CHANGE OF PARADIGM IN UNDERGROUND HARD COAL MINING THROUGH EXTRACTION AND CAPITALIZATION OF METHANE FOR ENERGY PRODUCTION

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Abstract: *Besides oil and gas, coal is the most important fossil fuel for energy production. Of the energy mixture of our country, the internal production gas share is 80% of the required annual consumption, of about 14 billion cubic meters, the rest of 20% being insured by importing, by the Russian company Gazprom. The share of coal in the National Power System (NPS) is of 24% and is one of the most profitable energy production sources, taking into account the continuous increase of gas price and its dependence on external suppliers. Taking into account the infestation of the atmosphere and global warming as effect of important release of greenhouse gas and carbon dioxide as a result of coal burning for energy production in thermal power plants, there is required to identify new solutions for keeping the environment clean. Such a solution is presented in the study and analysis shown in the paper and is the extraction and capitalization of methane from the coal deposits and the underground spaces remaining free after mine closures. Underground methane extraction is considered even more opportune because, during coal exploitation, large quantities of such combustible gas are released and exhausted into the atmosphere by the degasification and ventilation stations from the surface, representing and important pollution factor for the environment, as greenhouse gas with high global warming potential (high GWP) of about 21 times higher than carbon dioxide.*

Key words: methane, coal, greenhouse gas, technological process, energy

1. INTRODUCTION

Through burning, coal is the largest carbon dioxide CO_2 production source which lays ground for climate changes, through the warming of the planet and occurrence of greenhouse effect, as result of the adsorption of thermal radiations and reflection of a part from the infrared radiations, by destruction of the ozone layer [1], [2].

It is estimated that approx. 30% of the planet's pollution with carbon dioxide is represented by coal burning in thermal power plants. By continuing the current rhythm of coal extraction, it is estimated that the cost for protecting the environment against CO_2 emissions by year 2100 will represent 20% of the global GDP.

It is estimated that of the 70% CO_2 emissions, 40% belongs to China and USA, whose coal production is about 1.8 billion tons (tep), respectively of approximately 900 mil. tep (1 tep. = 11.6 MWh = 10Gcal), followed by India with 230 mil. tep. EU registers 290 million tep, meaning approx. 8% of global consumption (Poland produces 130 mil. tep, Russia – 90 mil tep, etc.).

In Romania, coal reserves highlighted in 2011 represented 4,121 million tons, availability for energy production for approximately 200 years, of which 721 million represented by hard coal, 2.4 billion tonnes lignite and 65 mil tones brown coal.

For 2015 it is foreseen that the maximum level of greenhouse gas emissions will be reached, after which these shall decrease. Until 2020, the nuclear power, hydro-power and renewable energies shall have an energy production share similar to the one of coal, respectively of approximately 60% of which the share of green power will be approx. 20%. In 2020-2030, renewable energies and gas are estimated to 70% (gas maintaining its' level at 30%). In 2030, fossil fuels (coal and gas) will be each of approximately 25% of the energy mixture, with a decrease tendency for coal down to 20% and an increase of gas up to 30% [3].

Taking into account the decrease of power resources which produce major ecological de-synchronisations, the development of methodologies and technologies for degasification of coal layers Jiu Valley underground mines, the increase of methane recovery and capitalization of own power resources, the improvement of work conditions and increase of occupational safety in hard coal extraction by reducing the CH_4 quantity in the coal faces, there has been developed more and more the idea of extraction and capitalization of methane, both from operating mines and from the underground of closed mines and of abandoned areas.

2. CONSIDERATIONS ON THE GEOLOGY STRUCTURE AND ON THE PRESENCE OF METHANE IN PETROSANI COAL FIELD

Petrosani coal field is the largest coal field of the country if we take into account the coal reserve over the surface, the quality of coal and the experience gained in time during its' exploitation and capitalisation. The sediment complex of Petrosani is formed of deposits from the Upper Cretaceous, Paleogene, Neogene and Quaternary. It has a width of approx. 150 – 300 m and comprises compact clays, sandstone, marl, brown marls and has a number of 21 coal beds. The coal beds have variable extent and width, of centimetres up to tens of meters, with variations within the same bed, both on the direction and on the inclination [2], [3], [4].

