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MINING PROBLEMS OF UNDERGROUND COAL GASIFICATION – REFLECTIONS BASED ON EXPERIENCE GAINED IN EXPERIMENT CONDUCTED IN KHW S.A. WIECZOREK COAL MINE

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Abstract: Basing on hitherto research and tests, including results of experimental underground coal gasification (UCG) conducted in Wieczorek coal mine, conditions a UCG process has to meet to become in the future an industrial scale technology applied to exploit deposits are analysed. Paper contains an analysis of broadly defined range of mining conditions (geological – mining conditions of a deposit selected for exploitation with the UCG process; type and properties of coal deposit; detailed technological and organizational solutions; conditions for the safe use of technology for the personnel and the environment) and also characterizes the conditions for economic viability of UCG technology as an coal exploitation method.

Keywords: underground coal gasification, mining technology, unconventional mining technology.

INTRODUCTION

Within the framework of Strategic Research and Development Program titled: "*Advanced Technologies for Energy Generation*", financed by the National Centre for Research and Development, among others, a task titled: "*Developing a technology of coal gasification for high efficient production of fuels and electric power*" has been realised. The issue was divided into eight research areas, one of which, realised by the Central Mining Institute together with Katowicki Holding Węglowy S.A. (KHW S.A.), was to

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conduct pilot scale coal gasification in underground workings of Wieczorek coal mine, Katowice. The experiment also checked whether it is possible (in pilot scale) to conduct such a process in an operating mine or a closed one. During the experiment the demands and criteria guaranteeing safety for the personnel working underground, mining operations and natural environment had to be met.

Basing on experience gathered during preparations to the experiment and its termination, in the article, initially, we tried to assess possibility to apply underground coal gasification (UCG) as an industrial scale technology to exploit hard coal deposits. We present conditions which have to be met to make its application safe, technically feasible and cost-effective.

UNDERGROUND GASIFICATION – ONE OF MINING TECHNOLOGIES

A mining technology is a method of producing fossil fuels dedicated to produce energy or satisfy other human needs (Fig. 1).

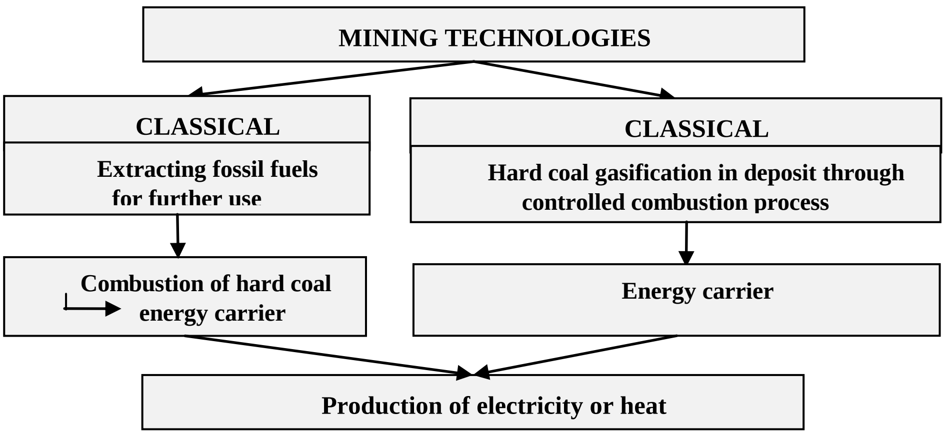

Fig. 1. Types and aim of applying mining technologies
Source: own elaboration

Underground coal gasification – an unconventional mining technology – is a technological process in which coal deposited in a selected fragment of a seam is transformed into gas. Through a previously drilled well the combustion initiating agent is injected. Then, with the same well, a so-called gasification agent (reagent) – oxygen, air, steam or a mixture of them, is injected. Through a production well the combustible gas is received and transported to the surface along a pipeline. Gasification, initiated with ignition, is sustained by combustion of a part of deposit (20–30%) where the process actually occurs. The selected fragment of the deposit and the wells injecting the gasification agent and wells receiving the produced gas form a so-called underground gasification reactor (georeactor).

