Arch. Min. Sci. **67** (2022), 1, 195-204

Electronic version (in color) of this paper is available: http://mining.archives.pl

DOI: https://doi.org/10.24425/ams.2022.140861

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MEASUREMENTS OF THE METHANE CONCENTRATION ALONG THE LONGWALL EXCAVATIONS AND LONGWALL

One of the most hazardous places in mines are longwall areas. They emit a considerable amount of methane to the ventilation air. The emission depends on many but mostly known factors. The article presents the research results on changes in the methane concentration along the longwall excavations and longwall. The distributions were obtained based on a measurement experiment at the ZG Brzeszcze mine in Poland. The author's research aimed to experimentally determine the concentration of methane as a function of the length of excavation for the longwall excavations and longwall. As a result, methane concentration trends along the excavations were obtained. The conclusions show the pros and cons of the method used, and it allows to set the right direction in the development of measurement systems and sensors.

Keywords: measurements of the methane concentration; section measurements; Y system; individual methane meters; inspection and monitoring; mining; data fusion

1. Introduction

The measurement of the methane concentration in mines is within the scope of responsibilities, resulting in the need for safety and maintenance. They are one of the most important ventilation measurements. Methane poses a threat to the health and life of workers and the continuity of the mining plant operation. For this reason, the monitoring of the methane concentration and ongoing risk control is carried out. The known solutions, such as gasometric stationary systems or portable methane metres, are used to control methane content. There are increasingly more attempts to implement innovative solutions based on fuzzy logic, artificial intelligence, expert systems, or

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wireless sensor networks [1-8]. The measurements of the methane concentration in Polish hard coal mines, in accordance with the Regulation of the Minister of Energy [9], are carried out by the frontmen, methane fighters, blasters, management and traffic supervision personnel, shearer operators, gasometric system conservators, drillers and designated employees of the methane drainage unit. In addition, methane measurement is performed by measurement technicians and foremen from the ventilation department within the scope defined by internal regulations and instructions. In addition to the measurements performed as part of the crew's duty, continuous monitoring is carried out, such as methane & carbon monoxide concentration, air velocity and other gases, including atmospheric pressure monitoring [10]. Automatic gasometric monitoring is carried out at fixed measurement points, and stationary sensors are installed at these points [11]. The automatic methane measurement system enables the transmission of measurement results to the gasometry control room, signalling exceeded permissible gas concentrations and turning the electricity off in a specific area.

Methane concentration measurements are used to monitor the safety status by controlling the methane concentration value in designated places. The measurement is compared with the permissible methane concentration threshold, which could be 0.5%, 0.75%, 1.0%, 1.5% or 2%, depending on the nature of the place and in the light of the legal regulations in a given country. In Poland, for the headgate (inlet), the maximum concentration of methane is 1%. In the tailgate (outlet) it is 2%. From the point of view of safety, it is important to constantly monitor the concentration of methane, especially within the longwall, where the values of the methane concentration can change rapidly [12-15]. Measurements along the galleries can reveal potentially dangerous places due to a high methane release or local accumulation [13,16]. The properly conducted prevention of the methane hazard is to prevent accumulation and counteract the appearance of high concentration methane in workings [17,18]. For this purpose, auxiliary ventilation devices are used in the form of additional duct fans refreshing the areas with increased methane emission, compressed air nozzles or jets and ventilation partitions directing the circulating air stream to the places of methane accumulation or outflow [19]. Sometimes these preventive actions are not enough to stop the hazard, as the statistics show [20]. More automated and remotely working systems with intelligent data exchange can contribute to this improvement.

2. Sectional measurements of methane concentration

It is worth mentioning that the mine gasometry sensors work connected in a network that allows for joint data collection and analysis. Portable methane metres work only by recording measurement data to the internal memory of the device and older models do not save data at all. Individual methane metres are being used to collect and process data during the crew transition, thus supplementing the point measurements from the gasometric network and obtaining knowledge about the concentrations in intermediate places.