The presence of methane in Jiu Valley coal field has been highlighted during exploration, opening, and preparation workings and during the exploitation of the deposit. In some areas, methane has been noticed accumulated in large quantities and having high pressures. Following the exploration workings, based on the observations and measurements carried out on the drillings in which there has been noticed gas, there has been performed a zoning of methane presence in the coal field. There has been noticed a maximum in the central-axial area of the field, in Vulcan, Paroseni and Lupeni mining fields, where occurred powerful methane releases. On the inclination of the deposit, methane presents a maximum intensity in the lower and central part of the productive complex, respectively in the area of coal bed no. 3 and of the roofs of l beds no. 5, 8/9 and 13. This horizontal and vertical zoning may be interpreted as follows:

- in the central-axial area of the field, due to the crystalline threshold, the medium and upper horizon have been lifted up. Therefore, methane migrated from neighbouring mining fields towards this area on the direction of the beds and on the rift planes. Besides this aspect, due to the high carbonisation of coal mass, coal beds have a higher methane content than in other areas of the field.

- vertically, the highest methane concentrations are generally due to the pelitic facies (clay-marly) from the central area of the medium horizon located between beds 5 and 13, which has hindered the natural degasification of coal beds.

Methane presence in surrounding sterile rocks may be caused by the following:

– the migration of mine gas from coal towards the accumulation rock;

– the surrounding rock comprised organic components which have suffered the same biochemical and geochemical transformation as coal (i.e. the presence of bituminous shale).

As a base component of mine air (firedamp), methane is the product resulting from anaerobic transformation of plant litter during the carbonisation process. This is located in coal beds and surrounding rocks, comprising methane in mixture with carbon dioxide, nitrogen, hydrogen and methane homologues (some percentage) and traces of carbon oxide. The beds known to have high methane content are subject to degasification before their exploitation (pre-degasification) and can be kept into operation simultaneously with the digging of preparation and exploitation workings, as well as after the end of the exploitation (for the goaf's degasification). Once with the horizontal and in depth extending of the exploitation level, the degasification regime has been altered. The methods for fighting against methane only based on the ventilation have become very difficult, due to the limitation of air quantity inserted underground.

In order to ensure a higher advancing speed of coal faces and related preparation works, implicitly in order to increase the underground work safety, the exploitation of coal beds with methane releases has been performed only through their prior degasification The degasification principle consists of capturing and draining a large part of the methane from coal beds (base bed or non-exploitable beds), from sterile rocks or from goafs and the exhaust through tightened pipes up to the surface (central degasification) or within a return air current in which is possible its' dilution down to the limits allowed through regulations (local degasification).

In Jiu Valley mines have operated in time several central degasification stations. Now, there are working four such degasification stations in Lupeni, Paroseni, Vulcan and Livezeni mining units. Each station disposes of 4 vacuum pumps, with a nominal installed capacity of 100 gas cubic meters/min. Of the pollutants regulated by international agreements related to the insurance of environmental conditions, there are subject to monitoring the greenhouse gas emissions, especially methane. In Romania, the methane released into the atmosphere following the coal, oil and natural gas extraction represented during 2005-2010, 32.7% of the entire methane quantity released at national level, of which the methane emissions from coal represented approximately 12%. [1], [5].

3. CBM TECHNOLOGY FOR CAPITALISATION OF CH_4 EXTRACTED FROM JIU VALLEY UNDERGROUND MINES

Besides the occasionally applied procedures for extraction of methane through degasification of coal beds and through the ventilation of mines in Jiu Valley, worldwide there is applied the CBM method (Fig.1), as results of vertical or horizontal drillings, technology which is internally proposed for the exploitation of methane from closed hard coal mines, from virgin beds or from operating mines, with coal beds in exploitation [1], [2], [6].