The produced gas can be used either as fuel to produce heat or electricity, or as so-called syngas, which is a mixture of combustible gases such as carbon monoxide, hydrogen and methane; applied as a component in many chemical syntheses – e.g. to produce methanol, ethanol and synthetic petrol.

To produce gas of given parameters, the gasification process can be controlled through changes in such factors as (Żogała et al., 2013):

- chemical composition of a gasification agent and the way it is injected into the reactor (concentration of nitrogen in a gasification medium ought to be limited – its presence in a gasification medium is unfavourable, as it inhibits contact between carbon particles and oxygen, hence the reaction is less intensive),
- temperature of the process– the higher, the more carbon monoxide and hydrogen in gas,
- pressure of the process – the higher, the more methane gas.

Nowadays, after years of tests and experiments, depending on the intended application, there are a lot of technologies of coal gasification, with different construction solutions in georeactors, methods of injecting gasification agents, receiving and processing the produced gas (Dubiński & Koteras, 2014). All of them share one quality – coal is not mined and transported to the surface as a mineral resource. Instead, underground, an energy carrier is produced from coal which then is applied e.g. to produce electricity or heat. It is an essential difference in comparison with hitherto applied classical mining technologies, in which minerals are extracted from the deposit, leaving behind voids which either cave in or are backfilled.

Before Geological and Mining Law was amended in 2011, it was problematic to determine the legal base for conducting the experiment, as currently applying underground coal gasification as a deposit exploitation technology is not legally regulated, starting from the most important document concerning mining operations i.e. Geological and Mining Law (at present, its amended Article 2. provides such a possibility, but only for academic, research, experimental and training purposes), (Dz. U. Nr 163, poz. 981).

In classical underground mining, including preparatory, basic and auxiliary processes, the life cycle of a mine working follows four basic stages (Turek, 2010):

- opening and development works,
- reinforcing works – equipping mine workings with necessary machinery and devices,
- mining operations,
- liquidation works and securing selected mining voids.

A UCG process, especially the one realised with a shaft method, aimed at obtaining energy from gasifying coal directly in the deposit, applies mining techniques in underground workings. Basing on such a conclusion, similar stages can be distinguished for the experiment conducted in Wieczorek coal mine,:

- mining works associated with accessing the part of seam selected for gasification,
- works associated with building necessary technical infrastructure – pipelines, gas separators, measuring instruments,
- exploiting part of a seam through gasification,
- works associated with closing a georeactor – extinguishing, cooling and backfilling the void.

Like in systems of classical mining, there is a "mining" void in the gasified coal, a burnt-out cavern in a georeactor (Fig. 2), which is partially filled with by- products of gasification like slag and ash. The probable shape and volume of the georeactor were also a subject of research after terminating the gasification process, extinguishing and cooling a georeactor.

A UCG exploitation process causes also a reserve decrease. There is still a problem how to determine it to assess accurately to what extent the deposit was exploited and reserve decreases, caused both by exploitation, and other actions.

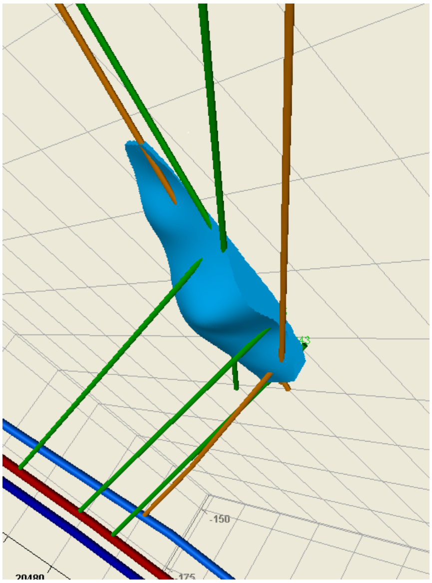

Fig. 2. Probable shape of a cavern resulting from underground coal gasification in part of seam 501 of Wieczorek coal mine, with marked technological boreholes and monitoring boreholes
Source: own elaboration

UCG – RESEARCH CONDUCTED AT THE CENTRAL MINING INSTITUTE. CONDUCT AND RESULTS OF WIECZOREK COAL MINE EXPERIMENT

Employees of the Central Mining Institute in Katowice are also involved in the UCG process research. In 1950s and 1960s there were conducted experiments in surface reactors simulating a UCG process in a scale of few hundred kilograms of coal in various configurations as well as in natural conditions in a seam of thermal coal in Mars decline, Sosnowiec. The experiments resulted in rich material on technological indicators and kinetics of coal gasification conducted with air, oxygen and steam.