The failure to use individual methane metres for joint collection and processing indicates a significant lack of development of the mine telemetry network. To supplement this deficiency, a method of sectional measurements of methane concentration was proposed. Sectional measurements of the methane concentration consist in measuring the gas concentration along the mine excavations, or the galleries or generally any ventilation duct divided into measuring sections in such a way that changes in the methane concentration can be observed in terms of the arithmetic mean, maximum value, change trend and the shape of the course of the methane concentration along with each separated fragment of the excavation.

The idea of segmental measurements of the methane concentration was presented at the conference entitled “10th Academy of Mining Aerology” and in the article [21], where the idea and preliminary numerical simulations were presented. This article presents measurement data and a detailed description of the experiment, which is a continuation of work in this field.

3. Preparation for the experiment

3.1. Place of measurements

The experiment was conducted in the ZG Brzeszcze mine belonging to the company Tauron Wydobycie S.A. Longwall 02 was selected for the experiment, located in seam 510, classified as the IV category of methane hazard, B class of coal dust explosion hazard, I category of gas and rock outburst hazard and I degree of rockburst hazard (Fig. 1). Longwall 02 was ventilated with a system with double ventilation galleries (ventilation on the so-called “short Y”). The analysis of the air current stability in the wall showed that the air current is very strong (N = 19240 W) with satisfactory stability (St = 0,17). The total length of longwall 02 is 760 m, length is 160 m, while the operating height is up to 4.5 m at the time of measurements, longwall 02 was at the stage of the full run (160 m from start point).

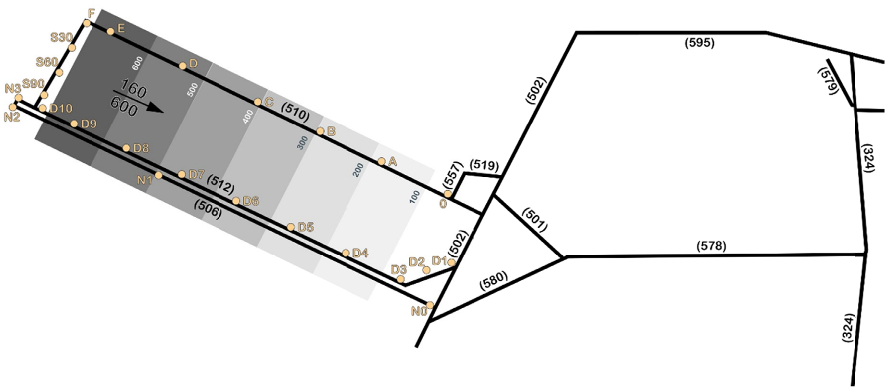

Fig. 1. Longwall 02 area. Prepared on the basis of the bed 510 map

3.2. Devices used in the experiment

Measurement devices made at the Strata Mechanics Research Institute, Polish Academy of Sciences were used to perform the measurements. These were the SOM 2303 Methanoanemometers [22]. The methane sensors have been adjusted and calibrated based on the standard methane mixtures. Instrument indications were also checked after the experiment and no significant differences in indications were found. The accuracy of the methane sensors in the range from 0 to 2% is 0.1% V/V. The time constant T_{90} is less than 3 s.

4. Methodology

Reference points at the ends of the measurement sections have been defined. It was assumed that the average length of the section would be 150 m, which results from the assumption that the time needed to stop and record the position should be much shorter than the time required to pass the section. The reference points were given names that marked the arch support. The miners participating in the experiment recorded the time and name of the point when they passed the reference point. From this, the times of entry and exit from the measuring sections could be recorded. These records were used to fragment the measurement data concerning the sections.

Four people took part in the experiment. Each person had a set route. There was also a meeting point at the junction of the wall with ventilation gallery No. 512. All four people were to meet at the assembly point. The experiment can be divided into two stages. The first stage from the beginning to the meeting of everyone at the assembly point, the second stage began at the assembly point and ended after everyone met again at the entrance to the ventilation gallery near the stationary telephone.

People participating in the experiment were given the following designations: A, B, C, D, for the purpose of easier description and anonymisation of personal data.