3.1 Vertical drillings versions

Vertical drillings are performed in the coal bed, the release of methane following to be carried out through fracturing (Fig.2). Technologies for stimulating the fracturing in order to increase the methane release efficiency are the following (Fig.3):

●***Hydraulic fracturing*** resulting in a vertical fracturing in two directions at approximately 180^0 towards the exterior of the borehole. Following the occurrence of a fissure as well as the possibility to pump large volumes of fluid at low velocities, the penetration potential required for fissuring can be large, reaching tens of meters in a lot of cases. This is the most spread technique CMM/CBM.

●***Fracturing through explosives*** – involves a very fast tensioning of the massif, resulting in a pronounced fracturing of the area surrounding the borehole, but whose radius does not usually exceed 3-4 m. Due to the fact that peak pressures exceed the minimal and maximal horizontal tensions in the massif, there occurs a radial fracturing which creates an advantageous fracturing near the borehole.

●***Pulsed fracturing*** – is characterised by pressure peaks which exceed the minimal and maximal tensions from the massif, also creating a radial fracturing system. This technique results in a pronounced vertical fracturing, with extent around the borehole, with 3-7 meters fracturing potential.

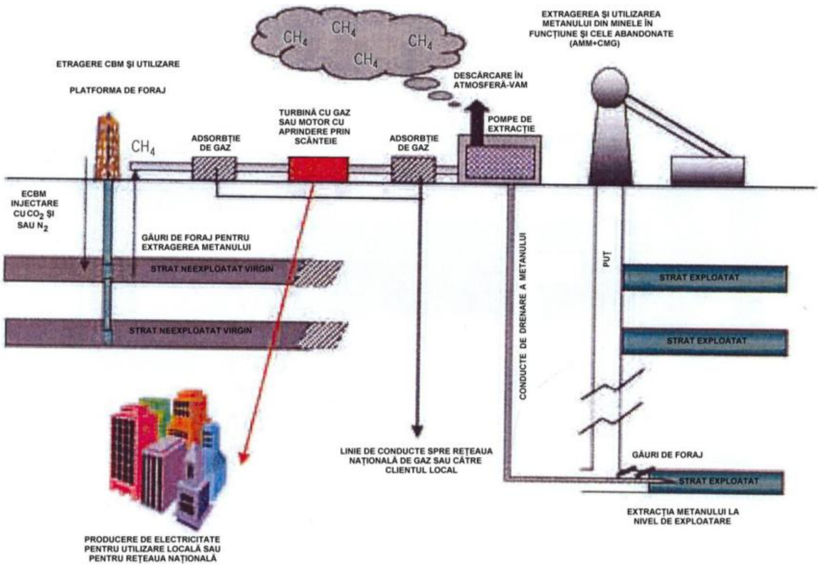

Fig. 1 Methane extraction and usage types

Two of these fracturing techniques – hydraulic and pulsed – are used on large scale in the CMM/CBM technology. Within these two fracturing technologies, five technological subversions found to be used largely: three hydraulic ones, with liquid and stabilizer CO_2, nitrogen without stabilizer, helicoidally tubes and other two pulsed type subversions. A coal bed pressurization-depressurization method with compressed air for removing coal particles and for forming a free space has been developed as an alternative of the hydro-fracturing, but its' application has been limited due to the relatively low permeability of coal beds.

