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UTILIZATION OF THE METHANE FROM POLISH MINES**

1. Introduction

Methane is formed in the nature in result of oxygen-free decomposition of organic matter:

- It is a constituent of natural gas,
- It occurs together with oil,
- It occur in hard coal deposits.

In mines, methane is accompanying the hard coal exploitation. If not drained, methane is emitted to ventilation air forming methane-air mixtures of various methane concentration and then it is emitted to the atmosphere.

Methane explosions always accompanied mining works killing many workers. However, recently the methane from coal beds is used as the fuel for various power making installation.

Utilization of methane from coal beds is very important because of various reasons:

- Economic reasons, what is concerned in Mining Law classifying methane from coal beds (MPW) as basic useful minerals.
- Ecological reasons, because emission of the methane into atmosphere results in greenhouse effect, what was mentioned in Kioto protocol.

Development of the underground methane draining is observed in Polish mines from many years, including economic use of obtained methane in heat-power making installations. However, utilization and economic use of methane from mine ventilation air is made not only in Polish but also worldwide mining.

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2. Reserves of methane in coal beds MPW

According to report of Polish geological Institute coal bed methane in Poland occurs mainly in deposits of Lower Silesian Coal Basin.

It is hard to evaluate the amount of the reserves because of processes of gas filtration in coal beds and between the beds, and also through overburden into atmosphere..

2.1. Geological methane reserves in coal beds

Documented [7] balance methane reserves amount for about 85.9 mld m³, including not manager beds — about 26 mld m³, and not manager reserve beds occurring at the depth below 1000 m — about 60 mld m³. Whereas industrial reserves in managed deposits amount for 3 486.37 mln m³. Potential methane coal bed reserves are assessed for about 350 mld m³. According to research Works, the perspective reserves of the Upper Silesian Coal Basin [7] are assessed for about 254 mld m³, including balance reserves assessed for about 150 mld m³.

Since the year 2001 methane content in Polish hard coal mines systematically increase, also the coal production was reduced. Absolute methane content of hard coal is very high and in the year 2011 it amounted for 828.8 mln m³ CH₄. Underground methane drainage amounted for about 250.2 mln m³ CH₄, and 662.5 mln m³ CH₄ was emitted to the atmosphere with mine ventilation air [9].

Methane drainage, ventilation methane content and resulting absolute methane content was continuously growing up in the last decades, what is show in Figure 1.

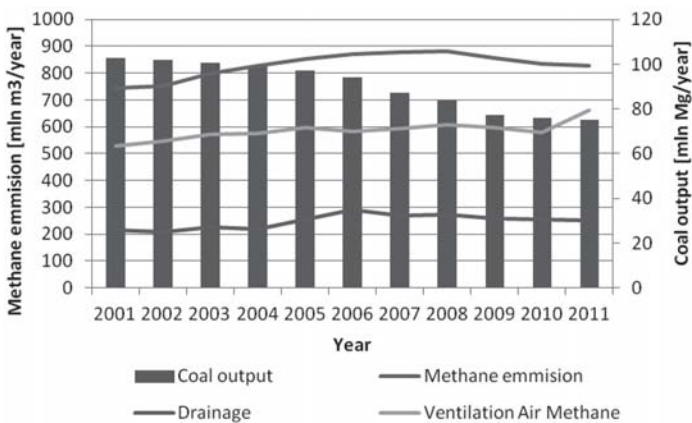


Fig. 1. Methane content in hard coal mines with reference to a number of mines and coal excavation output in a period 2001–2011

It results from the above diagram that yearly reserves of methane in ventilation air of hard coal mines in the year 2011 amounted for about 662.5 mln m³ [9] and their volume is increased each year.

2.2. Concessions for obtaining methane from hard coal beds

According to Geological and Mining Law, many companies applied to Ministry of Environmental Protection and obtained concessions for:

- Excavation of hard coal — 58 concessions,
- Exploration and recognition of methane deposits — 12 concessions,
- Methane exploitation from coal beds — 3 concessions.

3. Methane utilization from coal beds

Research studies and practical experiments, particularly conducted in the recent years, allowed designing a number of devices and technologies allowing economic use of the methane obtained from hard coal mines drainage in heat-energy producing installations.

