nabiera szczególnej wagi w warunkach rosnącej koncentracji wydobycia. Projektując eksploatację, wyniki obliczeń prognoz wydzielania metanu do ścian są podstawą doboru sposobu przewietrzania zakresu stosowanej profilaktyki, w tym odmetanowania, często również i planowanej wielkości wydobycia.

Przeprowadzona w artykule syntetyczna analiza zagrożenia metanowego w ścianie N-12 w pokładzie 329/1, 329/1-2 w KWK „Krupiński", w której w dniu 5.05.2011 r. nastąpiło zapalenie metanu, pozwoliła na

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wskazanie czynników kształtujących zagrożenie metanowe w tej ścianie przy uwzględnieniu usytuowania parceli ściany względem dokonanej wcześniej eksploatacji w tym pokładzie. Występujące rozbieżności pomiędzy całkowitą ilością wydzielającego się metanu do ściany N-12 a wartością prognozowaną wskazują na okoliczności dodatkowego dopływu metanu spoza jej środowiska. Potwierdzeniem takiego przepływu metanu są wyniki obliczeń rozkładu pola potencjałów aerodynamicznych w wyrobiskach okonturowujących wyeksploatowaną ścianę N-14 oraz prowadzoną ścianę N-12, jak również, będące istotnym szczegółem, wyniki oznaczeń metanonośności na płocie węglowym rozdzielającym zroby poeksploatacyjne obu ścian. Artykuł wskazuje na potrzebę uwzględnienia na etapie projektowania ścian uwarunkowań wentylacyjnych oraz wpływu pola potencjałów aerodynamicznych na możliwość przepływów gazów zrobowych, które mogą przyczynić się do wzrostu zagrożenia metanowego.

Słowa kluczowe: zagrożenie metanowe, pole potencjałów, prognozowanie bezpiecznej wentylacji

1. Introduction

The article presents findings of research justifying the need to carry out detailed analysis of ventilation-methane hazard for designed longwalls situated in surroundings of strongly methane bearing seam on the basis of methane emission forecasts, as well as ventilation conditions having bearing on possibilities of methane inflow to longwall from its surroundings. Subject matter covered in the article is connected with longwall N-12 in seam 329/1, 329/1-2 in JSW S.A., 'Krupiński' Coal Mine, in which on 5.05.2011 methane ignition took place.

On the basis of mining-geologic, gas and ventilation conditions as well as the scope of utilized prevention, a systematic analysis was performed in the article of ventilation-methane hazard in the environment of mined longwall N-12 in the period from the commencement of longwall run to the incident of methane ignition. Such an analysis was conducted by the Team composed of members of the Committee appointed by the President of the State Mining Authority to investigate causes and circumstances of the incident of methane ignition and corporate occupational accident in longwall N-12 in 'Krupiński' coal mine. In the present article, an analysis has been carried out encompassing methane emission to the environment of longwall N-12, taking into consideration the following factors:

- emission of methane to longwall N-12 from extracted seam as well as from undermined and overmined seams situated within the scope of destressing associated with mining,
- methane emission from surroundings of previously conducted exploitation in seam 329/1, 329/1-2.

Determination of the amount of emitted methane at the stage of planning longwalls is a result of prognostic calculations made (Krause & Łukowicz, 2000) for exploitation regions, in accordance with the binding law regulations in this scope. Values of predictions of methane emission at the stage of designing exploitation have influence on the selection of conditions as well as a mode of longwall ventilation and scope of methane prevention (Krause, 2009; Dziurzyński et al., 2010). Accuracy of calculations of forecasts of methane emission to the environment of longwall is of profound significance with previously assumed mode if its „U" ventilation along the body of coal. Occurrence of discrepancies between results of forecasts and actual emission during mining of longwalls frequently has a negative influence on the level of safety. Objectively estimated value of forecast should be a basis both, for determination of ventilation condition, selection of means of prevention including methane drainage, as well as determination of safe volume of coal output from longwall.

At the stage of designing longwall N-12, in seam 329/1, 329/1-2 in 'Krupiński'coal mine, Zakład Odmetanowania Kopalń Sp. z o.o. (Mines Degasification Plant Co Ltd) in Jastrzębie Zdrój developed a forecast of absolute methane content, which underlay the selection of parameters of ventilation and the scope of prevention. Moreover, after the incident of methane ignition on 5.05.2011, the Team composed of members of the Committee appointed by the President of the State Mining Authority performed a detailed analysis of methane emission to longwall N-12, basing on adopted in detail parameters encompassing mining-geological conditions, gas conditions, edges of earlier led underground extraction as well as factors which could have contributed to the increased methane emission to workings of longwall region. Supplement of these investigations is adoption of methods of computer simulation of ventilation process (Dziurzyński, 2003), which enabled to devise a scheme of potential region of longwall N-12 and N-14 in seam 329/1, 329/1-2 and revealed directions of methane migration in the investigated region of the mine.