3.2 Horizontal drillings version

A more recent alternative consists in drilling in the coal bed several horizontal boreholes from a single vertical drilling. The increase of contact surface with coal leads to the increase of methane emission, removing the necessity of hydro-fracturing (Fig.4). In a first phase there is drilled a whole which is tubed into the coal bed. In case of tanks which are not confirmed, which will produce gas at high pressures through the drilled borehole, the simple crossing of the coal bed will not lead to the flow of CBM. Generally, a fluid – rarely a nitrogen foam – has to be brought to the surface and pumped under pressure in the drilled borehole, respectively into the coal bed through natural fissures (cleavage system), increasing their dimensions, the process being known as hydraulic fracturing. Adding an additional material in the drilling fluid, such as sand, will maintain open these fractures, aiming to fill and dislocate spaces filled with gas, migrating along with the water to the surface. In order to stimulate migration/flow of CBM, the natural pressure from the coal bed has to be decreased through coal interception. A pump located in the upper part of the drilling exhausts water which normally occupies the fissures.

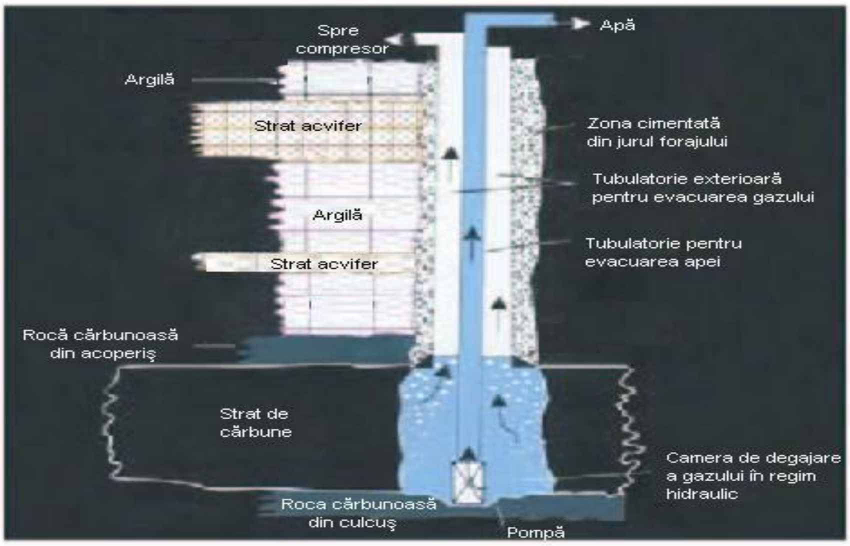

Fig. 2 Vertical drilling for CH_4 extraction

The pressure decrease in the free space of a certain coal bed leads to the adsorption of methane from coal, allowing it to flow through the borehole. Dewatering may last from several months up to several years. After it reaches the surface, there takes place the separation of gas from water, gas being led through a pipe towards a measurement station where the extracted volume follows to be recorded.

CBM is collected from several drillings, then being led to a central compressors station where it is compressed into a transport pipe. Water is conducted to a discharge station, and depending on its quality and quantity is either injected underground or used at the surface. CBM production has to be continuous in order to ensure a gas flow with constant low pressure and for the viable operation from the commercial point of view.

If a CBM drilling is stopped for a longer time period, after restarting it, the water from coal shall be collected from the borehole, requiring the repeating of the dewatering process. CBM boreholes are carried out by applying techniques which are similar to the ones used for normal drillings.

If coal beds are located at small depths and if they have reduced width, there may be used modified cheap installations, such as a water drilling installation. Obtaining initial gas regimes is more possible by carrying out a horizontal drilling than in case of a vertical (perpendicular or inclined) one. Types of installations used for CBM are manufactured by the following companies: Atlas Copco, Boart Longzert Gefco (models150 K and 185 K), Technicoil etc

4. CBM PURPOSE, DESTINATION AND USAGE

Accessible and/or available CBM usage purposes include the following [1], [2]:

- electricity production
- heating industrial or urban spaces
- home and industry users (at low pressure in the distribution columns)
- into the national gas distribution system (at high pressure).