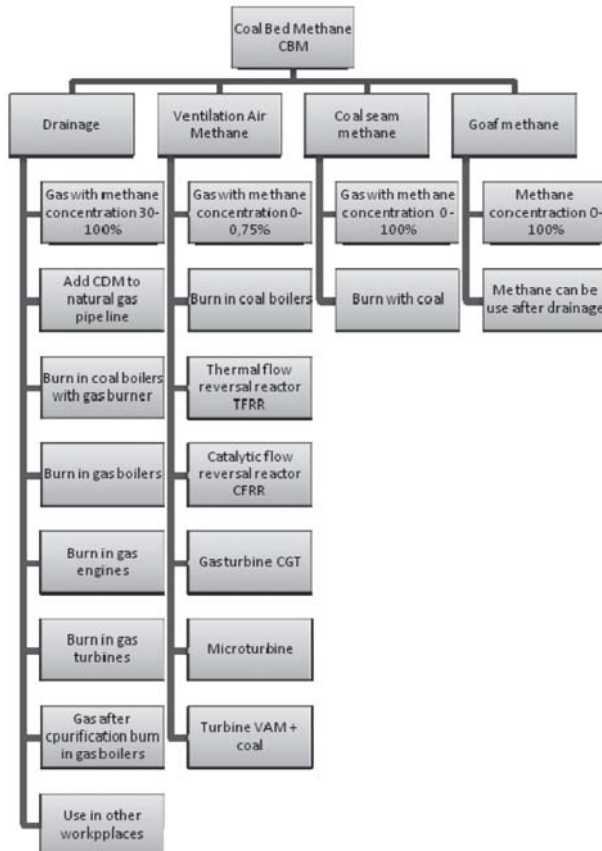


Fig. 2. Main directions of coal Bed methane utilization

Technologies of methane use in state economy (energy and chemistry) depend mostly on the manner of the methane obtaining and methane concentration in methane-air mixture (Fig. 2). Coal bed methane can be also used in chemical industry.

4. Utilization of methane obtained from coal bed methane drainage

Gas mixture obtained in the methane drainage process and this in pipeline from methane draining station contains in average about 30–60% of methane and the resting part comprise nitrogen and oxygen, thus calorific value of the gas mixture from drainage balances from 10 to 21 MJ/m³.

Methane from coal beds drainage can be used in the following technologies:

- Pressing the gas obtained from methane drainage into natural gas networks,
- Use of drained methane as a fuel for gas burners of coal boilers or gas boilers,
- Use drained methane as a fuel for gas engines,
- Use of drained methane as a fuel for gas turbines.

4.1. Balance of methane obtained from coal bed drainage in the year 2010

Methane obtained in the process of mine coal Bed drainage is used for heat and electric energy production, or it is sold to external receivers. Use of the coal bed methane drained in hard coal mines in the year 2010 is shown in Table 1. Comparison of gas engines powered with coal bed methane is show in Table 2.

4.2. Combined Power system in “Krupiński” hard coal bed

In the year 1997, in “Krupiński” hard coal mine belonging to Jastrzębie Coal Company SA a gas engine of type TBG 632 V 16 was installed and connected with electric power generator by Van Kaick (Fig. 3 and 4).

Technical data of he gas engine are as follow:

- fuel — gas of flow 14 m³/min obtained from methane drainage from “Krupiński” coal mine, of the methane concentration of 50–60%,
- electric power — 3,0 MW,
- thermal power — 3.2 MW.

In the year 2005 the second engine TCG 2032 V16 by Deutz was connected with electric current making generator.

Technical data are as follow:

- fuel — gas of the flow 17 m³/min from coal Bed methane drainage in “Krupiński” coal mine, of methane concentration of 50–60%;

- electric power — 3.9 MW;
- thermal power – 4.2 MW.

Electric energy and heat generated during the engines operations is used in:

- electro-power system of the mine,
- mine heating network.

