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PRO-ECOLOGICAL TECHNOLOGY OF MINE METHANE UTILIZATION**

1. Introduction

Each year, about 600 mln m^3 having calorific value amounting for $2.1 \cdot 10^8$ GJ and economical value amounting for 1.2 mld PLN is emitted to the atmosphere together with mine ventilation air. This amount of gas could cover demand for heating of about 300 thousands households. Methane can be also used as greenhouse gas.

Because of the problem of coal bed gas emission into the atmosphere, Poland is localized at 6-th place in the methane emission into atmosphere. The AGH University of Science and Technology, Wroclaw University of Technology and Maria Curie-Skłodowska University in Lublin, have formed a Consortium of Coal Bed Methane Utilization, which realises a project entitled: "Pro-ecological technology of coal bed methane utilization", executed in scope of Operational Program – Innovative Economy, task 1.3.1. registered as POIG.01.03.01-24-072/08.

Both in Polish and worldwide mining, utilization and making use of the methane from the ventilation air is the most important problem as because of the work safety the methane concentration in the air is lower than it results from the lower limit of the explosiveness of methane-air mixture.

In result of intensive research-development works are conducted worldwide, numerous technologies and devices allowing execution of process of combustion of methane-air mixtures having methane content below 2%.

In Poland, research works on making use of methane obtained from mine ventilation air in electrical and heat energy production have been conducted, however there are number of technical-technological obstacles stopping development of economic utilization of such fuel.

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Since many years, in Poland are also conducted examinations and studies:

— At the AGH University of Science and Technology in scope of methane-draining of coal beds and utilization of methane obtained from methane-draining of coal beds and from ventilation air of underground mines.
— At Wroclaw University of Technology and Maria Curie Sklowowska University in Lublin in scope of catalytic oxidation of hydrocarbons, including methane.

Advanced state of research works in mentioned universities allowed making examinations which in turn allowed building special devices used for utilization of methane obtained from coal beds, including ventilation air from mines.

Laboratory scale installation marked with symbol IUMK-1 (Installation for utilization of methane from mines of thermal Power 1 kW) — allowing utilization of methane from mine ventilation air, which is located in Laboratory of the Chemistry Faculty of the Wroclaw Unversity of Technology, as well as installation in semi-technical scale marked with symbol IUMK-100 (Installation for utilization methane from mines of thermal power 100 kW) installed in the mine Jas-Mos — prototype research installation taking gases from mine ventilation system, which thanks to catalythic reactor and heat exchangers allows utilization of methane from ventilation air and heat production, have been made in scope of the project.

2. Methane content in hard coal mines

In Polish hard coal mines the absolute content of methane grows up systematically since the year 2001 irrespectively from the fact that number of mines and coal excavation is reduced. Methane content in Polish hard coal mines is very high and in the year 2011 it amounted for 828.8 mln m^3 CH_4, whereas underground methane-draining covered about 250.2 mln m^3 CH_4, and 662.5 mln m^3 CH_4 [1] was emitted to the atmosphere together with mine ventilation air.

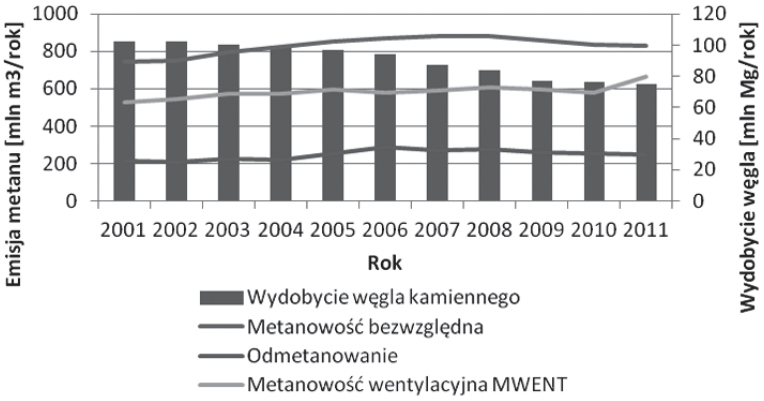

Fig. 1. Methane content of hard coal mines in the period 2001–2011 [1]

Ventilation methane content, methane-draining and absolute methane content of Polish hard coal mines in the period 2001–2011 is shown in Figure 1 [1].

3. Project of utilization of methane from mine ventilation air

The project is aimed at development of technical-technological documentation for utilization of methane obtained from mine ventilation air.

Because of high economical and ecological value of economic utilization of methane obtained from ventilation air of Polish hard coal mines, and also because of actually conducted examinations and experiments worldwide, realisation of the Project "Pro-ecological technology of utilization of methane from coal mines" is legitimated.