Next, the routes of individual people's passage will be presented. Fig. 2 shows A passage route.

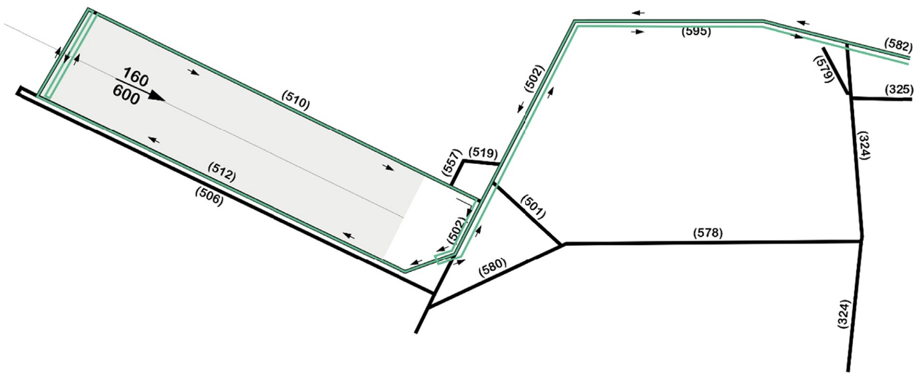

Fig. 2. Longwall 02 area with the person's route marked (A)

The A route started at the entrance to the area of longwall 02, where the safety doors were built. Then, following the fresh air current along the galleries 582, 595, 502, it passes through the ventilation doors and enters the ventilating gallery. Then it goes to the assembly point along the ventilation path, out of the longwall. After a while, it goes through the longwall towards the inlet and back again. The shearer was stopped while it was going through the longwall. The second stage begins by going through the longwall to the inlet. Then, along the gallery no. 510 to the junction with 502. Then, it turns right and goes through the ventilation doors to the entrance to ventilation gallery 512.

Fig. 3 shows B passage route.

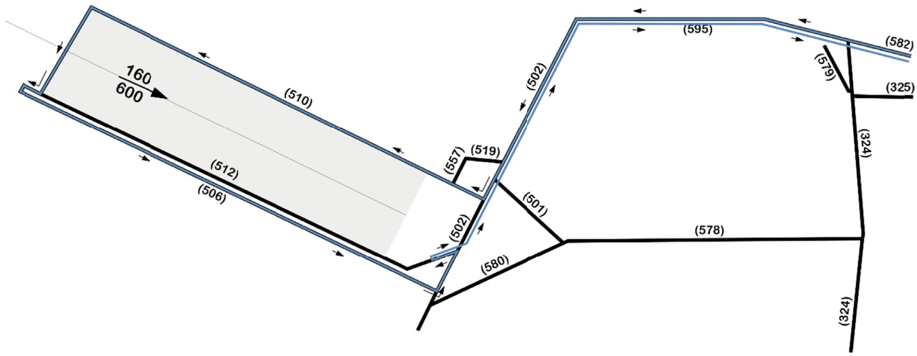

Fig. 3. Longwall 02 area with the person's route marked (B)

The B route was similar to A, as it starts from the inlet to the area at the junction with the 510 maingate and ends where the A and B routes divide. The B route goes to the longwall along the maingate (in the fresh air current). It then passes through the longwall and waits at the meeting point until the end of stage 1. Stage two begins at the meeting point from where the route travels through the intersection behind the face of the longwall to the longwall gallery 506. Then, follow gallery 506 to gallery 502, then over the ventilation doors, and after, it turns to the ventilating gallery 512, where it waits for the rest of the people.

Fig. 4 shows the C passage route.