Carried out systematic analysis of forecasts and actual emission of methane to mined longwall N-12 in seam 329/1, 329/1-2, allowed to form conclusions referring to accuracy of estimation of the severity of predicted methane hazard.

2. Predicted methane emission to longwall N-12 in seam 329/1, 329/1-2

At the stage of designing mining of longwalls, the most frequent reasons of the occurrence of discrepancies between values of forecasts and actual methane emission, are:

- incorrect determination of methane bearing of exploited seam on panel length of longwall in conditions of its previous destressing and degasification,
- inaccurate estimation of methane bearing distribution of undermined and overmined seams,
- not taking into account possible methane inflow to longwall from the surroundings of post-exploitation goaf.

Values of seam saturation with methane, in which mining is planned to a considerable extent have an effect on the values of determined forecasts, thereby actual emission of methane directly into working of longwall.

Taking into consideration the above, appropriate estimation of distribution of methane bearing in mined seam as well as the deposit surrounding longwall has influence on accuracy of forecasts as well as their conformity with values of actual emission during exploitation.

In conditions of the increasing concentration of output, detailed knowledge of distribution of methane bearing in the parcel of extracted seam, as well as in undermined and overmined seams, allows to eliminate personal errors, making it impossible to predict methane emission to the environment of longwall more accurately.

Frequently, in undermined and overmined seams, surrounding the designed longwall, mining works are not conducted, thereby also research on methane bearing and its vertical distributions are accepted intuitively.

Distribution of methane bearing in rock mass in surroundings of designed longwall is of significance for the predicted amount of methane, which will be released as a result of degasification of undermined and overmined seams to the environment of longwall.

Significant influence on distribution of methane bearing in extracted seam and in undermined and overmined seams has previously conducted exploitation in seams causing destressing and partial degassing of coal-bed in surroundings of carried out exploitation process.

For the purpose of carrying out an analysis of distribution of methane bearing in the part of seam 329/1, 329/1-2 on workings contouring previously mined out longwall N-10 and N-14 as well as discussed longwall N-12, results of determinations of methane bearing have been marked setting the course of isoline of methane bearing (Fig. 1).

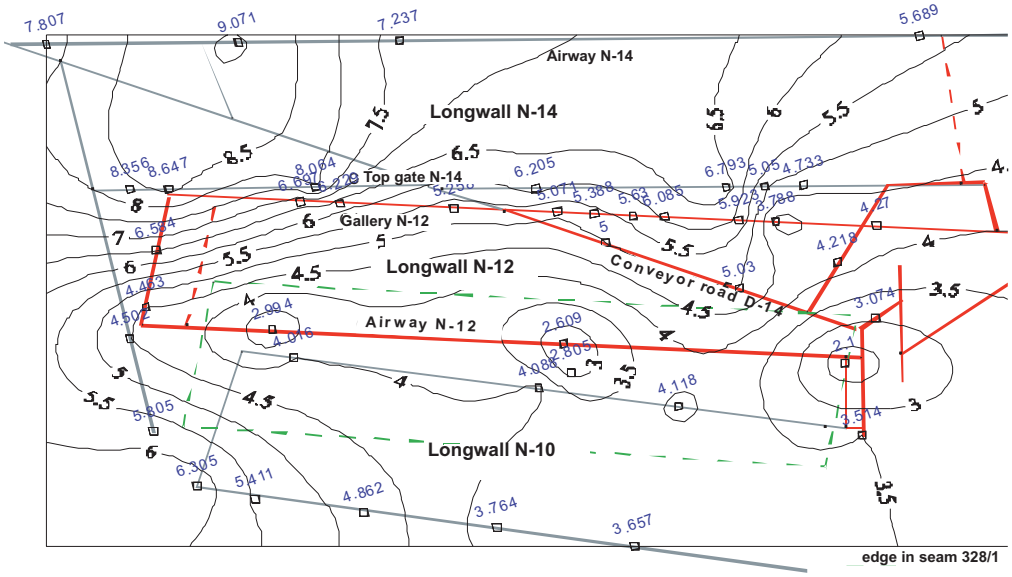

Fig. 1. Map of the isoline of methane-bearing capacity on the panel length of longwall N-12 in seam 329/1, 329/1-2 in hard coal mine "Krupiński"