TABLE 1
Effectiveness of coal Bed methane in hard coal mines in the year [9]

Mine	Obtained, mln m ³ /rok	Losses, mln m ³ /rok	Utilization, mln m ³ /rok	Effectiveness wykorzystania, %
Brzeszcze-Silesia	37,4	0,1	37,3	99,8
Zofiówka	15,4	0,8	14,6	94,8
Pniówek	44,6	5,2	39,4	88,3
Jas-Mos	9,6	1,4	8,2	85,4
Jankowice	7,8	0,6	7,2	92,3
Budryk SA	15,1	4,9	10,2	67,5
Halemba-Wirek	7,5	3,3	4,2	56,2
Mysłowice-Wesoła	10,2	4,3	5,9	57,8
Marcel	3,8	2,1	1,7	44,7
Borynia	4,0	1,5	2,5	62,5
Krupiński	44,1	24,0	20,1	45,6
Staszic	4,6	2,9	1,7	37,0
Bielszowice	5,8	3,6	2,2	37,9
Sośnica-Makoszowy	15,2	13,0	2,2	14,5
Szczygłowice	13,3	11,2	20,1	15,8
Wójeck-Śląsk	5,2	5,2	0,0	0,0
Rydułtowy-Anna	8,0	8,0	0,0	0,0
Chwałowice	3,8	3,8	0,0	0,0
Knurów	4,4	4,4	0,0	0,0
Total:	259,8	100,3	159,5	61,4

TABLE 2

Comparison of installed gas engines powered with coal Bed methane

Start	Mine	Company	Electric power, MW	Engine type
1997	KWK Krupiński	JSW SA	3,00	TBG 632 V16
1999	KWK Bielszowice	KW SA	0,54	JMS 312GS-B.LC
1999	KWK Halemba	KW SA	0,54	JMS 312GS-B.LC
2000	KWK Pniówek	JSW SA	3,20	TBG 632 V16
2000	KWK Pniówek	JSW SA	3,20	TBG 632 V17
2005	KWK Krupiński	JSW SA	3,90	TCG 2032
2006	KWK Pniówek	JSW SA	3,90	TCG 2032
2008	KWK Borynia Zofiówka	JSW SA	1,90	JMS 612 GS
2009	Sośnica Makoszowy	KW SA	1,95	Tedom Quanto D 2000 SP
2009	Szczygłowice	KW SA	1,95	Tedom Quanto D 2000 SP
	KWK Budryk	JSW SA	1,60	TBG 620 V20K
	KWK Budryk	JSW SA	1,60	TBG 620 V20K
	KWK Budryk	JSW SA	1,60	TBG 620 V20K
2009	KWK Mysłowice Wesola	KHW SA	1,40	JMS 420
2009	KWK Mysłowice Wesola	KHW SA	1,40	JMS 420
2011	KWK Krupiński	JSW SA	2,00	Caterpillar
2011	KWK Krupiński	JSW SA	2,00	Caterpillar
2011	KWK Pniówek	JSW SA	3,90	TCG 2032
Suma:			40	

