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Extraction of methane from the closed mine "Moszczenica"

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Abstract:

Closed methane hard coal mines may become a source of methane used in the energy industry. There are many unliquidated tunnel workings left, they contain lot of workings with a large capacity of free space, and a network of cracks formed in the rock mass. Release of methane to the atmosphere is practically reduced to zero. Closed mines can be a source of methane used to produce energy. This article presents the example of the "Moszczenica" mine as a source of methane, which is captured and converted into electricity and heat.

Keywords: methane mine, methane drainage station, methane intake, electricity generation

1. Introduction

Hard coal seams in many Polish mines are accompanied by methane, which is treated as an accompanying mineral. Methane, like carbon dioxide, is classified as a greenhouse gas. There are statements in the literature that the greenhouse effect caused by the methane is 21 to 30 times greater than that caused by the carbon dioxide. According to [1], there are 1000 times more carbon dioxide (CO_2) in the Earth's atmosphere than methane (CH_4), and due to the increase in emissions [2], increase in CO_2 concentration in the rate of intensification of the greenhouse effect is almost three times higher than that caused by increase in CH_4 concentration.

According to [3], one ton of CH_4 heats our planet as much as 86 tons of CO_2.

In the USA [4, 5, 6, 7, 8, 9, 10], methane is extracted by drilling the earth's surface. They are most often performed before the coal seam is mined. This type of extraction is possible when the seam is not very deep.

In deep mines in the USA, underground methane drainage is used [11, 12], and drainage holes are drilled from near-wall preparatory workings (similarly to Poland) or from specially made roadways above the mined seam.

Methane in coal seams appears as sorbed methane (bound by van der Waals forces to the internal surface of the coal) and free methane (in mesopores, macropores and cracks), and in the rocks accompanying coal seams. During coal mining and drilling the roadways, free methane flows under its own pressure from the surrounding rocks (coal, sandstones, mudstones, claystone) into the workings. After the end of exploitation, release of methane into the dammed workings and into the voids associated with many years of coal extraction. As a result, free methane accumulates in the rock mass of closed mines. Methane from closed mines can be extracted through an unliquidated methane drainage system connected to a methane drainage station on the surface or connected to the methane drainage system of an active, neighboring mine.

The hard coal deposit in the area included this research work had a high content of methane in the coal, which was released into the mine workings. To maintain the permissible methane content (below 2%) specified in safety regulations, large amounts of air were fed to active mine workings.

To secure work safety in mines (limiting methane emissions to mine workings), the technology for methane removal from the rock mass (coal and surrounding rocks) is used, which includes drilling holes into the rock mass from mine workings or to the surface and removing the gas (methane with air) under the impact of the negative pressure generated by blowers located in mine workings or on the mine surface.

Methane captured from Polish mines was usually used as a fuel in the energy industry.

During mining the hard coal deposits in the Rybnik Coal District, with high methane capacity in the range 20 - 25 m^3 of methane per Mg of pure coal, the methane drainage system was used in mine workings. The first installation was built in the 1 Maja coal mine (launched in 1960), and the next ones in the Jastrzębie mine (launched in 1962) and Moszczenica mine (launched in 1965).

2. Materials and testing methods

2.1. Mine methane drainage station

In the years 1962 - 1997, the Jastrzębie and Moszczenica mines had the separate methane drainage networks. The Jastrzębie mine had methane drainage stations near the shaft

Jas-VI, and the Moszczenica mine had two methane drainage stations:

- at the Mos-VI shaft - for the main shaft area,
- at the Mos-VII shaft – for the western shaft area.

Both the Jas-VI shaft and the Mos-VII and Mos-VI shafts were closed.

Due to liquidation of the western shafts of the "Moszczenica" mine in 1994 and undertaken operation of the western shaft pillar, the methane drainage station at the shaft Mos-VII was closed. In turn, in connection with the liquidation of the main shafts of the Moszczenica mine in 1997, the methane drainage station at the Mos-VI shaft was closed.

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Currently, the only active methane drainage station is the station located near the closed down Jas-VI shaft, which captures methane from the western part of the mining area of the former Moszczenica mine.

Figures 1 to 4 show the equipment of the methane drainage station located at Jas-VI shaft.