The course of isoline of methane bearing in seam 329/1, 329/1-2 (Fig. 1) and edges of exploitation in seam 328/1 (Fig. 2) enabled to arrive at the following conclusions:

- distribution of methane bearing in seam 329/1, 329/1-2 is characterized by a tendency towards the increase of saturation with methane down the decline with the depth of deposition,
- parcel of seam 329/1, 329/1-2, contouring longwall N-12, has been partially degassed (in parallel to air-heading N-12) as a consequence of previous mining in seam 328/1 (Fig. 2),
- results of determinations of methane bearing made during drivage of air-heading N-12 confirm that driven working has been led in partially degassed seam 329/1, 329/1-2. Values of methane bearing are given in Figure 2 in red colour,
- mining longwall N-12 until 5.05.2011 (incident of methane ignition) was conducted in not de-stressed with extraction part of seam 329/1, 329/1-2,
- values of determinations of methane bearing in the region of rise gallery N-12 crossing with heading N-12, confirm local degasification of coal pillar of seam 329/1, 329/1-2, separating this heading from goaf of longwall N-14.

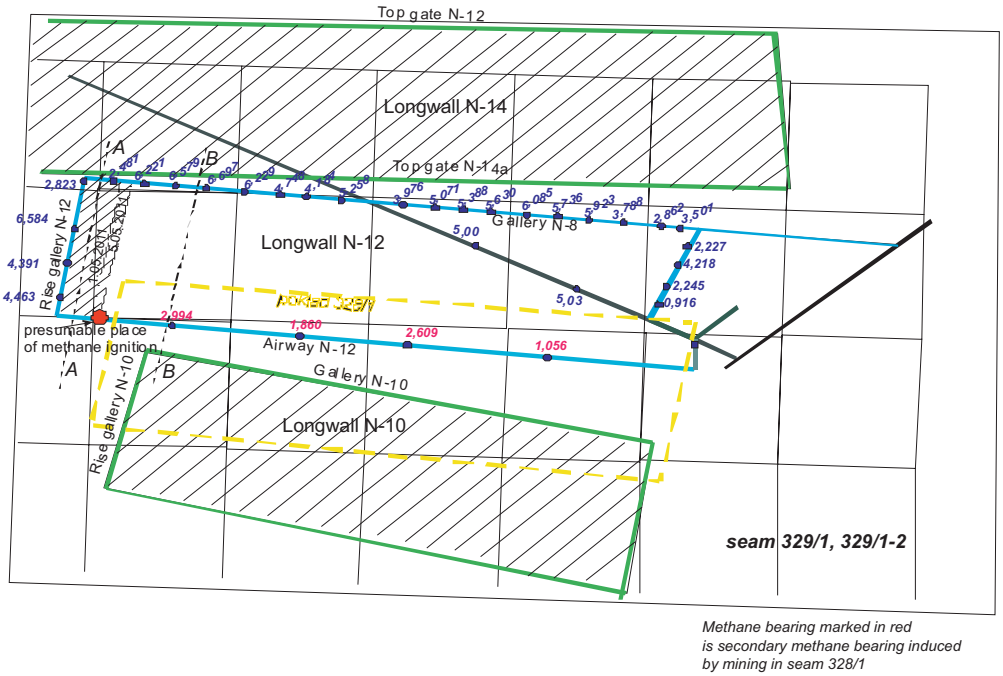

Fig. 2. Planned mining of seam 329/1, 329/1-2 with longwall N-12

As it has been mentioned before, previously conducted exploitation of seam 328/1 exerted an influence on partial degasification of the parcel of extracted seam 329/1, 329/1-2 as well as seams within the destressing and degasification zone.

Longwalls N-12 was mined until 5.05.2012 (incident of methane ignition) in part not de-stressed by mining in seam 328/1; however, from 80 m of its panel length it was to be mined in a part of the seam partially de-stressed.