In September 2007, GIG started (in cooperation with 10 other partners) a 3-year UCG research project in Barbara experimental mine, Mikołów, aimed at producing hydrogen – HUGE (Hydrogen Oriented Underground Coal Gasification for Europe). Within the framework of the project, a heat-resistant surface reactor was built. An approximately one-ton solid block of coal was placed inside. The pipes supplying oxygen, steam or nitrogen, if it is necessary to extinguish the georeactor; were installed at its front, while the pipe at the back of the reactor received and transported the produced gas.

In 2010, the experience gained in the surface experiment enabled formulating conditions of safe underground gasification. The aim of the project was to select parameters and the way the process, aimed at maximum production of hydrogen in the gas, ought to be conducted. Coal gasification was conducted with oxygen. During the experiment 22 Mg of coal was gasified and 71,764 m^3 of gas, of average calorific value of 3.8 MJ/m^3, was produced. The second underground test was conducted as continuation of HUGE project (HUGE2 project) in 2013, also in Barbara experimental mine. It was aimed at verifying in an experiment if it is possible to produce hydrogen in a UCG process, in seams where it is impossible to apply classical mining methods, especially in deep mines which were being closed. During the experiment a total of 5.4 Mg of coal was gasified producing 11,043 m^3 of gas of average calorific value of 8.91 MJ/m^3.

The pilot scale test conducted in a part of seam 501 of operating KHW S.A.'s Wieczorek coal mine (Fig. 3) was somehow crowning the previous research and experiments. The UCG process lasted from 30 June (ignition) to 25 August 2014 (the last 'portion' of process gas). During the experiment, approximately 245 Mg of coal was gasified (gasification rate was approximately 200 kg/hour), producing over 1.030 million m^3 of gas (approximately 680–850 m^3/hour), of calorific value between 3.0 and 4.5 MJ/m^3 and temperature of between 470 and 520 ºC at the production well. In tests of gasification process course and influence of various factors on its parameters, the following agents were used:

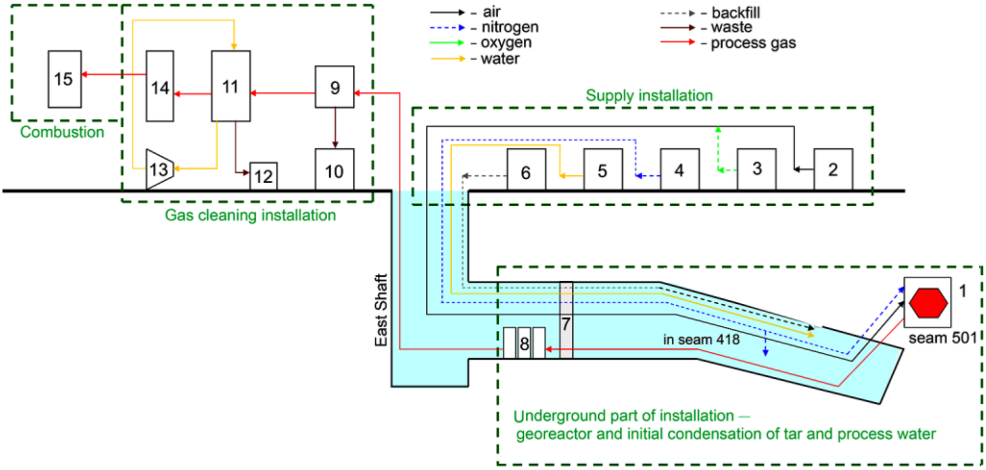

Fig. 3. Schematics of UCG installation in part of seam 501, Wieczorek coal mine: 1 – georeactor, 2 – air compressor, 3 – oxygen tank and vaporiser, 4 – nitrogen tank and vaporiser, 5 – water pumps, 6 – backfill system, 7 – explosion-proof stopping with sand sealing, 8 – system of three tar separators, 9 – cyclone, 10 – solids tank, 11 – scrubber, 12 – sediment tank, 13 – water supply pump, 14 – cooler,15 – surplus-gas burner
Source: own elaboration based on (Czaplicka-Kolarz et al., 2013)