Fig. 1. The building of the methane drainage station

On the left side of the photo, you can see the pipeline supplying methane from the mine to the methane drainage station. Visible metal chimneys (three on the left side of the building and one on the front side) they discharge methane into the atmosphere in the event of a failure at the methane drainage station or in the event of no methane collection. The metal columns next to the building are lightning conductors.

Fig. 2. Equipment of the methane drainage station at the methane inlet

The visible "canisters" between the lower and upper pipes are fire arresters, preventing the transfer of an explosion in the methane drainage station to underground equipment. They are filled with washed gravel with appropriate granulation to ensure fire extinguishment. The standing column plays a role dehydrator of captured methane.

Fig. 3. Pumping unit

The pipe on the left side of the photo supplies gas from the steam trap to the pump (suction side), and the pipe on the right side (discharge side) discharges the compressed gas to the recipient. The pump is driven by an electric motor connected to the pump by a clutch.

Fig. 4. Outlet pipe arrangement

The upper pipe, visible in Figure 4, during normal operation of the methane drainage station, leads to the lower pipe, which discharges methane to the recipient. The central pipe, during normal operation of the station, discharges excess gas to the atmosphere (through the chimney shown in Figure 1). The top tube is connected to the atmosphere. This connection is poorly visible in the photo where the pipe connects outlet with a pipe discharging methane from the first pumping unit. In case of methane explosion, the membrane in the pipe connecting to the atmosphere is ruptured on the discharge side, what prevents the explosion from spreading to the pipeline connecting the methane flow to a recipient. The methane drainage station operates under constant supervision of the people employed there.

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3. Results

3.1. Analysis of methane intake from December 2017 to November 2023

In order to determine the variability of methane intake from the mining area of the closed Moszczenica mine, monthly data relating to the period from December 2017 to November 2023 were analysed. These data are presented in the table below.

Table 1. Development of the gas mixture and methane intake in from December 2017 to November 2023

Date	Gas mixture intake, m^3/min	Methane intake, m^3/min	Intake of other gases, m^3/min
12-2017	26.83	16.53	10.30
01-2018	26.64	16.54	10.10
02-2018	27.30	16.5	10.80
03-2018	25.77	16.79	8.98
04-2018	26.15	16.63	9.52
05-2018	26.03	16.29	9.74
06-2018	26.32	16.61	9.71
07-2018	25.81	16.53	9.28
08-2018	25.97	16.68	9.29
09-2018	26.43	16.72	9.71
10-2018	26.80	16.65	10.15
11-2018	26.18	16.67	9.51
12-2018	25.48	16.77	8.71
01-2019	25.32	17.02	8.30
02-2019	25.25	16.89	8.36
03-2019	25.01	16.92	8.09
04-2019	24.91	16.86	8.05
05-2019	24.35	16.93	7.42
06-2019	24.45	16.62	7.83
07-2019	24.38	16.92	7.46
08-2019	24.49	16.8	7.69
09-2019	26.38	16.8	9.58
10-2019	25.78	16.88	8.90
11-2019	25.32	16.96	8.36
12-2019	25.16	16.81	8.35
01-2020	26.22	16.55	9.67
02-2020	24.57	16.79	7.78
03-2020	24.07	16.58	7.49
04-2020	24.53	16.72	7.81
05-2020	23.94	16.79	7.15
06-2020	23.92	17.03	6.89
07-2020	23.11	16.62	6.49
08-2020	22.98	16.54	6.44
09-2020	23.03	16.67	6.36
10-2020	23.12	16.69	6.43
11-2020	23.41	16.65	6.76
12-2020	23.52	16.61	6.91
01-2021	23.10	16.6	6.50
02-2021	21.87	15.99	5.88
03-2021	23.14	16.62	6.52
04-2021	23.81	16.77	7.04

