Combating the effects of methane accumulations and reducing the impact on the environment

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Abstract. Methane gas accompanies all coal deposits. Methane gas was formed over the years through the process of anaerobic transformation of plant material, at very high temperatures and pressures without the supply of oxygen.
The extractive industry is characterized by specific working conditions imposed by the natural peculiarities as well as by the character of the production process. The ventilation of mining operations is carried out mechanically, by upward air currents, under the depression created by fans mounted at of the shafts.
With the expansion of mining operations horizontally and their descent vertically, the regime of gas releases increased and the methods of combating methane solely by the ventilation system became difficult. Capturing and draining methane on the surface using central degassing stations has proven to be an effective means of combating gases.
Methane released into the atmosphere has a double ecological impact, it participates in the destruction of the ozone layer and accentuates the greenhouse effect.

1 Introduction

The ventilation of mining operations in the Jiu Valley coal basin is carried out mechanically, by upward air currents, under the depression created by fans mounted at the mouth of the shafts or aeration pipes. Within each individual ventilation system, clean air is introduced underground, from where it is distributed in several main ventilation circuits. These circuits must ensure maximum stability of the air flows both in size and direction, as well as a minimum depression on the exploited space. [1]

The contaminated air consisting of methane, carbon dioxide, carbon monoxide, sulfur dioxide and nitrogen oxides, is discharged to the surface where it pollutes the atmosphere, often exceeding the threshold values mentioned in the National Guide to Pollutant Emissions.

Gas emissions harm health by affecting the lungs, airways and heart. [2]

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The general ventilation of the mining operations is carried out by means of the main ventilation installations. The purpose of these installations is:

- ensuring air quality, so as not to affect workers' health;
- preventing the danger of explosion and the harmful effect of the dust formed;
- creating a climate suitable for the specifics of the productive activity.

The set of existing conditions in a workplace that ensure the optimal performance of work determines the notion of work comfort. Work comfort is generally determined by the following factors:

• air temperature;
• air humidity;
• air pressure;
• air speed;
• the working space and the chemical composition of the air;
• lighting, etc.

Work comfort is determined by the ability of the surrounding air to absorb the heat produced during exertion. It is essentially influenced by three parameters: air humidity, air temperature and air speed, the other factors having a minor role.

The air leaks through the mined space transport the oxygen in the mined space area and at the same time evacuate the methane trapped in the voids between the broken rocks as well as the heat resulting from the oxidation of the material.

2 Sources and impact of methane on the environment

The greenhouse effect is an essential feature of the Earth system and has exerted its action throughout the history of the planet.

The atmosphere determines the maintenance of a relatively constant temperature on the surface of the planet that favors the development and maintenance of life.

Greenhouse gases, of which methane is also a part, absorb radiation and retransmit it to the earth's surface. In this way both the atmosphere and the land surface become warmer.

Methane gas, water vapor in the atmosphere, carbon dioxide, nitric acid, and ozone let the short-wave radiation, full of solar energy, pass, absorbing the long-wave radiation emitted by the earth.

Among all the factors that influence the climate producing greenhouse effect are methane gas and carbon dioxide.

A warmer planet will have more precipitation and extreme events that will be very difficult to manage.

There are other possible sources of release of methane gas into the atmosphere, the warming of the planet's atmosphere can intensify the release of methane gas from the sediments of the oceans, marshes and permafrost. In all these areas, a significant amount of methane gas remains bound to water molecules.

However, the average "life" of methane in the atmosphere is relatively short, around 12 years, compared to that of carbon dioxide of around 200 years.

The heating of the atmosphere is mainly done indirectly, by means of the earth's surface which transmits its heat to the air in its immediate vicinity. This heated air, due to convective movements, moves to the upper layers of the troposphere, replacing the cooler air from these heights, which will descend to the ground. The decrease in air temperature with height is different in the layers of dry air (on average about 0.60 ºC at 100 m) and moist air (about 10º C at 180 m).

Most greenhouse gases are residual gases, which represent less than 1% of the total volume of gases. Greenhouse gases, whose emissions must be reduced, according to the Kyoto protocol, are carbon dioxide, CO_2, methane gas, CH_4, nitrous oxide, N_2O, partially

halogenated fluorocarbons, H-FCKW/HFC, perfluorinated hydrocarbons, FKW/PFC, sulfur hexafluoride, SF6.

3 Methods to combat methane accumulations

3.1 Generalities

The release of methane in the mining front area is a very complex phenomenon, which depends on a multitude of geological factors and exploitation techniques. Studying the methane balance of the mining front revealed that the source with the largest weight in the total methane balance is the methane from the exploited space in a proportion of 15-75%.

The highest concentrations of methane are located near the exhaust gallery of the stale air from the mining front to the exploited space.

The knowledge of the method of forecasting the occurrence of methane emissions in the exhaust stream of the mining front, to which is added the new knowledge in the complicated mechanism of the emission of methane, must allow the use of appropriate means of solving the difficult stages that appear in the efforts made to maintain security underground.