- mixture of oxygen and air of different composition,
- air of various flow rate between 230 and 350 m^3/hour,
- air with addition of water between 25 and 75 l/hour,
- air with addition of carbon dioxide approximately 60–75 m^3/hour,
- air with addition of nitrogen approximately 30–150 m^3/hour.

On 19 August, gradual extinguishing of the georeactor started through supplying nitrogen into the georeactor. Initially it was 30 m^3/hour. In the following days the amount was gradually increased to 150 m^3/hour. During the extinguishing and cooling phase, until 20 November, 100 kg/hour (approximately 80 m^3/hour) of nitrogen was supplied into the georeactor. Then approximately 600–650 m^3/hour of nitrogen, cooled to the temperature of 2–3°C, was supplied. The actions stopped on 31 January 2015 when the temperature in the georeactor, determined basing on chromatographic analyses, dropped below 50°C, reaching 49.6°C, and values of fire indicators, determined basing on concentrations of ethylene, propylene, acetylene, carbon monoxide and hydrogen, were lower than the required threshold values. It allowed us, after opening and airing the area of georeactor, to examine rocks surrounding the georeactor and the georeactor itself. Afterwards, in May, the georeactor was backfilled, and its area finally sealed off.

Results of research and tests, obtained during the experimental underground coal gasification process, conducted in workings of an operating mine, were the foundation for further works aimed at solving technical problems associated with applying the technology. Applying them within the framework of the same task with the funds of National Centre for Research and Development, "Initial feasibility study for UCG installation" and "Technological project", being an introduction to building a Polish shaft UCG demo installation, were formulated.

ASSESSMENT OF POSSIBLE RANGE OF APPLICATIONS CONSIDERING AMOUNT OF RESOURCES, ENVIRONMENTAL CONDITIONS AND COST-EFFECTIVENESS

Applying the UCG process as an industrial scale technology of exploiting hard coal deposits requires meeting a number of conditions, which nowadays are often being at the stage of analyses, research and tests. The most important of them are presented in Figure 4.

Geological conditions of a deposit can seriously limit (and even bar) possibility of safe application of underground gasification. The basic factors are (Nieć et al., 2013; Żogała et al., 2013).

1. Deposit (seam coal) parameters, e.g. thickness and dip. At present, thickness is the only criterion, sufficiently supported with practice. The process is effective, assessing calorific value of the produced process gas, when coal gasification is conducted in seams of thickness of over 1.5–2.0 m. At lower thickness, effectiveness of the process dramatically decreases, which is caused by heat loss in the roof and the floor of the gasified seam. The UCG process will be more effective in a seam of greater dip – the gasification zone migrates upwards, while ash and slag fall to the bottom of georeactor. Then the reactions occurring in the reactor are not inhibited, and gasification medium has direct contact with coal.

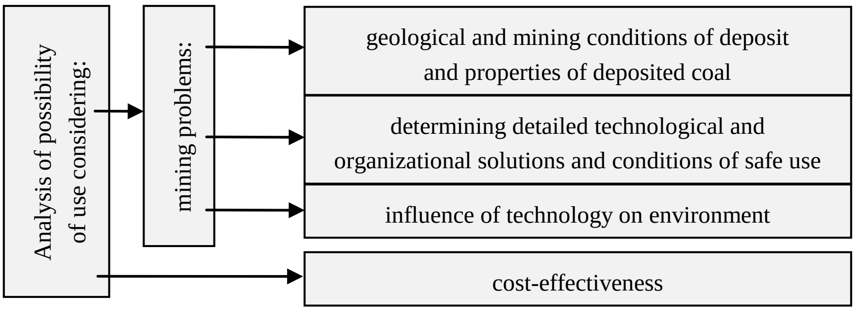

Fig. 4. Conditions concerning possible use of UCG process
Source: own elaboration.