In Figure 3, vertical cross-sections through the deposit in part not de-stressed with mining of seam 328/1 (cross-section A-A) as well as in de-stressed part (cross-section B-B) are presented. Vertical cross-sections through the destressing zone of deposit as a consequence of exptraction in seam 328/1 as well as longwall N-12 in seam 329/1, 329/1-2 confirm overlapping of zones of distressing connected with mining. The above signifies that extraction of longwall N-12 in seam 328/1 has de-stressed and partially degassed small surface of seams: 327/3, 329/1and 329/1-2 ,which to insignificant extent might have had an influence on a decrease of actual absolute methane-bearing of the environment of longwall N-12 on panel length from 80 m of panel length, until its termination.

For longwall N-12 in seam 329/1, 329/1-2, on the basis of initial data and the analysis of:

- distribution of methane bearing in exploited seam,
- vertical distribution of methane bearing of seams and coal strata within the scope of destressing,
- surroundings of performed mining operations in seams 328/1 as well as 329/1 and 329/1-2

the predicted amount of methane emission to the environment of longwall N-12 was calculated.

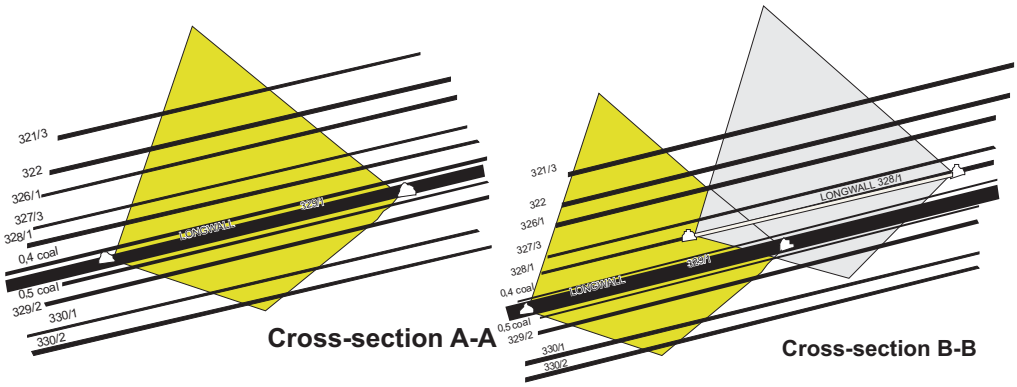

Fig. 3. Zones of destressing with longwalls in seams 329/1, 329/1-2 and 328/1, not de-stressed part (cross-section A-A) and de-stressed part (cross-section B-B) from Figure 2

Estimated forecasts of methane emission indicate high degree of regularity of their values on the designed longwall N-12 panel length (Fig. 4). Cross-sections S1 to S8 of subsequent 100-meter sections of longwall N-12 panel length have been marked on x-axis. The highest methane emission to the region of longwall N-12 encompasses the first 150 m of exploitation panel length, where at daily advance of 5 mb/day (i.e. 2560 Mg of coal from longwall N-12) will be developed on the level of 18 m^3CH_4/min.

Absolute methane-bearing capacity of longwall N-12 in the period preceding the incident, i.e. from 27.04.2011 to 4.05.2011 was within the range of 20.16 – 23.20 m^3CH_4/min.

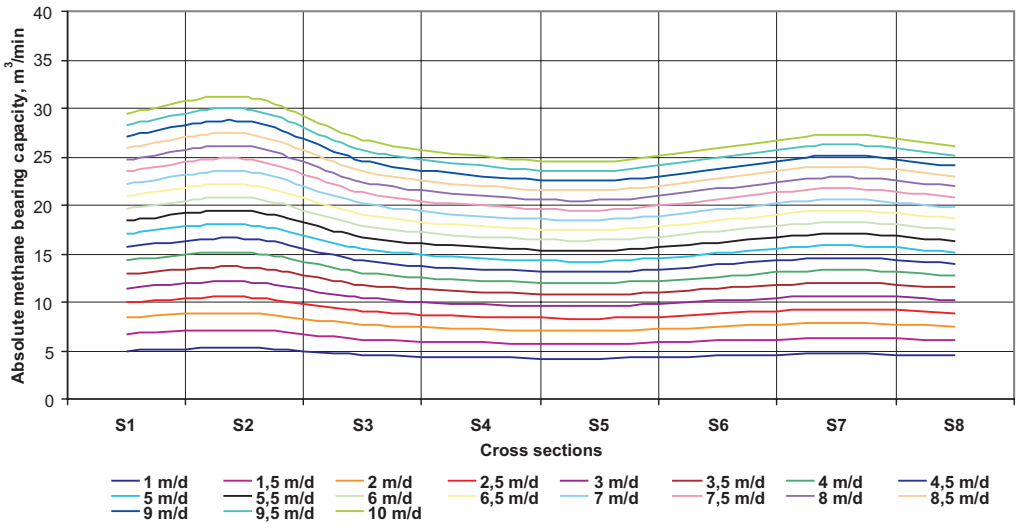

Fig. 4. Forecasts of methane emissions on designed panel length of longwall N-12 in the scope of advances 1-10 m/d