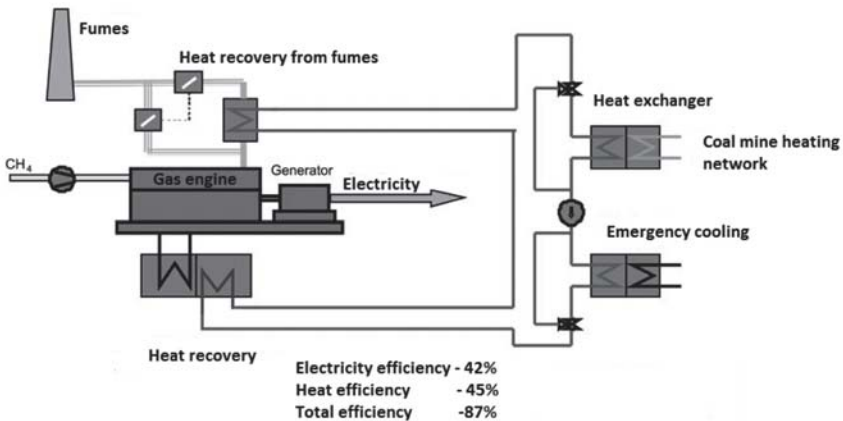


Fig. 3. Cogeneration plant in EC Suszec

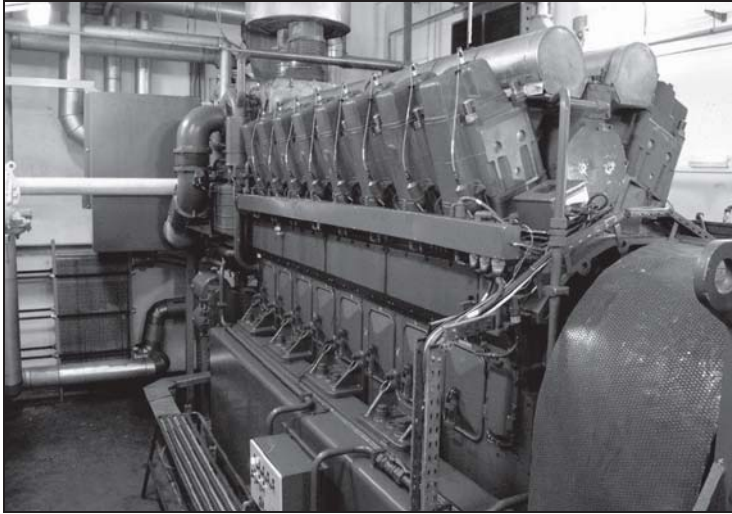


Fig. 4. Cogeneration plant in EC Suszec — gas engine

4.3. Combined power system i “Pniówek” Hard Coal Mine

The “Pniówek” hard coal mine exploits coal beds occurring at the depth of 700–1000 m under the Ground surface, which characterize with high methane content of high original temperature of the rock body 40–45°C. Necessity of improvement of working conditions was a basis of building central air conditioning in the coal mine KWK “Pniówek” — being the first installation of this type in Poland.

Power of the air coolers should amount for about 7.5 MW. In result of conducted analysis of central air conditioning, a combined Power-cooling system was chosen, which is based on gas engines and electric energy generators and absorption and pressing coolers, (Fig. 5 and 6). The coolers are powered with use of mine coal bed methane drained from the mine. Heat produced in this process is used for exchange in adsorption coolers. A part of produced electric energy is used for powering screw compressors. The rest of the electric energy is used for needs of local transport. The central air conditioning system in “Pniówek” coal mine was started in the year w 2000.

E part of electric energy produced by the generator is used for powering the scew compressors. The rest of electric energy and heat is used for needs of local transport system.

Technical data of the combined power-cooling system in “Pniówek” coal mine are as follow:

- two gas engines of type TBG 632 V 16 by Deutz;
- fuel — gas from methane drainage of the mine “Pniówek” with flow rate of 50 m³/min, methane concentration 50–60%;
- electric power — 6.4 MW;

- thermal power — 7.4 MW;
- two adsorption coolers — cooling power 4.7 MW;
- three compression coolers — cooling power 3.2 MW;
- cooling power — 7.9 MW.

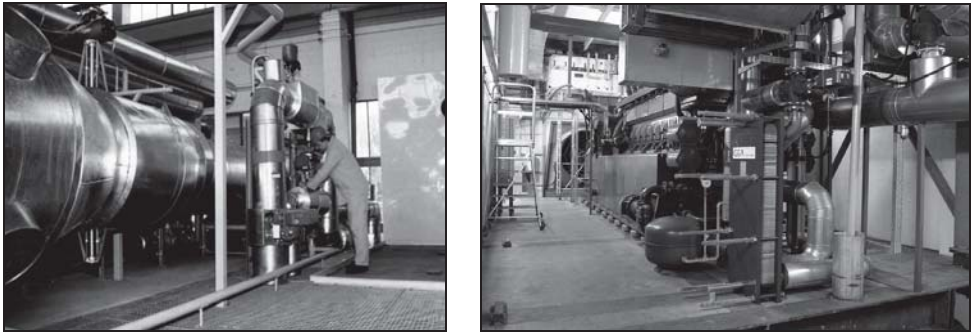


Fig. 5. Combined Power-cooling system in coal mine “Pniówek”