2. Type of coal – effectiveness of gasification of given types of coal is diversified. It is possible for thermal coal type 31 and 32 (alternatively 33) – as they demonstrate

no sinterability, and fusion temperature of their ash in oxidising atmosphere ranges between 800 and 1200°C.

3. Hydrogeological conditions of the deposit and its surrounding – coal moisture content in a seam and the volume of natural inflow of water. During a gasification process, a limited amount of water favours reaching a high temperature in the georeactor, which facilitates reactions producing combustible components. When there is more water, it turns into steam which absorbs a lot of heat. As a result, temperature in the georeactor lowers and its efficiency drops. It is assumed that coal moisture content ought not to exceed 15–20%, and the georeactor ought to be located at least 100 m away from water-saturated formations in the roof strata. The experiment in Wieczorek coal mine confirmed it. Air with water, among others, was supplied as the gasification medium (25 to 75 l/hour). Initially we observed an increase in calorific value of the produced gas from 3.1 to 4.2 MJ/m^3, and an increase in temperature at the production well of the georeactor from approximately 465°C to approximately 506 °C. As the volume of supplied water increased, the values started to decrease and at 2.8 MJ/m^3 water supply was stopped.
4. Type, structure and thickness of the overburden. An important quality of a seam where a georeactor is to be located, is its separation from the surface, underground water reservoirs and aquifers. Gasification products are toxic liquid and gaseous products, which, once emitted, can pose a serious hazard to the environment. There are various opinions concerning required thickness of impermeable rocks, insulating a georeactor, yet it is assumed that it ought to be at least 100 m.
5. Type and properties of rocks a deposit consists of and changes they undergo under influence of mining operations – in case of the disturbed rockmass, e.g. resulting from earlier mining operations, there is a risk of far gas migration. It is advisable to locate a georeactor in the undisturbed rockmass.
6. Tectonics and internal structure of a deposit (its continuity, waste rock bands etc.) – tectonic disturbances and faults in continuity of a seam, result in permeability, which means a potential way of migration into the environment for gas products of the reaction. Faults disturb continuity of the deposit and may either inhibit conducting a gasification process or become routes of far migration for the produced gases. It is assumed that they ought not to occur within the radius of between 50 m and even 1 km.

The experiment conducted in Wieczorek coal mine was realised in a part of seam 501 deposited at approximately 450 m. Seam thickness was approximately 5 m, and its dip approximately 5°. In the area of the georeactor no tectonic disturbances were observed, and there were no previous mining operations in the seams deposited over and under the part of seam 501. Hence the basic conditions discussed above were met.

As it can be observed quite a lot of geological conditions of a deposit selected for exploitation with the UCG process are associated with the risk of negative consequences for the environment, both underground and on the surface (Fig. 5).

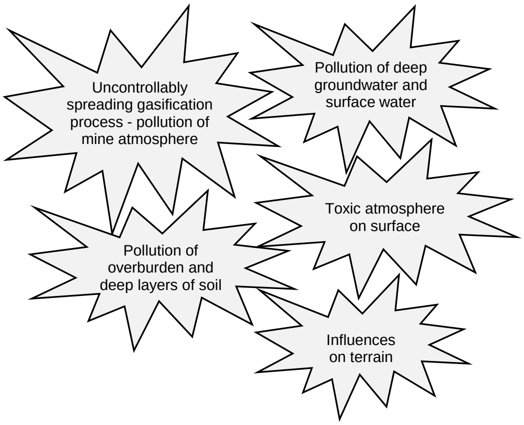

Fig. 5. Possible negative influence of UCG process on environment
Source: own elaboration

Underground coal gasification, as all types of mining activities, may lead to certain environmental losses. These may be mainly deep groundwater and surface water pollution, caused by migration of hot gas products or by groundwater leaching pollutants from post-gasification ash, as well as products of pyrolysis occurring in the georeactor and its surrounding, which may also lead to polluting the overburden and deeper layers of soil.