However, it ought to be mentioned that longwall N-12 on the day of the incident i.e. 5.05.2011, reached the advance of 58 m from the beginning of exploitation and the scope of destressing zone and degasification at desorption angle of 60° has not included all of the seams which should have been covered as a result of the obtained longwall N-12 face advance.

On the basis of the performed analysis, presented graphically in Figure 5, after reaching advance of 58 m, undermined seams to the distance of 100 m and overmined to the distance of 32 m from exploited seam have fallen with the scope of destressing and degasification. Estimated scope of mining induced destressing for longwall N-12 with the assumption of its length and inclination is 150 m 'upwards' and 56 m 'downwards' from extracted seam.

Exploitation with longwall N-12 for 58 m -face advance on the day of incident, i.e. 5.05.2011, has not de-stressed seams deposited in the distance of more than 100 m from mined seam, i.e. seam 322 as well as 5 strata of coal of total thickness of 4 m and none of the coal-beds in the roof of longwall N-12.

Furthermore, for extraction advance of longwall N-12 amounting to 58 m, destressing and degasification have not covered overmined seams 330/1 and 330/2 of total thickness of 1.2 m (Fig. 5). Total destressing of the deposit volume in the region of the environment of longwall N-12 would take place after reaching advance of about 87 m, which has been presented in Figure 5.

On the basis of estimations of forecasts as well as analysis of hazard level until the day of 5.05.2001, it can be stated that:

- values of forecasts of methane emission for longwall N-12 in seam 329/1, 329/1-2 are lower than the actual methane emission until 5.05.2011,
- reached since the beginning, extraction panel length of longwall N-12 of 58 m has not caused destressing and degasification of all of the seams for a full range of exploitation impact, thereby the amount of released methane to the region of longwall N-12 on 5.05.2011 was lower than the predicted value of emission,
- discrepancy between the predicted value, lower than actual methane emission to the environment of longwall N-12, could have been a consequence of free-methane migration from goaf of longwall N-14 through the crushed coal pillar separating goaf.

In conditions of considerably greater amount of methane emission than predicted value, it can be assumed, that in the area of longwall N-12 existed favourable conditions for methane migration, and even laminar flow between goaf of longwalls N-14 and N-12. A signal indicating possible methane migration between the goaf are low values of two subsequent determinations of methane bearing made during the drivage of heading N-12 in the region of the crossing with rise gallery N-12 (Fig. 2). It ought to be mentioned that low values of the two determinations of methane bearing on coal pillar in the place of its smallest width, separating driven heading N-12 from goaf of longwall N-14 confirm that coal has been partially degassed.

Degasification of coal seam on coal pillar in close vicinity of goaf of longwall N-14 indicates increased gas permeability of and its unsealing, which could have been a reason for partial degasification in close vicinity from longwall N-14 goaf. Exploitation with longwall N-12 might have contributed to complete destruction of coal pillar and combining goaf of longwalls N-12 and N-14.

In such situation, mining of longwall N-12 created a possibility of oriented methane migration between post-exploitation goaf in seam 329/1, 329/1-2.