3.1. Examination on methane utilization in great-laboratory scale

During the project realisation, in order to test basic assumption of the catalythic oxidation of methane with concentration below 1%, a great-laboratory installation marked with symbol IUMK-1, allowing utilization of methane obtained from mine ventilation air, has been made.

Methane oxidation in IUMK-1 takes place in bed temperature of about 350–600°C and methane concentration in air amounting for 0.4–1.0%. Chemical efficiency of the methane oxidation amounted for 97%. Housed heat exchanger of the thermal power 1 kW was designed in order to assure heat reception from the exhaust gases.

Parameters of the laboratory installation IUMK-1 (Fig. 3):

- Air stream — Vp = 20 m^3/h,
- Methane concentration in air — z_{CH4} = 0.4–1.0 %,
- Calorific value of the air-methane mixture — Wd = 0.14–0.35 MJ/m^3,
- Methane stream — VCH$_4$ = 0.08–0.2 m^3/h,
- Thermal energy — Q = 1.4–3.5 MJ/h,
- Usable thermal power — P = 0.45–0.97 kW.

Scheme of the heat energy obtaining from reactor of cathalitic methane oxidation is show in Figure 2.

Based on the results of examinations on methane oxidation in laboratory reactor and heat exchanger for various parameters of delivered fuel, a technical-technological documentation entitled "Installation for utilization of methane obtained from hard coal mine ventilation air IUMK-1" was developed. The documentation in question was used as a basis for making the installation project in semi-technical scale marked with symbol IUMK-100.

The examinations proved the operational correctness of the great-laboratory installation and taken assumption due to operations of metal and ceramic catalysts, including volume of the heat production. Installation IUMK-1 is located in Laboratory of the Chemistry Faculty of the Wroclaw University of Technology.

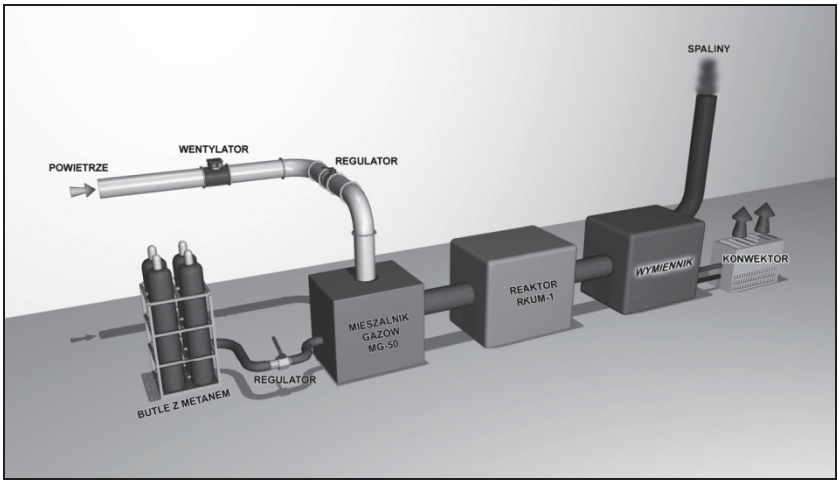

Fig. 2. Scheme of the installation IUMK-1

Fig. 3. Installation IUMK-1

3.2. Examinations on utilization of methane obtained from mine ventilation air in semi-technical scale

In result of cooperation of the AGH University of mining and Metallurgy with Jastrzębie Coal Company SA, preliminary tests of the operations of installation IUMK-100 were conducted near shaft VI in hard coal mine Jas-Mos. Belonging to Jastrzębie Coal Company SA.

In the mine "Jas-Mos" in ventilation shaft VI methane concentration in ventilation air balances from 0.04 to 0.2%. Minimal content of methane in ventilation air amounted for 4.75 m^3/min, an maximal 12 m^3/min.

Ventilation air used in the installation for methane utilization is taken from diffuser near exhaust shaft Jas VI of mine "Jas-Mos" without intervention in devices used for the mine ventilation. Air of the volume 1000–3000 m^3/h (16–50 m^3/min) via elastic suction and force air duct is sent to the next part of the installation.

Air taken from the diffuser is sent to centrifugal fun and then it is de-dusted in the filter. Clean air is sent to gas mixer where suitable methane concentration is set via adding the methane stream from methane-draining. Then the air is oxidated in catalytic converter in order to recover the heat from the reactor (Fig. 4).