Apart from that, an industrial scale UCG process will have similar results on the surface as classical underground mining. However, due to the fact that the cavern is partially filled with solid gasification by-products (ash, slag), the influence on the surface is smaller than in mining operations with roof caving. To assess the range and consequences of the influence, it is necessary to take into consideration the depth where the georeactor is to be located, geometrical parameters of the seam section selected for gasification and predicted width and height of the resulting cavern, provided that the assumed strength parameters of the rock mass consider influence of high temperature and occurring thermal stresses (Palarski et al., 2013).

Another issue, referring to the possible range of applications of the UCG process as an industrial scale technology to apply in coal deposits, is cost-effectiveness. It may be determined e.g. as a ratio of incurred costs and generated income, i.e. as process effectiveness. Productivity, determined with various indices, is a key indicator of effectiveness. It may be e.g. the ratio of production volume in a given period and incurred costs or used-up tangible and intangible assets. Obviously, to compare effectiveness of two technologies, they have to be expressed in the same units. In classical mining operations in coal deposits the effect is either a number of tons [Mg] or calorific value [GJ] of produced coal. In a coal gasification process the effect may be expressed as either the volume [m^3] or calorific value [GJ] of the produced process gas. The unit common for products of both of the technologies is calorific value. Knowing the costs incurred to produce the coal and the gas, it is possible to compare productivity of the technologies expressed in PLN/GJ (Dubiński & Turek, 2015).

Comparing cost-effectiveness of a classical mining system and a UCG process shows that the latter one has a huge advantage over the first one in terms of necessary costs (investment and operational costs) associated with:

- tangible and intangible production assets – lower costs of technical equipment, employed personnel (i.e. lower costs of work-related safety), opening a deposit and preparing a seam,
- processing products – no need to build a processing plant,
- negative effects of production– much smaller scale of mining damage, no need to dump waste.

However, the advantage is significantly "offset" with energy parameters of the gas produced in the UCG process – much less coal, produced with classical methods, is required to produce the same amount of energy. Approximately 600–850 m^3/hour of gas was produced during the experiment in Wieczorek coal mine, which would enable production of approximately 1.8–2.4 GJ of energy with gas of calorific value of 3.0 MJ/m^3, and approximately 2.7–3.6 GJ of energy with gas of calorific value of 4.5 MJ/m^3. These are values approximately 1000-fold lower than the energy which can be generated with coal produced in one hour in an average longwall. It is also worth adding that calorific value of gas produced in the UCG process is more or less 10-times lower than of commonly used high-methane natural gas. Yet, what is important, theoretical calculations show that only approximately 245 tons of coal was gasified during the experiment, producing over 1 million m^3 of process gas – hence it can be produced in large quantities. It is extremely important to use every possibility to produce large quantities of gas of possibly highest calorific value in the georeactor, which would increase productivity. Large quantities of gas can be obtained through multiplying georeactors where it is produced.

Analyses of cost-effectiveness ought to be performed prior to every application and taking a decision to ignite a georeactor (Magda et al., 2012). Although the surface elements of gasification installation are virtually identical (or very similar), the underground part may be totally different. It depends on the method of accessing the deposit and the type of gasification, volume and abundance of the part of deposit (seam), depth where georeactor is located, composition of the gasification medium, complexity of the technical infrastructure. It would be very useful to develop a model, procedures of conduct or a set of assumptions and data, necessary to prepare such an analysis. It is assumed that it would be one of aims of research conducted into a demo installation.

PREPARATIONS NECESSARY TO CONDUCT UCG PROCESS AND THEIR EFFECTS IN WIECZOREK COAL MINE EXPERIMENT

The above presented issues of analyzes, concerning conditions for safe application of an underground coal gasification process, were verified in practice during the experiment in Wieczorek coal mine. Assumptions made for the experiment and its safe conduct together with their effects are in Table 1.