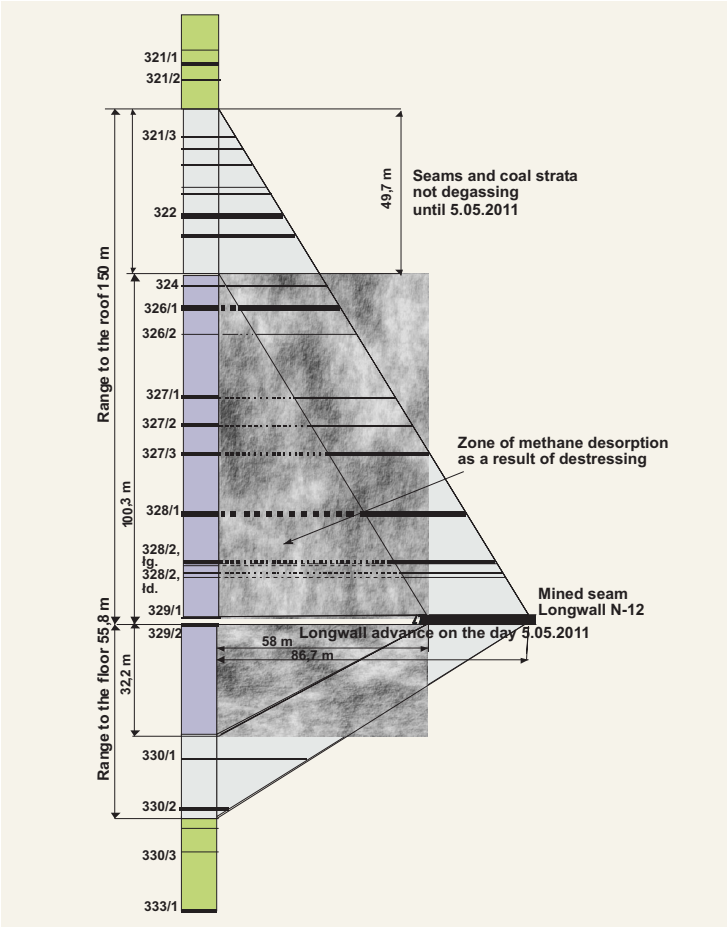

Fig. 5. Zone of destressing and degasification of undermined and overmined coal-beds of longwall N-12 in seam 329/1, 329/1-2 after reaching advance of 58 m on 5.05.2011

3. Methane migration between goaf of longwalls N-14 and N-12 from numerical calculations on the model of ventilation network perspective

Mining with longwall system causes that its destressing character contributes to intensive methane desorption from undermined and overmined seams. Percentage content of methane emitted to the environment of longwalls depends on such factors as: longwall length, methane bearing and thickness of exploited seam as well as undermined and overmined seams, but also their distance from extracted seam.

Formation of de-stressed seams in the surroundings of mined out seams results in their degassing and methane emission after exploitation termination.

On the basis of ventilation and methane balance in workings contouring goaf, a model of methane emission to post-exploitation goaf has been developed. Model of methane emission enables to predict emission of methane to goaf in close approximation in subsequent time intervals after exploitation termination (Krause & Łukowicz, 2000):

Methane emission to goaf is calculated with the equation:

$$V_z = 0.2 \cdot \dot{V}_{mean}\,(1-\frac{u}{15}), \qquad \mathrm{m^3CH_4/min} \tag{1}$$

where:

V_{mean} — mean absolute methane-bearing capacity of the region during exploitation, $\mathrm{m^3CH_4/min}$,

u — number of years since exploitation termination.

Longwall N-14 in seam 329/1, 329/1-2 was exploited in the years 2009-2011and on the day of the incident of methane ignition in longwall N-12, i.e.5.05.2011 it was prepared for decommissioning of longwall equipment and its liquidation. Methane emitted to post-exploitation goaf of longwall N-14 after its termination was partially carried with ventilation air and included in methane drainage. At average absolute methane bearing capacity in longwall N-14 amounting to 21.32 $\mathrm{m^3CH_4/min}$in the first half-year of 2010, on the basis of the formula (1), it is possible to estimate methane emission to goaf after a year since its termination. Value of methane emission to post-exploitation goaf of longwall N-14, calculated by means of the formula(1) is 3.98 $\mathrm{m^3CH_4/min}$. Methane flowing to post-exploitation goaf of longwall N-14 desorbs filling the volume of goaf, migrating along the rise of the seam as a result of the influence of natural depression and in accordance with distribution of values the field of aerodynamic potentials.

Exploitation of longwall N-12, commencing its run in the direct vicinity of goaf of longwall N-14 and situated over goaf of longwall N-12 created circumstances for the impact of natural depression (thermal and gaseous) on directed goaf gases migration with methane along the rise of goaf longwall N-14 in the direction of workings contouring mined longwall N-12. Direction of migration in goaf of longwall N-14 along the rise towards goaf of longwall N-12 could have been a result of both, favourable conditions of the effect of natural depression in goaf of longwall N-14 as well as unsealing of coal pillar separating goaf of these longwalls in the initial section of panel length of longwall N-12. Results of investigations on methane bearing made during drivage of heading N-12 in the region of crossing with rise gallery N-12 confirm partial degasification of seam 329/1 and 329/1-2, in this place resulting from destressing on account of close vicinity from goaf of longwall N-14. Partial reduction of methane bearing of seam on coal pillar affirms its unsealing and degasification adjacent to the rise gallery N-12. After the start-up of mining of longwall N-12 occurred gradual degradation of coal pillar separating goaf of longwalls N-12 and N-14 enabling methane migration between these longwalls goaf. The fundamental factor having influence on intensification of goaf gases migration with methane is developing a tendency of flows on the basis of values of the field of aerodynamic potentials in active workings connected with the region of liquidated longwall N-14 as well as mined N-12 by means of ventilation. In view of the above, for identification of the directions of goaf gases flows, a scheme of potential ventilation network has been devised, particularly taking into account mining of longwalls N-12 and N-14.

