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RESEARCH ON USE OF METHANE GAS FROM THE DEGASSING OF COAL SEAMS AND THE COGENERATION PRODUCTION OF ELECTRICITY AND THERMAL ENERGY

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Abstract: *The present work aims to analyze possibilities of using the methane gas resulting from degassing of coal seams under conditions of increased efficiency. Degassing is absolutely necessary for the safe exploitation of coal seams, the result being accumulation of substantial amounts of methane gas that we propose to use in the cogeneration system of electricity and heat.*
Keywords: *energy, methane cogeneration, safe in operation, explosion protection*

1. Importance of degassing in coal mines

In the context of mining operations, mines can be classified as gassy or non-gassy depending on the minerals / materials extracted and whether methane can appear in the mining works. In practice, all coal mines are considered gassy. In other types of mines, methane accumulations can also occur, for example, if minerals/materials are extracted near oil-bearing seams or unexploited coal formations disturbed by the extraction process, or mines with emissions of flammable gases.

In mines where flammable minerals / materials are extracted, there is a risk of explosion because small particles of the extracted product can become in suspension and can generate dust/air mixtures that can sustain rapid combustion [1]. Flammable dust can represent an explosion risk on its own (when in the form of an explosive dust/air mixture) or it can settle in layers on access paths and explode in the event of a methane explosion. Therefore, over time, the concept of explosion protection and explosive atmosphere has been developed, defining the mechanism of gas, vapor, or flammable mist/air explosions [2].

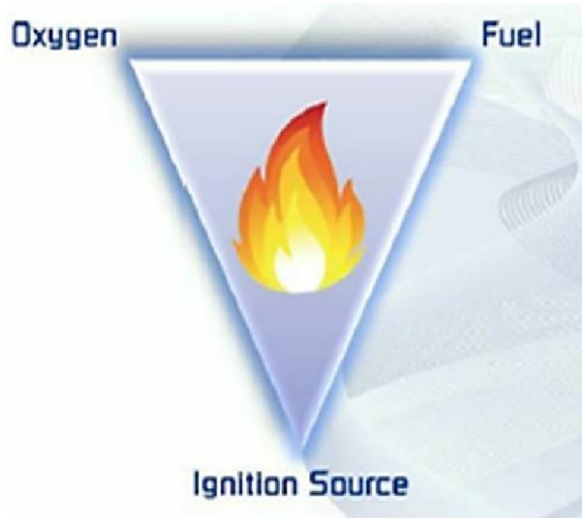

Fig.1. The mechanism of gas, vapor, or flammable mist / air explosions

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Flammable gases such as methane, in combination with coal dust resulting from the technological process of coal extraction, can accumulate in coal mines.

If these gases reach hazardous concentrations and come into contact with an ignition source, they can cause devastating explosions.

Degassing is the technological process through which the risk of explosion, as well as intoxication or asphyxiation for staff, is reduced. Gases such as carbon monoxide (CO) and carbon dioxide (CO_2) are dangerous at certain concentrations.

Removing gases from the mine helps maintain a fresh air flow and control underground temperature and humidity.

2. Degassing methods

- *Ventilation:* Using an efficient ventilation system to evacuate gases from the mine. This system involves fans and ventilation ducts that bring in fresh air and remove hazardous gases.
- *Drilling Gas Wells:* Before exploiting a deposit, wells can be drilled to release gases from the coal seam. These wells can be located either on the surface or underground.
- *Water Injection:* Injecting water into coal seams can help release gases. Water reduces surface tension and facilitates gas release from the coal.
- *Monitoring Systems:* Using sensors and monitoring systems to detect gas concentrations in real-time. These systems can trigger alarms and automatic ventilation actions if necessary.

Equipment used:

- *Fans:* To ensure the circulation of fresh air and gas evacuation.
- Gas Sensors: For monitoring methane, carbon monoxide, and other dangerous gas concentrations.
- *Degassing Wells:* Specialized structures for releasing gases accumulated in coal seams.
- *Automated Control Systems:* For managing and optimizing the ventilation and degassing process.

Compliance with safety regulations and standards is essential for protecting workers and the environment.

In conclusion, degassing in coal mines is essential for preventing accidents and maintaining a safe working environment [1]. Using appropriate techniques and equipment, combined with constant monitoring, can significantly reduce the risks associated with the accumulation of dangerous gases.

Degassing in coal mines is a critical process for the safety of miners and the efficiency of mining operations.