Table 1. Assumptions made for the experiment and its effects

Assumptions and preparations prior to experiment	Effects
Georeactor located in a seam of thermal coal type 32.1, thickness of approximately 5 m, dip of approximately 5°, depth of 450 m	Even when the process was disturbed, there was no threat to the process itself and mining operations
No tectonic disturbances in the area of the georeactor	Controllable process –changes in parameters of gasification medium predictably influenced parameters of the produced gas
No previous mining activities in the area of the georeactor	Formulated organizational and technological procedures enabled quick and efficient reactions to process disturbances
Possibility to seal off the area of the georeactor from other workings of an operating coal mine	
Formulating detailed organizational procedures for safe conduct and monitoring gasification process	
Formulating detailed technological procedures for conduct gasification process	

Tests conducted during the experiment showed that it is technically possible to steer the process parameters, especially through using the right gasification agent. We can clearly conclude that it was also possible to influence changes in temperature, volume and calorific value of the produced gas. The process was controllable, and changes in parameters of gasification medium injected into the georeactor influenced the parameters of the produced gas in a predictable fashion. The formulated assumptions, which were verified a few times, as well as the instruction for safe conduct of experimental underground coal gasification, fully confirmed accuracy of applied solutions. During the experiment, even when it was disturbed, there was never a situation which could pose a threat to the gasification process itself or mining operations in the coal mine. The procedures we followed enabled efficient reaction to arising problems, and the process itself was controllable.

Issues concerning organizational procedures require special attention. As it has been already mentioned, currently, application of the UCG process (apart from research purposes) is not legally regulated. Taking into consideration unconditional necessity to provide safety for the personnel and the environment, it is a significant problem. It may be concluded that actions taken to formulate the right procedures, which enabled safe conduct of the experiment in Wieczorek coal mine and its legal sanctioning, were somehow pioneer ones. All the formal and legal actions required a number of consultations and tight cooperation with the State Mining Authority, District Mining Office in Katowice, Regional Directorate for Environmental Protection in Katowice, the Marshal Office of the Voivodeship of Silesia and, last but not least, Katowice City Hall (Turek, 2014).

If the works were to start to fill the gaps, it would be advisable to apply experience gathered during the ‘pioneer’ experiment in an operating coal mine. It is well justified, as the process was conducted in a safe, and the formulated procedures of conduct (sometimes following just the ‘gut feeling’) proved their applicability in practice.

As it has been already mentioned, results of tests conducted during the experiment were, among others, the basis to prepare documentation, upon which so-called demo installation (an intermediary between research scale and commercial scale) can be built. It is planned that like in Wieczorek coal mine it would be a shaft underground coal gasification installation. A seam located in the vicinity of a shaft of one of Katowicki Holding Węglowy S.A. coal mines was proposed, and the obtained process gas would be combusted in a 20.5 MW double-fuel boiler.

The purpose of the demo installation is to check technical and technological solutions formulated by research units and business entities. It is also to provide data for full technical and economic analyses of the shaft method process, to base upon them the decision whether to build a commercial installation or not.

As far as industrial use of the produced gas is concerned, it is necessary to pay attention to one more problem – it will be necessary to determine how to use the produced gas as a fuel. Hitherto research and experiences concerning coal gasification, conducted both around the world and in Poland allow us to conclude that the method should not be perceived as an alternative to classical mining technologies, but rather as an auxiliary technology. It can be used in deposits where classical mining methods are either cost-ineffective or technically impossible.

Gas produced in a UCG process is of low calorific value. The experiment carried out in Wieczorek coal mine showed that, for various reasons, there may also occur disturbances in its flow. It means that applying the gas e.g. to heat boilers, a burner of special construction has to be used, enabling combustion of gas of low calorific value and unstable flow parameters (Góral & Rozpondek, 2013). Another concept is to co-combust it with coal or natural gas to produce heat. Research into such a use of the gas is to be conducted in the planned UCG demo installation (Świądrowski, 2015).