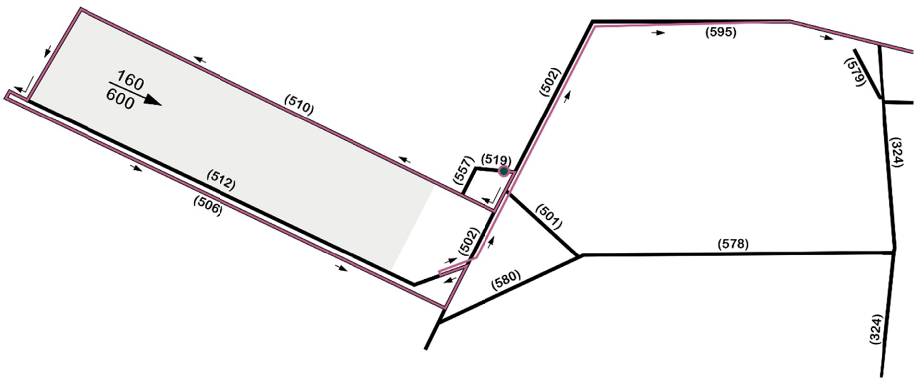

Fig. 4. Longwall 02 area with the person's route marked (C)

The C route starts on gallery 519, where the crew assembly point and work division were located. Then, similarly to the B route, it proceeds along gallery 502 to the junction with gallery 510. Then, in the fresh air flow, passes gallery 510 and continues towards the wall. It traverses the longwall and stops at the meeting point until the end of stage 1. In the second stage, together with the B, it returns along the longwall gallery passage 506 and passes through the ventilation doors separating the used and fresh currents and stops at the entrance to the ventilation gallery. From that moment on, they all walk together successively along galleries 502, 595 and 582.

Fig. 5 shows the D passage route

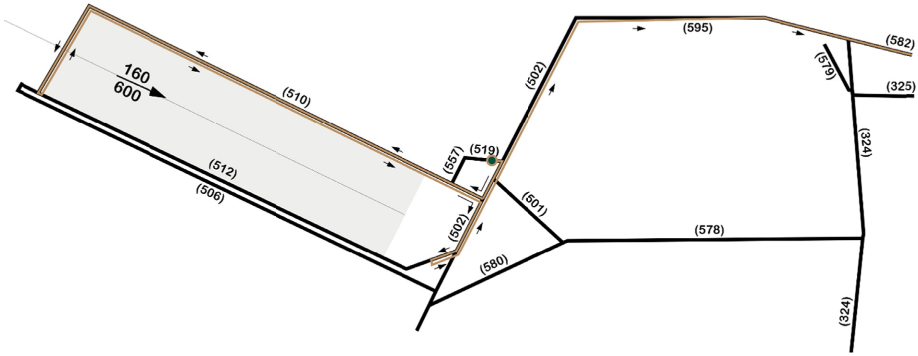

Fig. 5. Longwall 02 area with the person's route marked (C)

In the first stage, the D route is duplicated with the C route. In the second stage, it is duplicated with the A route.

The routes shown have many common parts, especially the longwall and the maingate (510). Only A passed through the ventilation gallery, and only B and C passed through the longwall gallery (506) together at the same time. At least two people went through the remaining sections.

After the measurements were taken, the data from the devices were read and divided into fragments according to the time of entering and leaving the sections. Then, the sections for which several data registrations were collected and compared. The sections that were travelled only once are shown in the diagram, and the nature of the changes in the methane concentration was determined.

5. Results

The results are presented in the form of graphs with marked intervals corresponding to the measurement sections. The x-axes of the abscissa show the distance from the front of the longwall in all the diagrams. In the case of a longwall diagram, the x-axis represents the distance from the intersection with the gallery.

Fig. 6 presents five passages of methane concentration recorded in successive moments of time. In Fig. 6, the lag in time relative to the earliest collected data is indicated.

The passage along the longwall took place 7 times, which resulted in obtaining similar measurement results (Fig. 7). The course of A.3 and D.2 were registered when people were moving in relation to each other at a distance of about 5 m. Then, the combine began working and moved towards the following A and D. After 4 minutes of work, the shearer has stopped.

The concentration of methane (Fig. 8) was increasing towards the longwall starting from about 350 metres in front of the longwall face. The concentration in the ventilation gallery increased exponentially, which indicates an increase in the number of methane emission sources. The source may be a coal sidewall, from which the surface of the sidewall from which methane is released increases with each metre of the length of the passage.