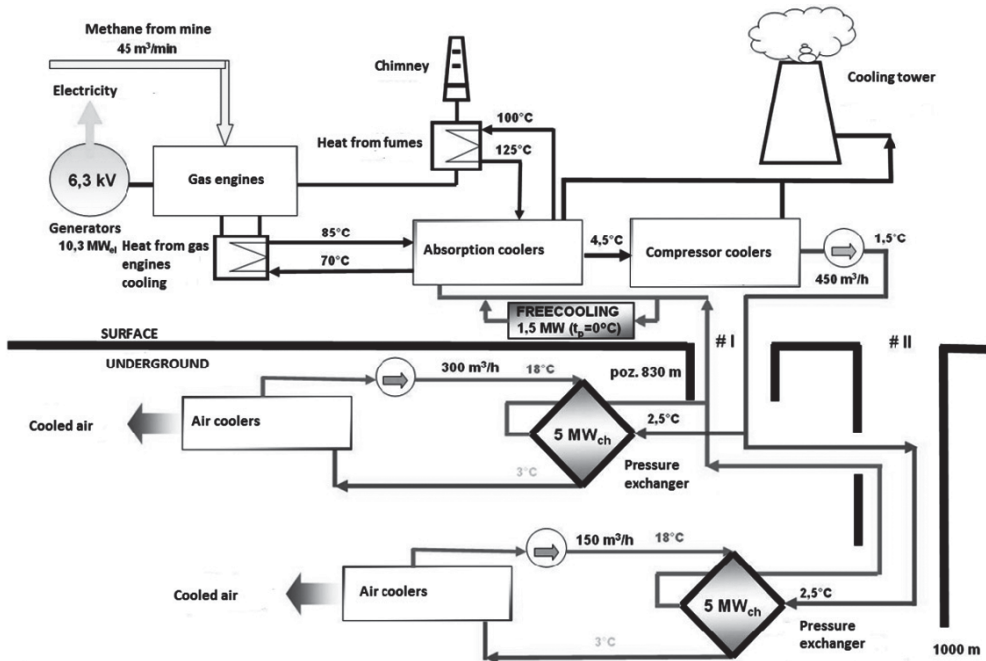


Fig. 6. Combined Power system in coal mine “Pniówek” [6]

Company Jastrzębie in coal mine “Pniówek” exploits also in combined system a combustion engine TCG 3032 V16 manufactured by MWM DEUTZ of electric power 3.9 MW and thermal power 4.2 MW. Additional gas engine of type TCG 3032 of electric power 3.9 MW and thermal power 4.2 MW was installed in the year 2011.

5. Use of methane from liquigated hard coal mine

Started in the year 2004 recovery of methane from liquigated hard coal mine “Morcinek” in Kaczyce by a company “Karbonia PL” Sp. z o.o. is a good example of methane reserves utilization.

From bore-hole “Kaczyce 1/01” methane was transported via pipeline of diameter 225 mm to coal mine CSM (OKD, DPB, a.s. — Czech Republic), where it was combusted in the local heat generating plant.

Activities connected with drilling bore-holes for methane exploitation from liquigated hard coal mine Anna – Południe (Pol-Tex Methane Sp. z o.o.) and mine Żory (Cetus Sp. z o.o.), were also undertaken, where gas engine and generator producing electric energy were implemented.

6. Cleaning and the air-methane mixture enriching (VPSA)

In order to develop further possibilities of use of the coal bed methane, an installation and technology of methane separation from an air-methane mixture obtained in the process of methane drainage from hard coal beds has been designed by the AGH University of Science and Technology and Institute of Heavy Organic Synthesis in Kędzierzyn, in cooperation with Jastrzębie Coal Company SA (Fig. 7).

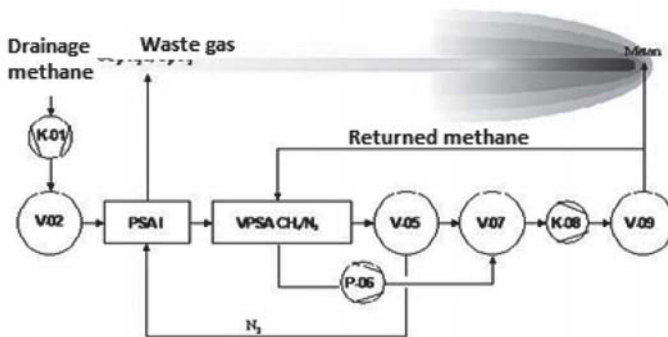


Fig. 7. Scheme of the installation of methane separation from methane-air mixture [4]; K-01 — gas compressor; V-02 — buffer; V-07 — buffer CH₄; PSA I — module PSA of cleaning; VPSA CH₄/N₂ — Module PSA of methane enriching; V-05 — buffer N₂; P-06 — vacuum pump; K-08 — compressor CH₄; V-09 — buffer CH₄

Gas obtained from coal bed drainage of methane concentration about 50% is exposed to a process of clearing from air. In result a gas of methane concentration about 96% is obtained, which possesses parameters needed in gas installations and it can be sold to PGNiG network. Variable pressure adsorption (PSA) will play important role in the future in enriching gas streams with methane, what will make possible its sale and in consequence it will restrict negative influence onto global climatic changes, as well as it will allow its greater use.