3. Methane gas storage facilities

Underground Storage:

Salt Caverns: Created by dissolving salt in an underground deposit. These caverns are airtight and allow rapid injection and extraction cycles.

Depleted Gas Reservoirs: These are former natural gas deposits that have been depleted. The geological structure of these deposits is ideal for gas storage because it has already proven capable of naturally retaining gases.

Aquifers: These are underground water layers that can be used for gas storage. The gas is injected into the porous rock layers, and the water helps maintain pressure.

Surface Installations:

LNG (Liquefied Natural Gas) Tanks: Methane gas is cooled to -162°C to liquefy it, reducing its volume by approximately 600 times. These tanks are well insulated and used for long-term transport and storage of gas.

Compressed Gas Tanks: Gas is stored at high pressures in cylindrical or spherical tanks. These are generally used for short-term storage and transport.

The presented work focuses on the efficient utilization of methane gas resulting from coal seam degassing by compressing and storing it in surface tanks.

In conclusion, methane gas storage facilities are vital for the efficient management of energy resources, ensuring the continuity of operation of installations and equipment for utilizing recovered methane gas from the degassing process. Implementing advanced technologies and rigorous safety and environmental measures is essential for operating these facilities.

4. Main composition of gas resulting from degassing

– *Methane (CH_4)*: 70-90%

Methane is the main and most important component energetically. It is a colorless and odorless gas in its pure state and is highly flammable.

– *Carbon Dioxide (CO_2)*: 0-15%

Carbon dioxide is an inert gas and, although not flammable, can be dangerous in high concentrations as it reduces the oxygen level in the air.

– *Nitrogen (N_2)*: 0-5%

Nitrogen is an inert gas and is present in the atmosphere at 78%. In mine gas, it does not significantly contribute to the energy value but dilutes the methane concentration.

– *Oxygen (O_2)*: 0-2%

The presence of oxygen in mine gas is an indicator of ventilation and can affect the risk of forming explosive mixtures.

– *Hydrogen (H_2)*: 0-1%

Hydrogen is a light and flammable gas. Its concentrations are usually small but can contribute to the reactivity of the gas mixture.

In all coal mining operations, specific installations are used for degassing and utilization of the extracted gas, known in the specialized literature as **„Coal bed methane" (CBM).**

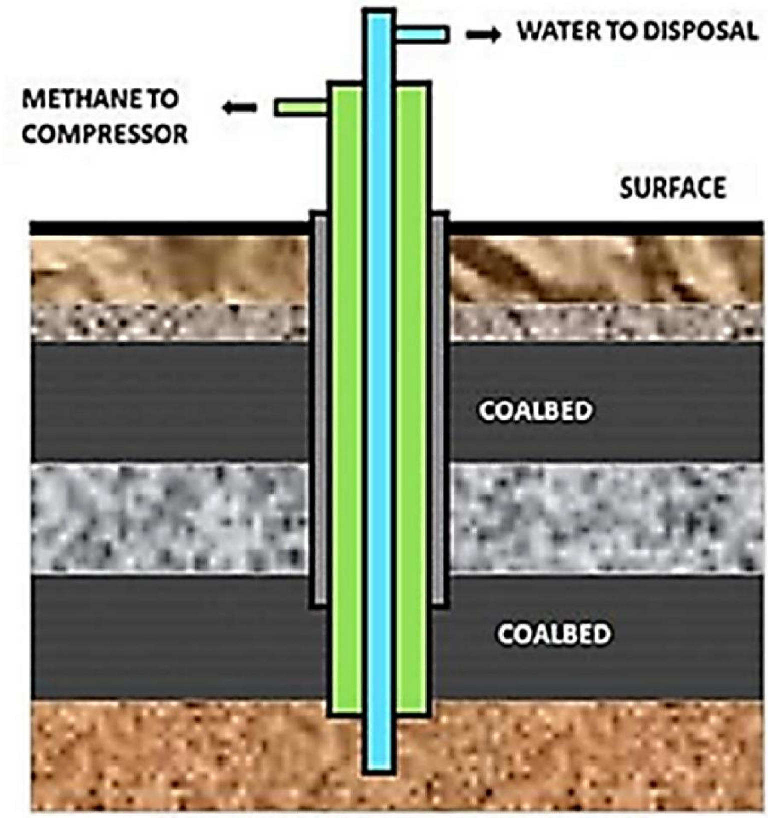

Fig. 2. Schematic presentation of degassing

The presented work proposes the use of methane gas resulting from degassing in high-efficiency cogeneration installations [3].