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05-2021	23.81	16.66	7.15
06-2021	23.93	16.65	7.28
07-2021	23.62	16.54	7.08
08-2021	24.08	17.08	7.00
09-2021	23.93	16.83	7.10
10-2021	23.72	16.61	7.11
11-2021	24.11	17.07	7.04
12-2021	23.28	16.29	6.99
01-2022	24.50	16.85	7.65
02-2022	24.46	16.77	7.69
03-2022	24.54	16.53	8.01
04-2022	24.63	16.74	7.89
05-2022	24.24	16.54	7.70
06-2022	24.67	16.92	7.75
07-2022	23.47	16.07	7.40
08-2022	24.65	16.85	7.80
09-2022	24.02	16.34	7.68
10-2022	24.43	16.57	7.86
11-2022	25.24	16.77	8.47
12-2022	24.76	16.69	8.07
01-2023	24.79	17.11	7.68
02-2023	24.28	16.42	7.86
03-2023	23.54	16.48	7.06
04-2023	23.58	17.04	6.54
05-2023	23.79	17.01	6.78
06-2023	23.76	16.83	6.93
07-2023	23.71	16.98	6.73
08-2023	23.35	16.92	6.43
09-2023	23.20	16.57	6.63
10-2023	22.98	16.23	6.75
11-2023	23.52	17.1	6.42

Observation period was 72 months. The amount of the captured gas mixture ranged from 21.87 m^3/min to 27.30 m^3/min. The calculated average value of the mixture one minute intake in the observed period was 24.52 m^3/min. The mixture intake was of low variability, as the standard deviation was 1.15 and the coefficient of variation was 4.70%. The mixture variability range was 5.43 m^3/min.

The amount of captured methane ranged from 15.99 m3/min to 17.11 m^3/min. The calculated average value of the minute methane intake in the period under study was 16.70 m^3/min. The mixture treatment was characterized by very low variability, as the standard deviation was 0.23 and the coefficient of variation was 1.38%. The methane intake was also had a very small variability range of 1.12 m^3/min.

Total flowrate of captured gases other than methane ranged from 5.88 m^3/min to 10.80 m^3/min, with the average value 7.82 m^3/min. The standard deviation was 1.15, which was equal to the standard deviation of the gas mixture. However, the coefficient of variation of 14.69% was much higher than for the mixture and methane. The range of variability of the amount of components other than methane was 4.92, which is a value close to the range of variability of the mixture. The variability of the gas mixture and pure methane during the observation period is presented in Fig. 5

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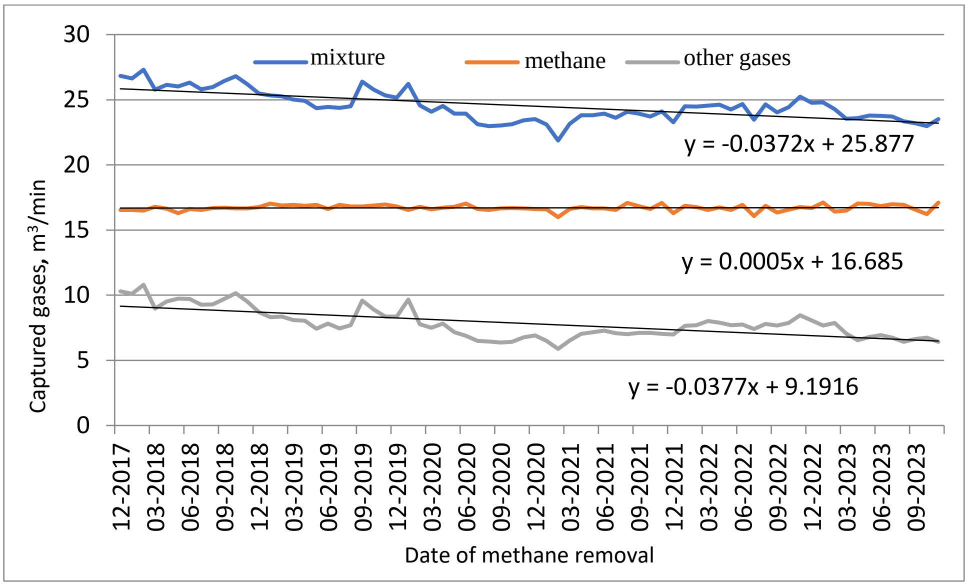

Fig. 5. Curves of the gas mixture and methane intake in the analyzed period

The amount of the gas mixture captured in the observed period showed a decreasing tendency. This is evidenced by the negative angular coefficient of the approximation line (-0.0372).