Testing the installation is semi-technical scale were conducted in hard coal mine “Pniówek” proving suitable effectiveness.

7. Condensation

Installation for condensation the methane obtained from coal Bed drainage produced by a company LNG Silesia Sp. z o.o. was started in the year 2011.

8. Compression of gas obtained from coal bed drainage

It results from forecasted methane reserves from liquidated hard coal mine Moszczenica that in post-exploitation old works and not-exploited non-balance beds occur methane reserves amounting for about 250–350 mln m³. Model of the gas container Pole Moszczenica belonging to Jastrzębie Coal Company SA is show in Figure 8.

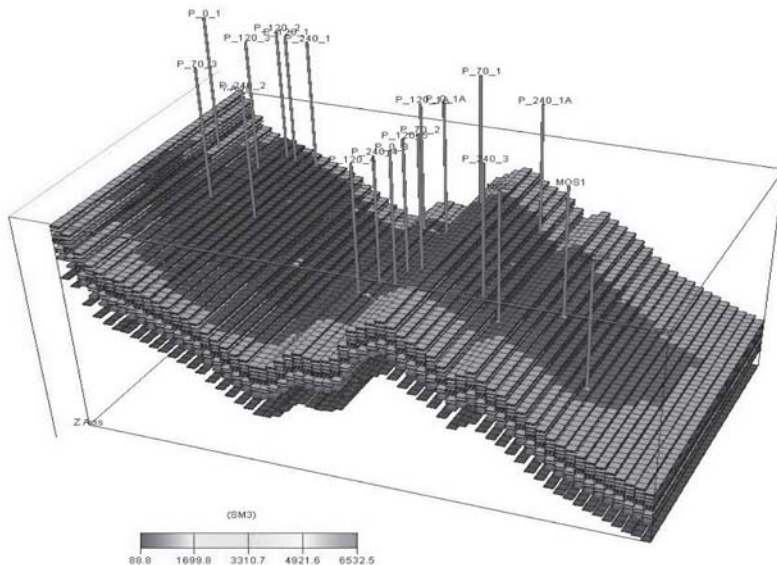


Fig. 8. Model of the gas container Pole Moszczenica

Gas samples collected from Pole Moszczenica via filling bore-hole P-3 proved the following gas composition: $O_2 = 0.69\%$, $CO_2 = 1.7\%$, $CO = 0.0000\%$, $CH_4 = 65.42\%$, $N_2 = 32.19\%$. Gas from Pole Moszczenica is considered as fuel of calorific value amounting for about 33 MJ/m^3 which can be used in suitable power making devices.

Gas compression and transport in containers (Fig. 9) to the user is one of the manners of making advantage from gas obtained from methane drainage of Pole Moszczenica.

The following devices are available:

- Compression of gas obtained from methane drainage bore-holes;
- Building of individual sets of containers allowing gas transportation;
- Building of installations used for filling gas containers installed in cars and buses.