The increase in mining depth makes the problem of isolating active mining works from the exploited space more and more difficult. Air leaks through the exploited area, carry the accumulated methane from below and above the surrounding rocks, out of the mined space.

This process prevents the advance of the mining front from increasing, while also increase the danger of the occurrence of dangerous concentrations of combustible gases. [3]

3.2 Analysis of the degassing system at the mining operations in the Jiu Valley

The presence of methane gas in the coal deposit in the Jiu valley coal basin was highlighted during the exploration works and later the opening, preparation and exploitation works, both in the coal bed and in the sterile rock existing between the layers of the productive complex.

In some areas, methane can be found accumulated in large quantities at high pressures, while in other areas its presence is reported at low pressures.

Following the exploratory work, based on observations and measurements made directly on the boreholes where gas manifestations occurred, a zoning was made of the presence of methane within the basin. Thus, a maximum was found in the central-axial area of the basin, in the Vulcan, Paroseni and Lupeni mining fields, where strong methane releases occurred. On the slope of the deposit, methane shows a maximum intensity in the lower and central area of the productive complex, respectively in the layer 3 area and in the roof of layers 5, 8/9 and 13.

With the expansion of mining works horizontally and in depth of the exploitation level, the regime of gas releases has changed. The methods of combating methane only due to aeration have become difficult (due to the limitation of the amount of air introduced underground), which is why other methods of combating them have been identified.

Methane capture and drainage has proven to be an effective means of combating gases. [4]

Determining the feasibility of degassing mining involves a detailed analysis of the complex of factors that influence methane emissions, a forecast of methane emissions, a diversified analysis of the aeration factor, a clear knowledge of the deposit reserve and exploitation dynamics.

3.3 Degassing application criteria

Establishing the technical possibility for the application of degassing depends on the one hand, on the geological-mining conditions, and on the other hand, on the specific degassing parameters.

Qualitative and quantitative criteria are considered when determining the appropriateness of applying the degassing of the massif of rocks with a methane content.

For the specific conditions of mining operations in Jiu Valley they are expressed by:

- the ability to dilute methane through aeration at the limit speeds imposed by the degree of comfort and to avoid raising dust in suspension;
- distribution of air flows underground and in areas with high methane releases;
- methane concentrations at the intersection of the mining front with the head gallery and in the exploited space;
- limiting the production of a mining front according to the allowed methane concentrations;
- prevention of gas-dynamic phenomena during the execution of mining works at the bottom of the sack. [5]

The optimal location of the methane capture points, in the areas and mining works established to carry out the degassing of the rock massif, directly determines the protection of the atmosphere against methane.

When placing the capture points, we considered the following criteria:

- the conditions of the deposit represented by the geometric characteristics of the layer, the nature of the rocks in the bed and their roof, the presence of tectonic accidents, the degree of danger of the area or layer in terms of phenomena gas dynamics;
- the amount of gas pressure in the rock massif. Gas pressure is tight dependence with adsorbed or free methane content, with permeability, respectively the permeability of the massive or unexpanded massif, these constituting the parameters that guide the location of the capture points;
- the amount of methane that can be released from rocks undergoing the degassing process, corresponding to the physical properties and their nature, respectively the conditions premises where the preparation and exploitation works are carried out;
- the type and destination of the mining work (galleries executed within the coal bed in undesignated areas, cuttings under the natural ceiling, accompanied by the formation of voids with methane accumulations in the exploited space, etc.).

From a technological point of view, the capture points can be:

- boreholes executed in the coal layer and/or companions, before the start of exploitation or during it;
- boreholes executed towards the voids or cracks created above the layer exploited;
- isolation damn of old mining works;
- boreholes executed towards known faults and tectonic disturbances.

The research undertaken so far by INSEMEX Petrosani has led to the development of degassing framework methods, depending on:

- the type of mining works;
- exploitation method;
- the thickness of the coal layers;
- tilting of coal bed.

Following the analysis carried out along the type, degassing in the Jiu Valley basin is mandatory under the following conditions:

a. for mining works at the bottom of the sack:

- the absolute flow of methane that results from the preparatory mining work in coal, is greater than 3 m^3/min;

- the absolute flow of methane that actually results from the preparatory mining work in coal, which is dug near faults located at a distance of up to 10 m, is greater than 1.5 m^3/min;
- the absolute flow rate of methane that actually results from the chamber discharge is greater than 3 m^3/min;

b. for mining fronts:

- the relative methane flow rate of the coal bed is greater than 15 m^3/t, or the absolute methane flow of the mining front in operation is greater than 6 m^3/min.

In relation to the limit value of the methane emission from which the application of degassing is mandatory, the work fronts are classified as follows:

- working fronts with "NORMAL METHANE EMISSION", where degassing is not mandatory (absolute and relative methane flows have lower values).
- working fronts with "CAUTION" work fronts, where degassing is mandatory (flows absolute and relative methane values are higher).