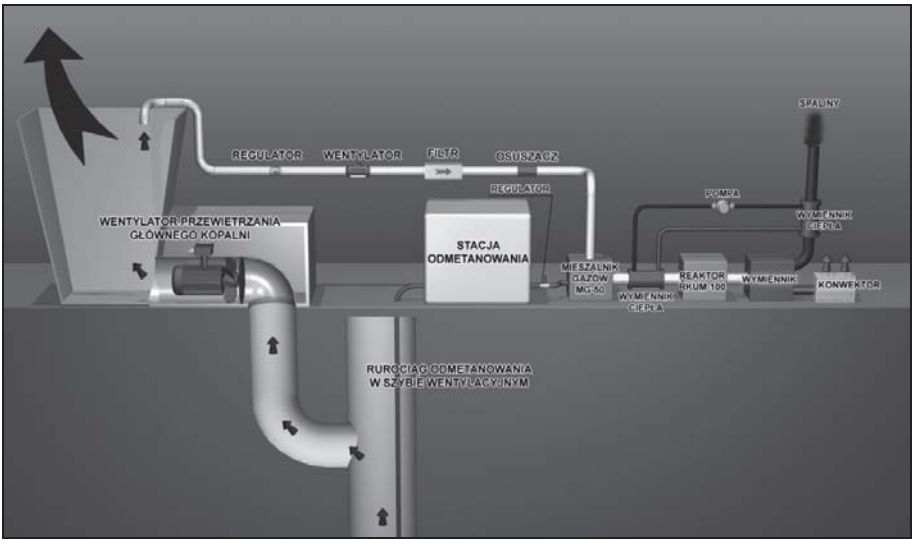

Fig. 4. Scheme of the installation used for methane utilization from ventilation air

Semi-technical installation IUMK-100 (Fig. 6) possesses the following parameters:

— Air stream — V_{VAM} = 1000÷3000 m^3/h,
— Methane concentration in air — z_{CH4} = 0.4÷1 %,
— Gas stream — V_{CH4} = 4.0÷12 m^3/h,
— Thermal energy — Q = 140÷1050 MJ/h,
— Useful thermal energy — P = 13÷100 kW.

Localization of the installation with reference to existing mine objects like shaft, methane-draining station, fan station is show in Figure 5.

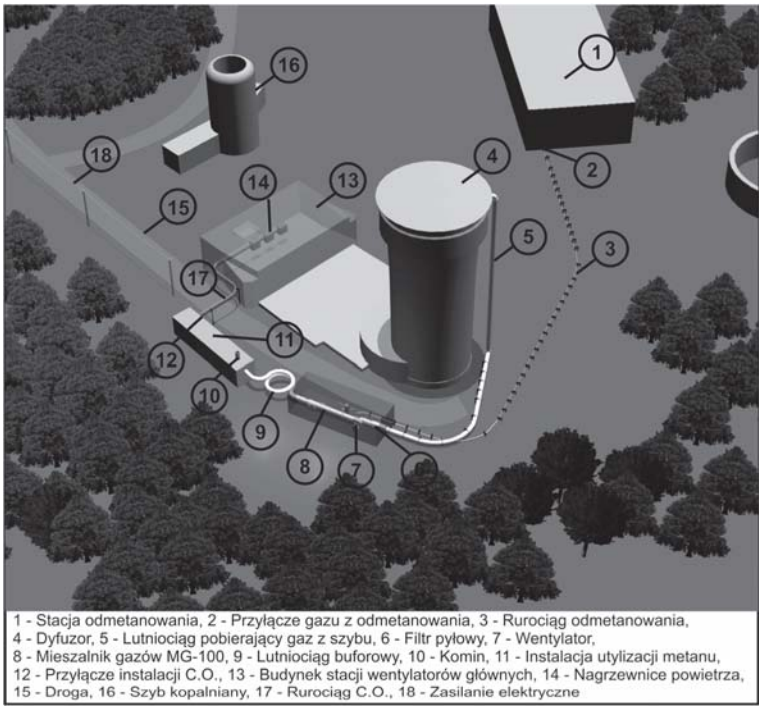

Fig. 5. Localization of the methane utilization installation near shaft Jas VI in hard coal mine "JAS-MOS"

Fig. 6. Localization of methane utilization marked with symbol IUMK-100 near shaft Jas VI in hard coal mine "JAS-MOS"

Installation IUMK-100 consists of the following elements:

— **Fan** — Ventilation air used in the methane utilization installation is taken from the mine exhaust shaft from the diffuser in volume of 1000–3000 m^3/h via elastic suction and force air-duct of diameter 500 mm, and then via centrifugal fan via filter to mixer.
— **Filter** — Air taken from the ventilation shaft is de-dusted via catalitic oxidation installation.
— **Agitator** — As the methane concentration in shaft amounts for about 0.2%, methane obtained from mine methane-draining is added, and then is mixed in the agitator. Gas streams from ventilation shaft and methane-draining network are mixed in this device.
— **Heater** — Electrical heater is used for the intake air heating up to 360°C, in order to initiate process of the methane oxidation in catalyser. After heating the intake air up to required temperature the heater is switched off and the intake air is heated by the thermal energy released in the process of methane catalithic oxidation.
— **Reactor** — Cathalitic combustion of the methane present in ventilation air takes place in reactor RKUM-100, where in result of chemical reaction the methane present in the air stream is oxidated and the oxidation products are carbon dioxide, water vapour and heat energy. Chemical reaction of the presence of catalyser — palladium is started in temperature of 170°C, and after reaching temperature of about 380°C the methane oxidation efficiency amounts for over 90%. In order to heat the gases up to temperature of 170°C electric heaters are used. If the oxidation process is started the reactor works in auto-thermal mode — without heaters.
— **Heat exchanger** — Heat exchange WC-100 allows recovering thermal energy from gases leaving reactor in Mount of up to 100 kW, which is used for heating purposes.

In the secondo half of May 2012 r., installation IUMK-100 was activated by Consortium Of Methane Utilization — shaft VI of the Hard Coal Mine Jas-Mos belonging to Jastrzębie Coal Company SA, which proved that the installation IUMK-100:

1) It works properly and in a safe mode.
2) It allows oxidation of methane from mine air (there is 0.2% of methane in the shaft) enriched with methane from methane-draining up to the value 0.5%.
3) It combusts about 10 m^3 CH_4/h.
4) It allows recovery of thermal energy in amount up to 100 kW.
5) It works in auto-thermal mode (without supplying additional energy from outside) at methane content of 0.5%.

The installation in question in the period of two weeks allowed utilization of 3360 m^3 of the methane (what corresponds to utilization of 84 000 m^3 CO_2) and production of 16 800 kWh of thermal energy.

The examinations on the influence of parameters of delivered air onto operatiom of the installatio IUMK-100, including reactor parameters, are still continued.

4. Conclusions

The presented material allows drawing the following conclusions:

1) Absolute methane content in Polish hard coal mines is very high and in the year 1011 amounted for 828.8 mln m^3 CH_4, whereas in underground methane draining about 250.2 mln m^3 CH_4 was recovered, and 662.5 mln m^3 CH_4 a was emitted to the atmosphere with mine ventilation air,
2) Yearly emission of 662,5. mln m^3 CH_4 to the atmosphere together with mine ventilation air results in greenhouse effect, what in turn results in increasing of the charges paid by coal mines.
3) There are technical-technological possibilities of utilization of methane from mine ventilation air.
4) A Project entitled "Pro-ecological Technology of Utilization of methane from Mines" finance by the European Union comprising the installation for utilization of methane from mine ventilation air was realized by the Mine Methane Utilization Consortium, consisting of the AGH Stanislaw Staszic University of Science and technology — project leader, the Wroclaw University of Technology and Maria Curie Sklodowska University in Lublin — POLAND.
5) Further development of the project of utilization of methane form mine ventilation air, including reduction of the methane emission to atmosphere is possible under conditio that the following problems will be solved:
   - — Increase of the investment in scope of full economic use of the methane as low-methane fuel in heat-power installations.
   - — Utilization of the methane from mine ventilation air.
   - — Introduction of trade comprising low-methane gas emissions of methane emitted with the air turing ventilation of hard coal mines.
   - — Legal acceptance of methane from mine ventilation air as a fuel used in power installation, in which the State will donate the energy production.
6) Problem of methane utilization from coal beds of underground mines as low-methane gas fuel should be urgently solved not only because of its negative influence onto the natural environment but also because of its high economic effectiveness.
7) Problem of effective utilization of methane from mine ventilation air (content of methane from 0.0 to 0.75% — in average 0.3%) is a subject of research work of Polish and foreign institutions.
8) Testing of the research installation marked with a symbol IUMK-100 — installation works without delivery of energy from outside, is conducted at the methane content in the air amounting for 0.5% and the installation produces thermal energy.
9) In a period of two weeks, the installation IUMK-100 allowed utilization of 3360 m^3 of methane (what corresponds to utilization of 84000 m^3 CO_2) and production of 16800 kWh of the thermal energy.

REFERENCES

[1] Raporty Roczne (2001–2011) o stanie podstawowych zagrożeń naturalnych i technicznych w górnictwie węgla kamiennego. GIG, Katowice 2001–2011
[2] *Nawrat S.*: Możliwości wykorzystania metanu z powietrza wentylacyjnego podziemnych kopalń węgla. Miesięcznik WUG nr 5/2006.

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