SUMMARY

1. Results of the experimental coal gasification process, conducted underground in Wieczorek coal mine, show that it is advisable to continue the research. The most important effect was producing a significant amount of gas out of a relatively small amount of coal. It was possible to steer the gasification process by influencing changes in temperature, calorific value and volume of gas, while changes in parameters of the gasification medium supplied into the georeactor predictably influenced parameters of the produced gas. There were no events which would pose a threat to coal mine operations, personnel's or the environmental safety.
2. Apart from: determining boundary geological and mining conditions of deposits selected for gasification, perfecting detailed technological and organizational solutions, and conditions of applying the technology which concern safety for the personnel and the environment; a sine qua non condition of using a UCG process, in the future, as an industrial scale technology, is its cost-effectiveness. Much lower investment and operational costs, in case of underground coal gasification, when compared with today's commonly applied classical mining technologies, are a significant indication to consider what conditions have to be met to reach a high level of productivity of the UCG process. Determining the way how the process gas is to be used, especially as an energy carrier, will also affect the considerations.
3. Underground coal gasification process technology should not be treated as an alternative to today's classical mining methods.
4. It is necessary to continue research and works employing results of hitherto theoretical studies and practical experiments. It is assumed that building and testing a so-called underground coal gasification demo installation, an intermediary between research scale and industrial scale, could help realise it.

BIBLIOGRAPHY

CZAPLICKA-KOLARZ K., GALINIAK G., KLICH J., STRUGAŁA A., 2013; *Badania procesu podziemnego zgazowania węgla w ramach Projektu NCBiR i ocena bazy surowcowej dla tego procesu*. Przegląd Górniczy 02/2013, s. 1–7.

DUBIŃSKI J., KOTERAS A., 2014; *Obecny stan i kierunki rozwoju technologii podziemnego zgazowania węgla w świecie*. Przegląd Górniczy 11/2014, s. 5–12.

DUBIŃSKI J., TUREK M., 2015; *Podstawowe aspekty produktywności procesu podziemnego zgazowania węgla*. Arc. Min. Sci., Vol. 60 (2015), No 2, s. 443–453.

GÓRAL J., ROZPONDEK M., 2013; *Palnik do spalania gazów z podziemnego zgazowania węgla – metodyka i algorytm projektowania*. Przegląd Górniczy 06/2013, s. 83–88.

MAGDA R., FRANIK T., WOŹNY T., ZAŁUCKI J. 2012; *Próba oszacowania kosztów procesu podziemnego zgazowania węgla kamiennego*. Polityka Energetyczna, Tom 15, zeszyt 2, s. 71–84.

NIEĆ M., CHEĆKO J., GÓRECKI J., SERMET E., 2013; *Uwarunkowania geologiczno-złożowe stosowania podziemnego zgazowania węgla w polskich złożach węgla kamiennego*. Przegląd Górniczy 02/2013, s. 26–29.

PALARSKI J., JENDRUŚ R., STROZIK G., 2013; *Wpływ deformacji górotworu na warunki ochrony powierzchni oraz zasoby użytkowe wód podziemnych przy podziemnym zgazowaniu węgla*. Przegląd Górniczy 08/2013, s. 149–155.

ŚWIĄDROWSKI J., 2015; *Raport końcowy z badań i prac technicznych części tematu badawczego 7.2 „Projekt technologiczny instalacji demonstracyjnej zgazowania podziemnego węgla" – Załącznik nr 1 „Wstępne studium wykonalności dla instalacji demonstracyjnej podziemnego zgazowania węgla"*. Opracowanie wykonane w ramach Strategicznego Programu Badań i Prac Naukowych „Zaawansowane technologie pozyskiwania energii". GIG, Katowice, praca niepublikowana.

TUREK M., 2010; *Podstawy podziemnej eksploatacji pokładów węgla kamiennego*. Wydawnictwo GIG, Katowice.

TUREK M., 2014; *Wybrane aspekty dokumentacyjnego przygotowania prowadzenia eksperymentalnej eksploatacji metodą podziemnego zgazowania węgla*. Przegląd Górniczy 12/2014, s. 5–10.

Ustawa z dnia 9 czerwca 2011 roku Prawo geologiczne i górnicze (Dz. U. Nr 163, poz. 981).

ŻOGAŁA A., KABIESZ J., IWASZENKO S., 2013; *Czynniki wpływające na skład chemiczny i wartość opałową gazu uzyskiwanego w procesie podziemnego zgazowania węgla*. Przegląd Górniczy 06/2013, s. 89–95.

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