The optimization of the operation of the capture networks is difficult to achieve because the adjustment procedures are often based on empirically established rules and principles, and the control and supervision of the characteristic parameters is not carried out in real time.

A degassing network must satisfy two basic requirements:

• reducing the methane content in the ventilation currents by capturing as much gas as possible, before it reaches the atmosphere of the mining works;

• capture of a gaseous mixture with a higher calorific value for recovery.

The main functions that an automatic management system of degassing networks must perform are the following:

• continuous control of the main parameters of the capture network, the parameters determined in its characteristic points;

• transmission of data to the surface;

• mathematical processing of data to determine development trends and to perform other necessary calculations;

• detection of abnormal operating situations by comparing the measured values with the preset ones, as well as the triggering of possible alarm signals;

• establishing ways to regulate the network in order to eliminate abnormal operating situations;

• recording and storing data, as well as the results of the analyzes performed;

• displaying, in synoptic form, the results (curves describing the evolution of parameters, etc.);

• self-regulation and optimization of network operation according to the requirements imposed by the operator.

3.4 Reducing the impact on the environment by exploiting methane gas

Electricity generation is an attractive option, as most coal mines are characterized by considerable energy consumption. [6]

➢ Conventional internal combustion engines generate electricity using medium quality gas. Moreover, they can, under certain conditions, also use part of the methane from the exhaust streams of the stale air from underground, replacing the fresh ambient air used in the engine injection.

➢ Conventional gas turbines, with modified burners, should be able to exploit the mixture with more than 30% methane, provided a supply is ensured at a relatively constant flow rate. Moreover, if the turbine system will be equipped with a catalytic burner, it can operate continuously with only 1% methane content in the air, going as low as 0.8% methane concentration.

➢ Electrochemical cells (cells) produce electricity by means of an electrochemical reaction, according to the principle like a standard battery. Currently, the only electrochemical cells with industrially proven reliability are those that use hydrogen as fuel, but the development of methane-based electrochemical cells is in full development. To generate electricity, three types of electrochemical cells have been developed: with phosphoric acid, with molten carbonate and those with solid state oxides. Finally, we must consider the fact that, due to their high cost, electrochemical cells cannot have wide industrial application at the moment. To expand the use of their application potential, a major innovation will be required, which will materialize in reducing costs and increasing reliability.

➢ Co-generation in thermal power plants: the original purpose of natural gas co-generation in conventional coal-fired thermal power plants was to reduce NOx emissions.

The advantages of co-generation include the reduction and valorization of captured methane, the generation of electricity with reduced greenhouse gas emissions (carbon dioxide), significant reductions in NOx emissions and lower capital costs. When studying the feasibility of such a project, however, the following determining aspects must be considered:

- the number of suitable locations is limited for the application of the technology, due to the need for the existence of a thermo-electric plant in the vicinity of the mine;
- the need for a network of pipelines for the transport of methane, which leads to an increase in the cost of modifications to adapt the conventional plant;
- variations in the concentration of methane and its flow can negatively affect the effective operation of the plant.

➢ An alternative option for using methane captured from coal mines can be as a feedstock for various chemical processes to produce synthetic fuels or chemicals, such as the production of methanol and carbon black.

4 Conclusions

In the area of influence of the mining works, the movement of gas in the massif is mainly carried out through the fissures produced as a result of the tensions that appear in the massif. This is a result of the redistribution of the rock pressure, which explains the large difference that exists between the gas permeability of the massif in the area undisturbed and the area of influence of a mining work. The gas permeability of the layers must be the basis of all studies regarding the regime and dynamics of underground gas emissions, knowing that the gas emissions from the working front and from the walls of the mining works come exclusively from the massif located in the area of influence of mining works, the influx of gas from the undisturbed area to the mining work being insignificant.

From the perspective of reducing the impact on the environment, it is of particular importance to forecast methane emissions as accurately as possible, as close to reality as possible.

Knowing the flow rate and intensity of methane emissions is also necessary for the judicious choice of mining execution technologies and for identifying the most effective means of combating dangerous methane accumulations.

Although the main reason for extracting methane from coalbeds continues to be to reduce methane emissions to the underground atmosphere, an important incentive has also been to drain this gas to provide a fuel source and, for many years, as well as the need to reduce emissions of greenhouse gases.

Methane emissions released into the atmosphere because of coal mining have a double ecological impact, namely, they participate in the destruction of the ozone layer and at the same time contribute to increasing the greenhouse effect. Methane gas molecules have a high

capacity to absorb heat, which means that even lower concentrations make an important contribution to the greenhouse effect.

The global warming potential of carbon dioxide is much greater than that of methane.

Accessible and/or available options for reducing methane emissions in the atmosphere by harnessing it include electricity production, industrial or urban space heating, domestic and industrial consumers (at low pressure in distribution columns), the national gas distribution system (at high pressure).

Other possible uses include fueling boiler burners, fueling various types of vehicles, use in fuel cells to produce hydrogen, in the chemical industry for the manufacture of methane, carbon black, formaldehydes and synthetic fuels.

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