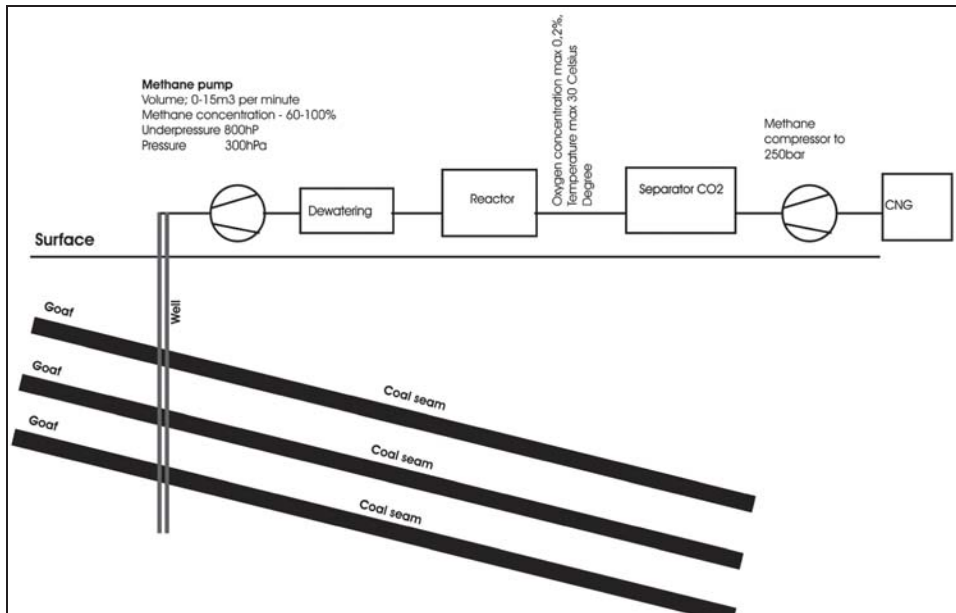


Fig. 9. Scheme of the system used for obtaining and utilization of coal bed methane

9. Technologies of obtaining methane from mine ventilation air

Each year about 600 mln m^3 of methane having calorific value $2.1 \cdot 10^8 \text{ GJ}$ and economic value 1.2 mld PLN (this volume could cover demand for heating about 300 households) is emitted to the atmosphere with mine ventilation air. In conditions occurring in Polish coal mines use of the methane obtained from mine ventilation air is possible for example via adding methane obtained from coal bed drainage to ventilation air directed to the methane combustion installation in reactors. Idea of controlled adding methane from coal bed drainage to

ventilation air taken from ventilation shaft into combustion installation where methane-air mixture is combusted is shown in Figure 10.

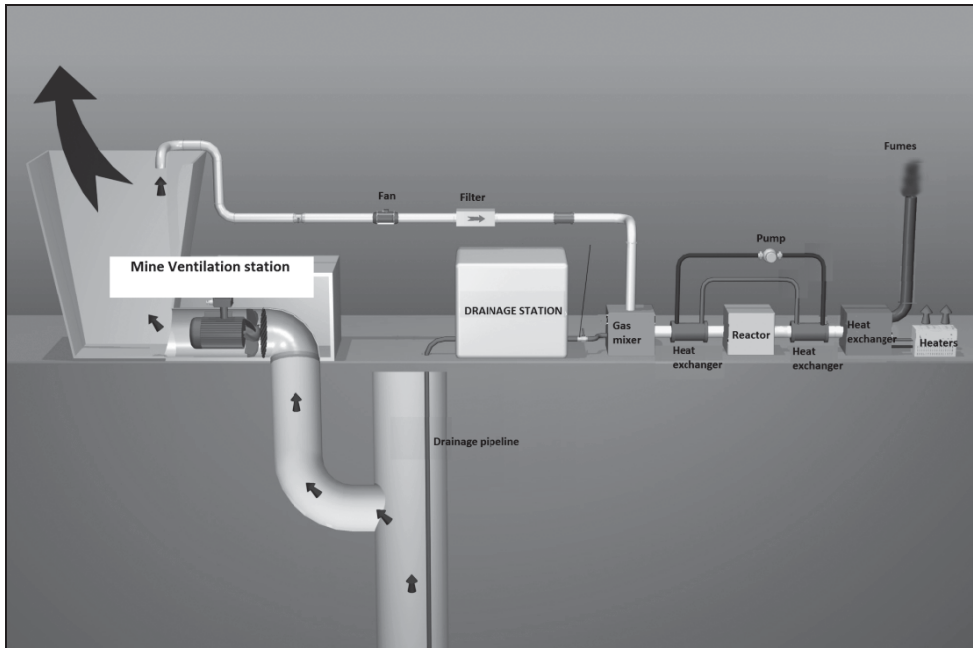


Fig. 10. Scheme of the installation using methane obtained from ventilation air as reactor fuel

AGH University Of Science and Technology, Wrocław University of Technology and Maria Curie-Skłodowska in Lublin in cooperation with Jastrzębie Coal Company SA conduct research Works Ahmed at designing a device for catalytic combustion of methane obtained from mine ventilation air. The project is realised within the program named “Operational Program — Innovative Economy, task 1.3.1. registered under number: POIG.01.03.01-24-072/08”. In scope of this project semi-technical installation marked with symbol IUMK-100 is realised via oxidation of methane obtained from mine ventilation air. The installation is located in coal mine Jas-Mos — visualization of the installation used for methane utilization is show in Figure 11.