Adoption of a computer programme *VentGraph* in solving current problems with ventilation is successfully utilized also in mining worldwide (Gillies et al., 2005; Fiuraskova et al.,

2010). On the basis of computer programme of Ventilation Engineer *VentGraph* (Dziurzyński et al., 2003), which, among other things, enables to determine aerodynamic potentials, update of the structure of ventilation network of 'Krupiński' Coal Mine was made for the state on the day of 5.05.2011. Workings of the region of longwall N-12 were introduced into the data base as well as prognostic calculations were made of air distribution in the whole ventilation network reconstructing the state in the air distribution before the incident on 5.05.2011. Results of calculations of distribution of the field of aerodynamic potentials in ventilation network 'Krupiński' Coal Mine on 5.05.2011 allowed to perform reasoning in the scope of the assessment of possible directions of goaf gases migration, including methane in post-exploitation goaf of longwalls N-14 and N-12. Calculated values of aerodynamic potentials between environments of longwalls N-14 and N-12, significant for analysis, have been marked on the map of seam 329/1, 329/1-2 (Fig. 6). Distribution of values of potentials shows possible tendency of goaf gases migration, including methane, results from shaping the difference of aerodynamic potentials between the environments of longwalls N-14 and N-12.

On the map of seam 329/1, 329/1-2 (Fig. 6), values of aerodynamic potentials for nodes on the crossing of longwall gates with longwalls N-14 and N-12 have been marked in Fig. 6. Difference of nodal potentials between inlets of fresh air to longwalls N-14 and N-12 amounts to 195 Pa, explicitly indicating direction of a tendency of goaf gases flow. Velocity of the flow of goaf gases from longwall N-14 (not-liquidated) in western direction depends on the resistance

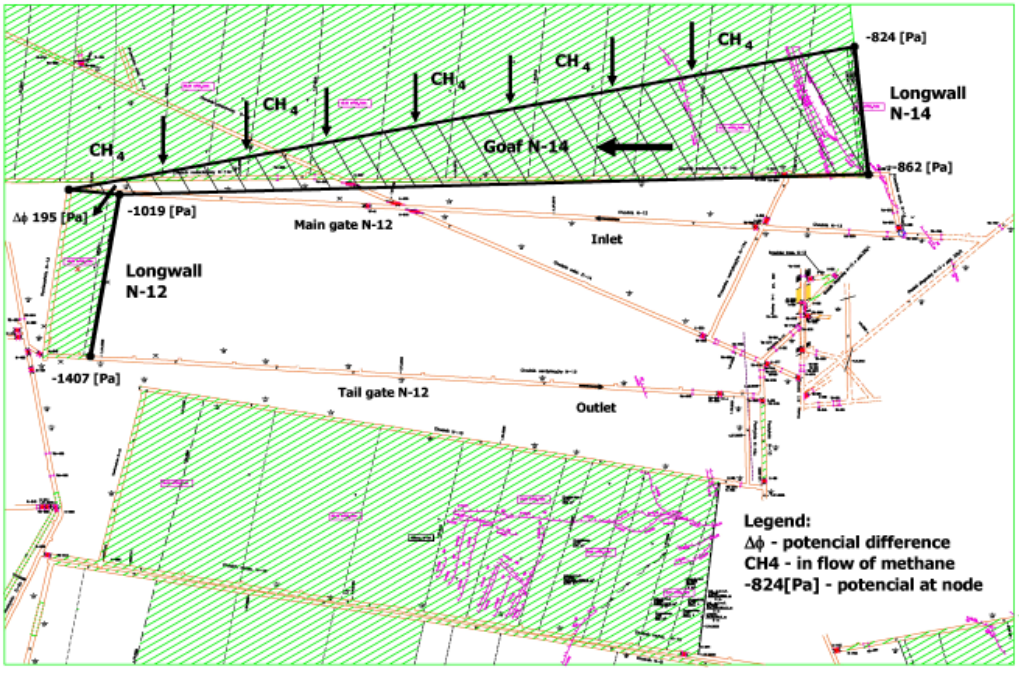

Fig. 6. Shaping of the tendency of goaf gases migration including methane in goaf between longwalls N-14 and N-12 goaf in seam 329/1, 3129/1-2

of post-exploitation goaf from the west side as well as integrity of coal pillars separating post-exploitation goaf of longwalls N-14 and N-12.