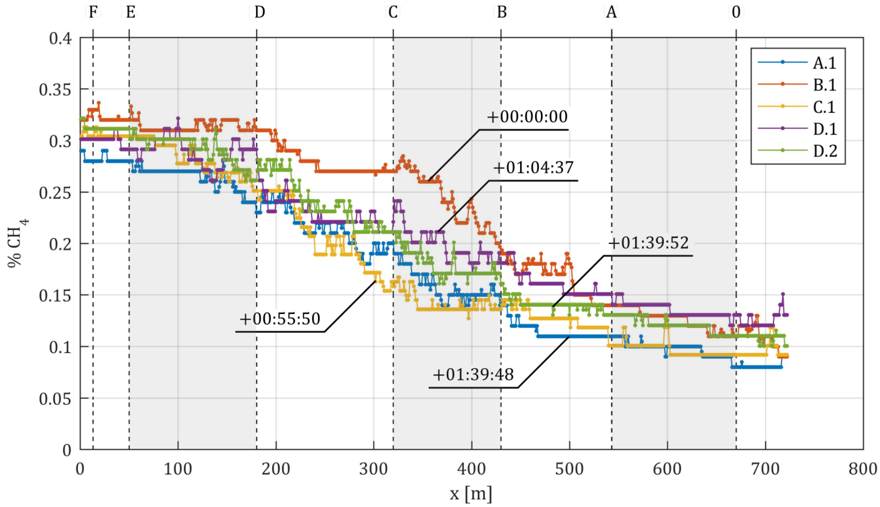

Fig. 6. Waveforms of methane concentration along the maingate (510)

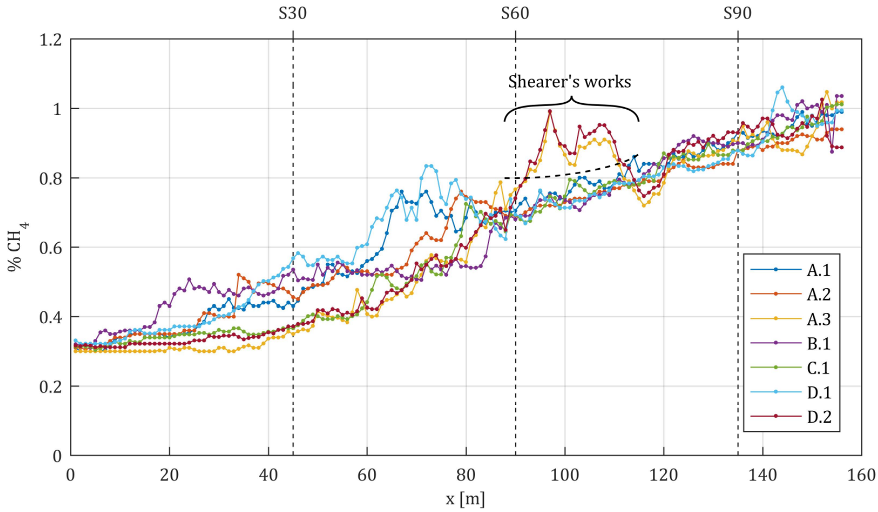

Fig. 7. The course of methane concentration along the longwall

The pathway that discharges used air from the longwall, which is difficult to explain the changes in methane concentration, especially in the first part (Fig. 9). In the range from zero to approx. 80 m, a slight increase in methane concentration can be observed. Then, there was a sudden jump to a value of about 1.9%. Then, a return to the pre-jump value. Later, the jump is repeated, but it descends more gently to a value of about 1.6%. The probable cause was a dynamic phenomenon resulting from the fall of roof rocks in the upper section of the longwall during the movement of the powered support section..