The amount of methane captured within the observed period was almost constant, independent of the amount of the captured gas mixture, evidenced by very small angular coefficient of the approximation line of 0.0005 (Fig. 5).

Figure 6 shows the relationship between the methane intake and the gas mixture intake.

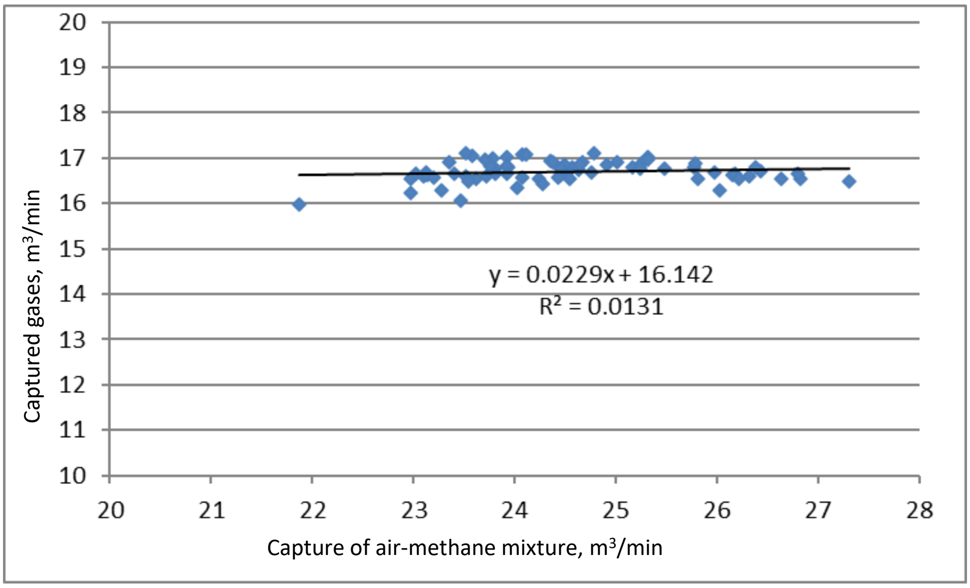

Fig. 6. Relationship between the methane intake and the gas mixture intake

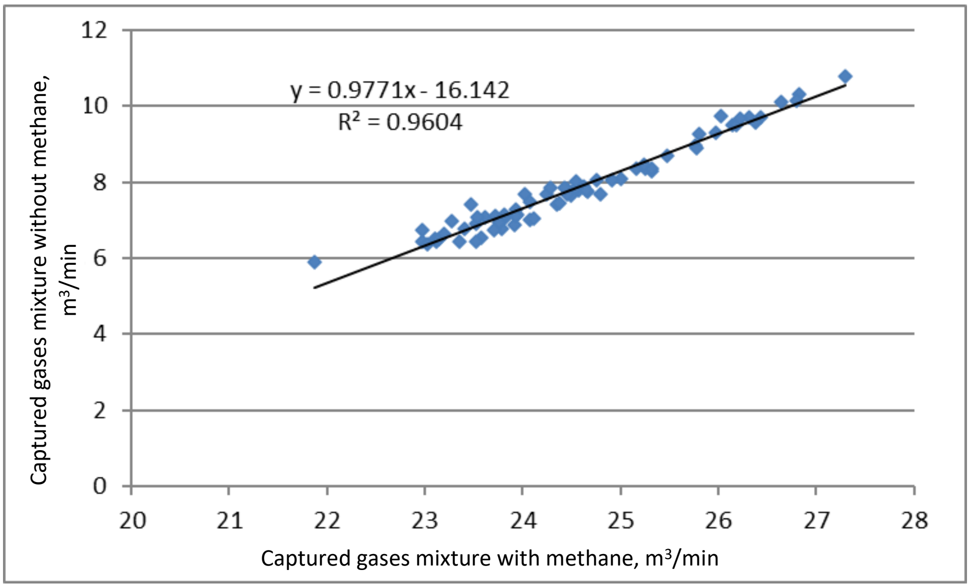

Fig. 7. Curves of the amount of captured components of the gas mixture without methane

The methane intake ranges from about 16% to about 17%.