Semi-technical installation IUMK-100 has the following parameters:

- | | |
|------------------------------------|--|
| — Air stream | — $V_{VAM} = 1000\text{--}3000 \text{ m}^3/\text{h}$; |
| — Methane concentration in the air | — $z_{CH_4} = 0,4\text{--}1\%$; |
| — Methane stream | — $V_{CH_4} = 4.0\text{--}12 \text{ m}^3/\text{h}$; |
| — Thermal energy | — $Q = 140\text{--}1050 \text{ MJ/h}$; |
| — Useful thermal power | — $P = 13\text{--}100 \text{ kW}$. |

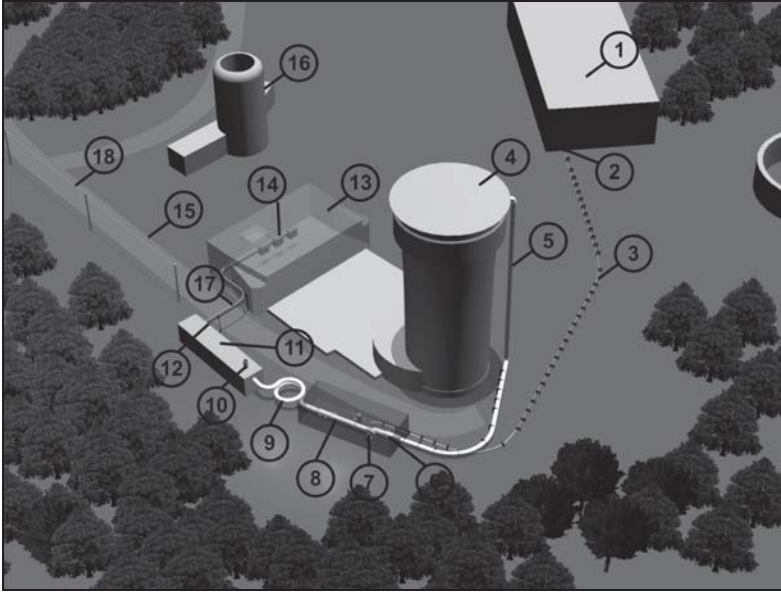


Fig. 11. Installation for utilization of methane obtained from hard coal mine ventilation air:
 1 — Drainage station, 2 — drainage methane connection, 3 — Drainage pipeline,
 4 — Schaft diffuser, 5 — Pipeline taking VAM from shaft, 6 — Filter, 7 — Fan,
 8 — Gas mixer, 9 — Buffer, 10 — Chimney, 11 — Installation of VAM utilization,
 12 — Heating network connection, 13 — Mine ventilation fan building, 14 — Heaters,
 15 — Road, 16 — Coal mine Schaft, 17 — Heat pipeline, 18 — Electricity connection

10. Economic prospects of use and limitation of coal bed methane emission into the atmosphere

Problem of utilization of coal bed methane used as low-methane gas fuel should be urgently solved not only because of negative influence onto natural environment but also because of its high economic profitability.

In Poland the further development in scope of utilization of mine coal bed methane and limitation of the methane emission into the atmosphere is possible under condition of solving the following problems:

- Intensification of the process of methane drainage from coal beds of underground hard coal mines;
- Increase of investment in scope of full economic use of methane as low-methane fuel used in heat and power making installations;
- Retention storage of coal bed drained methane in underground and surface gas containers what should assure qualitatively and quantitatively stable delivery of low-methane fuel to heat and power making installations;

- Utilization of methane obtained from mine ventilation air;
- Technologies of air separation from gases obtained by coal Bed methane drainage in order to increase the methane content in the fuel;
- Low-methane gas emissions trade — the methane obtained in coal bed methane drainage, including methane obtained from the ventilation air of coal mines.

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