Tendency of goaf gases migration with methane through the crushed rib of coal is a consequence of occurring difference of aerodynamic potentials between the environments of these longwalls; moreover, influence of natural depression. Difference of aerodynamic potentials between longwalls N-14 and N-12 orients migration in goaf of longwall N-14, which has been presented in Figure 6 (shaded area).

Exploitation with longwall N-12 at the initial panel length played a part in the gradual crushing of coal pillar, decreasing unit value of aerodynamic resistance, at the same time increasing the volume of gases migrating between goaf of longwalls N-14 and N-12. High volume of free-methane in goaf of longwall N-14 as well as its high percentage content is a result of continuous methane migration from undermined and overmined seams within the scope of destressing zone of longwall N-14. With the advance of mined longwall N-12, the width of coal pillar separating goaf of longwalls N-14 and N-12 will incease. It can be assumed with high probability that after the beginning of mining of longwall N-12 took place gradual unsealing of coal pillar separating goaf of longwalls N-14 and N-12.

Discrepancies between values of predictions of methane emission to the environment of longwall N-12 and actual methane emission during exploitation were a result of free-methane inflow from goaf of longwall N-14 through the crushed rib of coal. In conditions of longwall N-12 ventilation in „U" system along the body of coal intensification of free-methane inflow to its goaf results in the increase of intensity of emission of this gas in the region of longwall crossing with ventilation heading. Increase of methane hazard in the region of longwall crossing with ventilation heading depends on geometric parameters of longwall and air-heading, rate of air flowing through longwall N-12 and methane drainage of longwall goaf.

Carried out analysis of distribution of the field of potentials on neat lines of post-exploitation goaf of longwall N-14 and mined longwall N-12 indicates explicitly the tendency of possible methane flow from post-exploitation goaf of longwall N-14 to goaf of longwall N-12.

4. Conclusions

Fundamental significance for safety assurance of the work of mining personnel in deep mines has suitable ventilation, ensuring provision of the required amount of air to workings. The most important values determining the state of ventilation are: air volume stream in workings, concentrations of methane and other harmful gases (e.g. accompanying fires) in the air, barometric pressures, temperature and air humidity. State of ventilation is controlled by monitoring system and manual measurements. However, limited number of sensing elements of monitoring system and limited possibilities of performing manual measurements does not allow to discover the complete state of the whole ventilation network of the mine. Possibility of forecasting state of ventilation for the whole mine or its selected parts gives application of methods of predicting methane emission in environment of longwall and method of computer simulation utilizing mathematical models of phenomena accompanying exploitation.

Presented in the article ventilation and methane analysis indicates that development of a threat in the region of mined longwall N-12 was a consequence of methane emission form the environment of longwall and additional free-methane inflowing from post-exploitation goaf of

previously mined longwall N-14. Conducted investigations allow to form the following conclusions:

1. Designing exploitation in methane seams should take into consideration both, predicted methane emission to the environment of longwall, mode of ventilation, scope of prevention as well as goaf surroundings which may shape the level of methane hazard during exploitation.
2. Extraction in strongly methane bearing part of seam should take place with subsequent longwalls 'descending' along the decline. Such a way of exploitation limits the influence of natural depression effect on undesirable direction of methane migration.
3. Predicted amount of methane emitted to the environment of longwall ought to take into account possible free-methane inflow from post-exploitation goaf connected with the designed exploitation by means of ventilation.
4. High percentage content of methane emitting to goaf during mining of longwalls in their total methane-bearing capacity indicates potential sources, which in the future may shape methane hazard during designing sublevel exploitation.

The article refers to subject matter of stage 3, research task no. 2 of the strategic research project of the National Centre for Research and Development (Polish acronym: NCBiR), ent. 'Improvement of work safety in mines', encompassing of issues connected with the influence of ventilation network on methane hazard in the region of planned longwalls.

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