It is not possible to determine what part of the methane is captured directly from the roadway and what part is taken from not liquidated drainage holes. The approximation line is almost horizontal (Fig. 6). The slope of the approximation line is 0.0229. The coefficient of determination R^2 = 0.013, which is very low, what indicates for very small dependence of the methane intake on the amount of the collected gas mixture.

However, there is a very strong correlation between the remaining gas components in the captured mixture (Fig. 7). The slope coefficient of the line showing the dependence of the intake amount of gases other than methane on the intake of the gas mixture with methane is 0.9771, i.e. the line is inclined almost at an angle of 450 in relation to the horizontal coordinate. The coefficient of determination R^2 = 0.9604 indicates for almost functional relationship between the intake of a gas mixture without methane and the intake of a gas mixture with methane. From the above it results that the intake of the air-methane mixture at the level of 23 m^3/min gives the best gas mixture relating the energy content.

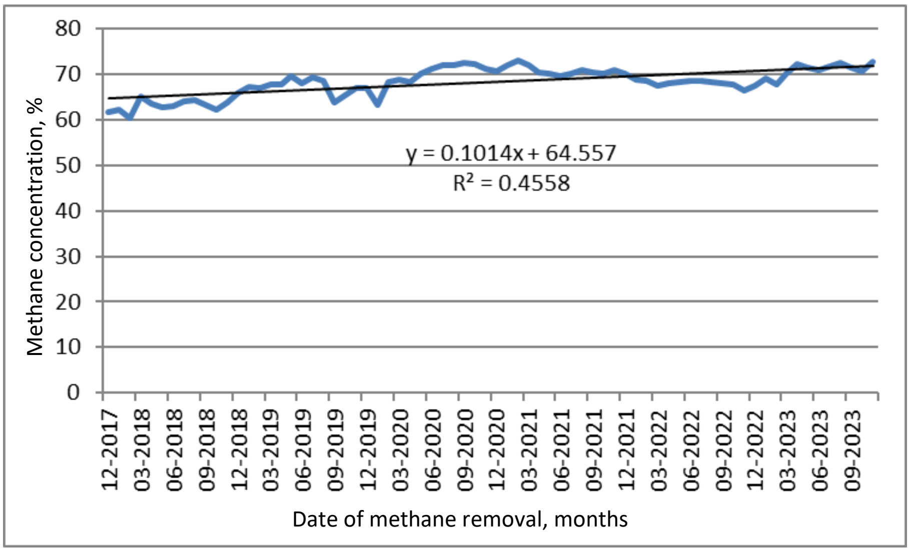

Fig. 8. Curve of methane concentration in the gas captured in the methane removal system

Figure 8 shows that the methane concentration in the mixture captured by the methane drainage system has an increasing tendency. This is because there are gases in the treated mixture from the atmospheric air remaining in the working. After damming the workings, the amount of incoming air decreased significantly, and in a result, methane concentration increased.

4. Conclusions

The article presents an analysis of methane capture from the closed Jas-Mos Ruch "Moszczenica" mine in from December 2017 to November 2023.

The analysis shows that:

- methane intake through the methane drainage system was almost unchanged throughout the entire observation period and was independent of the air-methane mixture intake amount. The slope coefficient of the line approximating the methane intake amount was 0.0005,
- intake of the air-methane mixture varied over time and had a decreasing tendency
- intake of the air-methane mixture had greater variability than the intake of methane,
- the intake of gases other than methane showed a decreasing trend. The slope coefficient of the approximation lines for the intake of the air-methane mixture and the non-methane gas mixture was almost identical. They differ by the value -0.0005,
- methane concentration in the captured air-methane mixture had an increasing tendency. The approximation line has a slope of 0.1014. It can be expected that as a result of cutting off the mine workings from the external atmosphere, the methane concentration will slowly increase.

Recovery of methane from closed mines reduces the risk of its uncontrolled release to the atmosphere, thus limiting the greenhouse effect. The methane captured by the methane removal system is used to produce electricity and heat.

Currently, excess of the captured methane is released to atmosphere. This practice will be subject to high penalties within three years. Injecting excess gas into a closed mine will allow it to be stored and used later.

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