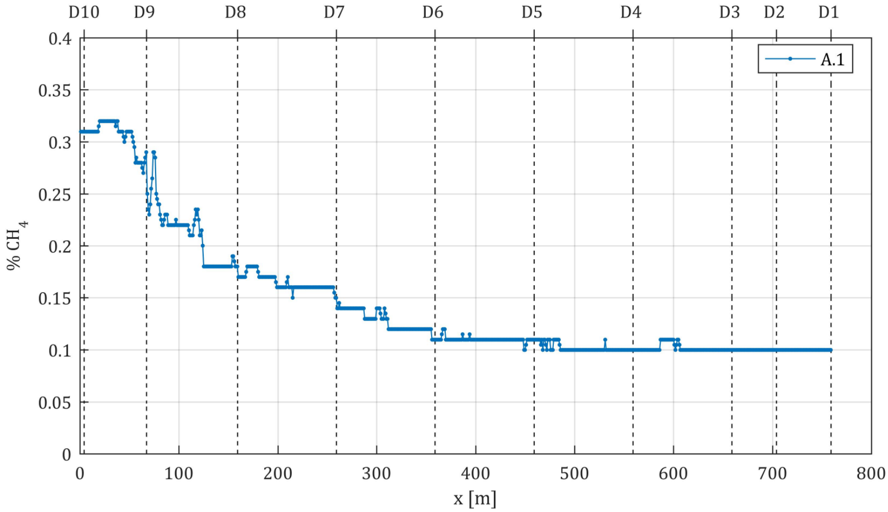

Fig. 8. The course of methane concentration along the ventilation road (512)

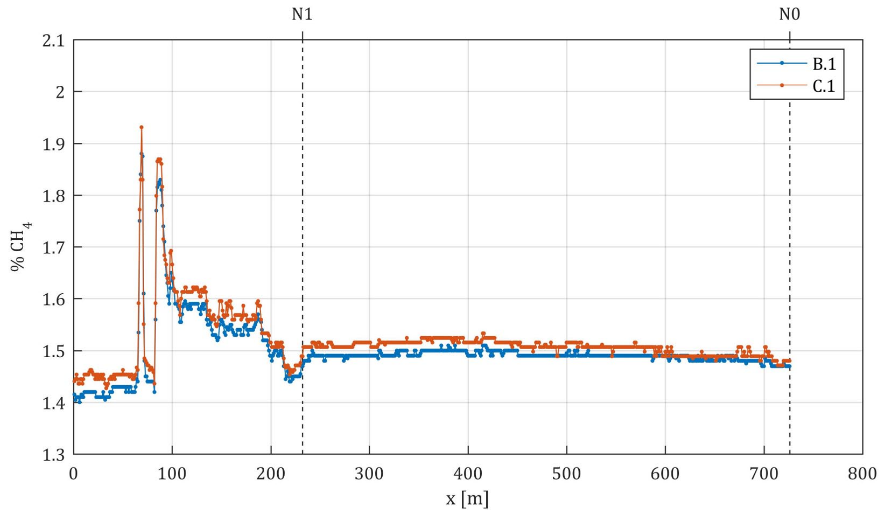

Fig. 9. Waveforms of methane concentration along the longwall gallery (506)

6. Summary and conclusions

The measurements of the methane concentration carried out along the mine workings show a similar nature of changes, even though the persons performing the measurements moved in different directions, at different speeds and at a significant time interval. The variability of the speed of the people over time is reflected in the measurement results, which indicates the direction of development of the method of segmental measurements of the methane concentration.

Monitoring the speed of movement of people can be more important than updating their location frequently. Monitoring the speed of the passage will allow for updating the rate of increase of the concentration in relation to the distance travelled on an ongoing basis.

Sudden changes in methane concentration may appear with a certain delay in the subsequent measurement intervals. Thanks to this dependence, it is possible to distinguish the phenomenon of a sudden release of methane caused by moving a powered support section from a person entering an area with a significantly different methane concentration, for example. Thanks to the use of a larger number of devices in dependent sections, it is possible to distinguish the local accumulation of methane from dynamic phenomena and roughly indicate the source of its occurrence. Such possibilities are provided by connecting devices into a network and collective analysis of segment measurement data from mobile devices.

Acknowledgments

This paper presents the results of the statutory research of the IMG-PAN Institute in the years 2021-2022.

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