Combined heat and power (CHP) is an efficient and clean approach for generating electrical and thermal energy from a single fuel source.

CHP places energy production at or near the end-user location, so the heat released from energy production can be used to meet the user's thermal requirements while the generated energy meets all or part of the site's electricity needs [4].

CHP benefits:

– Increased energy efficiency;
– Reduction of specific energy costs and increased economic competitiveness;
– Increased reliability and reduced risk of energy supply interruptions;

Cogeneration installations rely on internal combustion engines (ICE) that are competitive in several aspects [5]:

- Cogeneration or trigeneration of energy;
- A very wide range of unit powers: 1 kWh – 18 MWh;
- MODULAR execution – flexibility, easy capacity increase, etc.;
- Operation on all types of gaseous and liquid fuels;
- Operation based on the load curve or standby reserve;
- Rapid start (from 10 seconds);
- Energy autonomy;
- Intelligent energy generation.

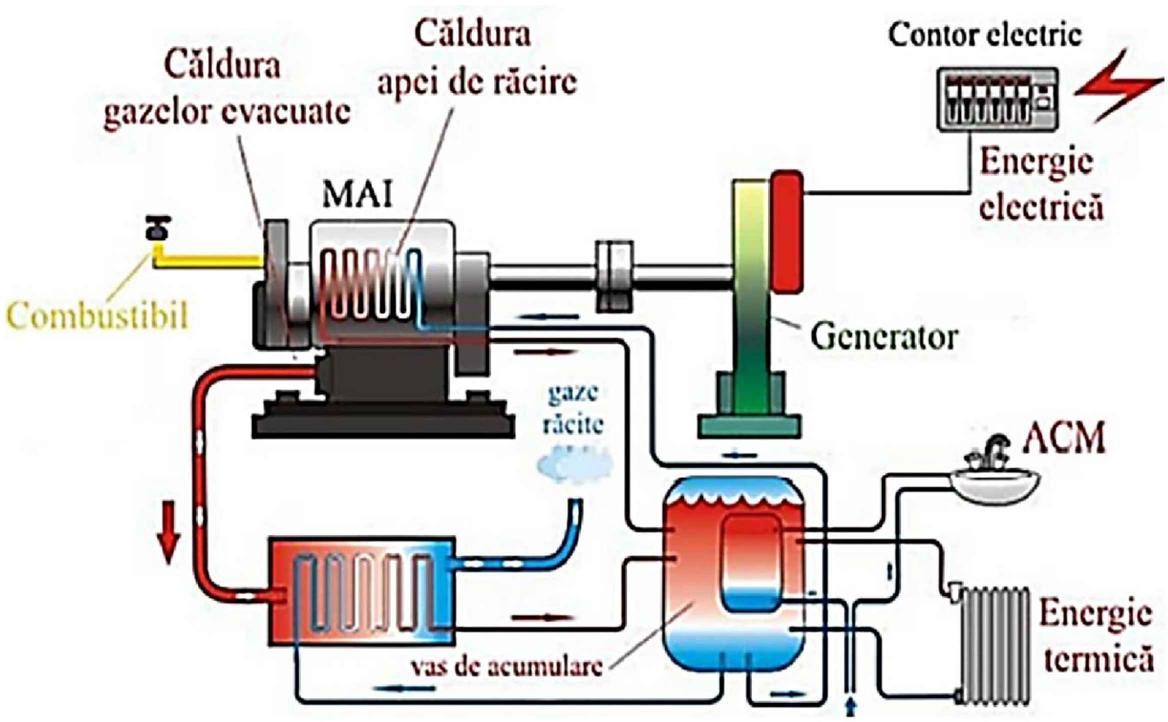

Fig. 3. Operation principle of a cogeneration installation

- The heat from exhaust gases (at 500°C) can be recovered up to ~70%
- The heat from cooling water and lubricating oil (at about 100°C) can be fully recovered.
- Recovered heat results from:
    - Cooling the equipment: 10-20%
    - Exhaust gases: 30-50%
- Heat recovery improves the total efficiency of the system to over 90% if all the recovered heat is used in a heating circuit with a supply temperature of about 100°C.

The following table presents the amount of gases resulting from degassing during the years 2015-2018 as well as graphically in table 1.