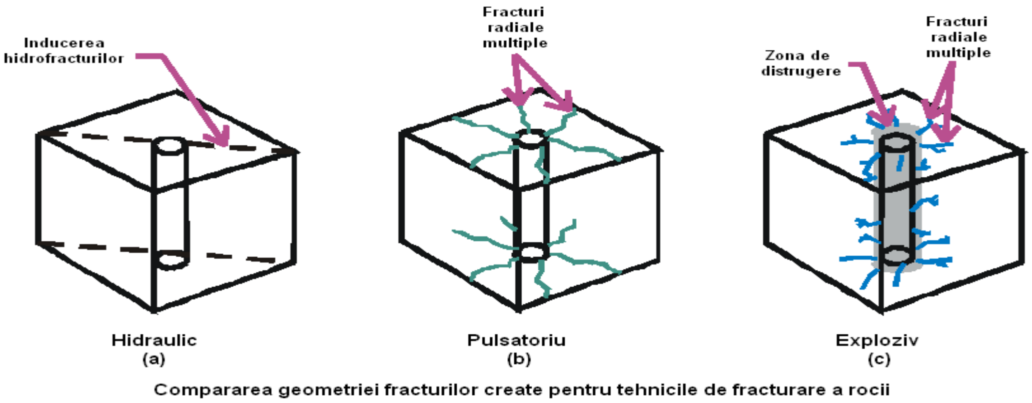

Fig. 3

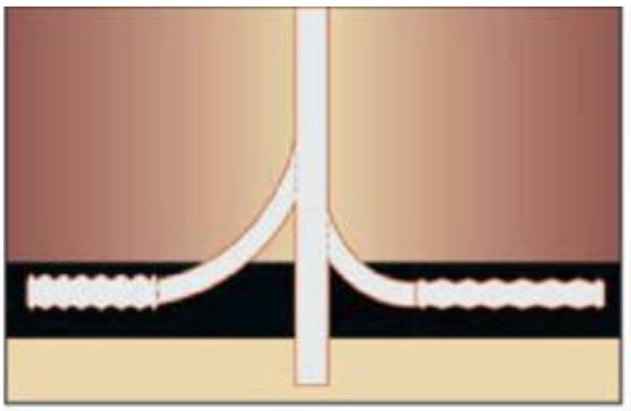

Fig. 4 Horizontal boreholes drilling into the coal bed

CBM is a substitute of natural gas and may lead to the local generation of electricity, its' usage being considered competitive, representing fuel for industrial users, obtained at a low price. Gas obtained from CBM may be used as singular fuel or along with coal or oil for obtaining hot water and heating up spaces (different uses in the perimeter of a mine or adjacent areas). Also it can be used for coal drying within its 'processing units. Also, it can be used in heating shafts, thus preventing the formation of ice hazard, leading at the same time to the increase of safety and comfort of workers. Other possible uses consist of: fuel supply for burners of boilers, supply of several types of vehicles, usage within fuel cells for hydrogen, within the chemical industry for methane fabrication, carbon black and synthetic fuels

5. CONCLUSIONS

By now, assessments and studies carried out for the exploitation and capitalisation of hard coal from Jiu Valley, focused exclusively on the development of technical solutions to ensure occupational health and safety of workers underground, as well as the protection of the deposit, and not the energetic potential of methane gas. In accordance with recorded aspects, by applying OHS measures in coal exploitation, the have been indirectly applied two versions of energetic uses of methane, namely the capitalization of methane exhausted through the return air from main ventilation stations (i.e. Paroseni mining unit), respectively the version for capitalizing methane from central degasification stations (Lupeni mining unit), the latter aiming to produce the thermal power for hot water and for heating up several neighbourhoods and workplaces of some companies.

Extraction and capitalisation of methane through the CBM procedure proposed in this paper, as energy resource, involves the achievement of the following technical-economic effects:

- increase of the occupational health and safety level of underground workers, protection of the deposit and machinery, by decreasing methane concentrations in workplaces;
- improvement of environmental factors quality and elimination of penalties caused by methane emissions released into the atmosphere;
- reducing the coal exploitation costs through the capitalisation of methane;
- streamlining the use of own resources by mining units.

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