Table 1. Evolution of methane gas resulting from degassing [m^3]

Year	Methane gas from degassing	Methane gas released into the atmosphere	Methane gas used in own installations
2015	7996194	7310782	685412
2016	7362585	6592851	769734
2017	5502617	4806764	695853
2018	6037725	5270161	767564

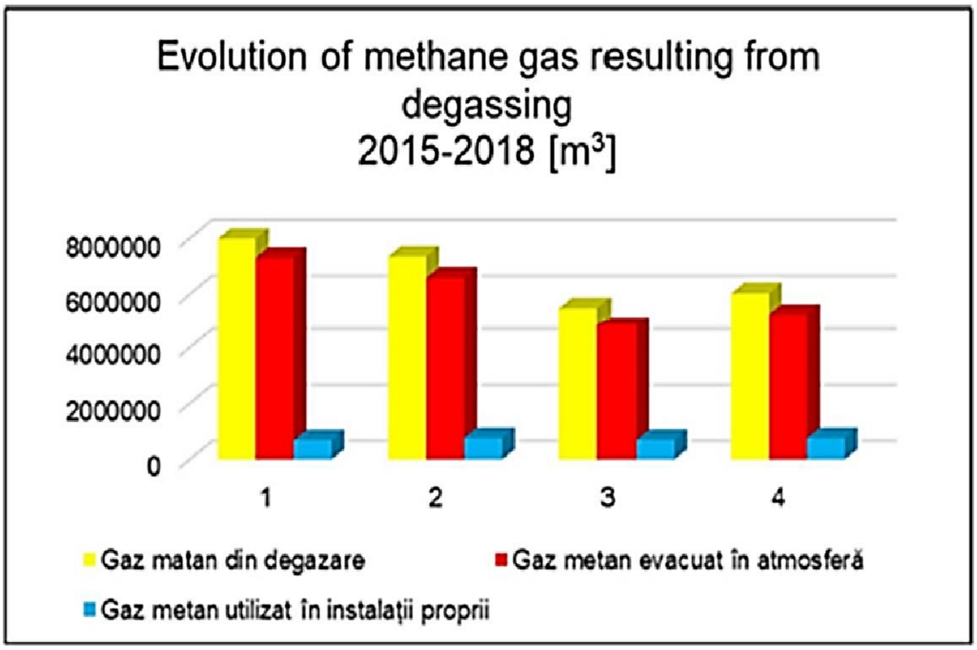

Fig. 4. Evolution of methane gas resulting from degassing 2015-2018 [m^3]

The widespread use of CHP (Combined Heat and Power) with ICEs (Internal Combustion Engines) is explained by numerous advantages [6]:

- relatively low specific investment;
- comparatively small dimensions;
- easy and rapid construction and installation;
- proximity to thermal energy consumers, which in turn eliminates losses during the transport and distribution of energy;
- elimination of the need to build costly and dangerous high-voltage power lines;
- ability to provide system services for stabilizing the electrical energy system;
- uninterrupted supply to the consumer;
- supply of high-quality electrical energy, maintaining specified voltage and frequency values.

4. Conclusions

Explosion First of all, it should be noted that this solution for using gas resulting from the degassing of coal seams in the Jiu Valley is mentioned in the „Strategy for the Transition from Coal in the Jiu Valley”.

The „Strategy for the Transition from Coal in the Jiu Valley” project was developed with funding from the European Union through the Structural Reform Support Program and in cooperation with the European Commission's Directorate-General for Structural Reform Support.

Extract from „Strategy for the transition from coal of the Jiu Valley”:

Consideration will be given to initiating pilot projects to harness the energy potential of the area (e.g., harnessing methane gas from the degassing of operational coal deposits using cogeneration plants for the production of electricity and heat, extracting and harnessing methane gas from coal deposits that are no longer in operation using surface drilling, underground pumped storage hydroelectric plant, etc.) to identify viable solutions and projects in the field of energy production, distribution, and storage (e.g., implementing a pilot project to supply energy using 'zero carbon' fuel, green hydrogen produced by electrolysis with solar energy converted to electricity through photovoltaic panels), followed by scaling these pilot projects based on demonstrated technical-economic potential.

The use of cogeneration installations in industry is already widely implemented and has exponential development prospects due to the presented advantages and achieved efficiencies of over 92%.

The technical conditions for implementing such installations are largely met at mining units, having the infrastructure for power supply and distribution.

The realization of such an installation has multiple benefits, on the one hand producing the necessary electricity and heat for own consumption, and on the other hand, the possibility of injecting surplus energy into the grid.

Not least, the implementation of this solution creates the prospects for fully utilizing the resulting gas, which has a major impact on reducing environmental pollution.

Acknowledgments

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