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# The analysis of the underground coal gasification in experimental equipment

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ABSTRACT

This paper describes an experiment of underground coal gasification in experimental equipment. The experiment was done within the range of the project APVV-0582-06, in May 2010. During the period of 63 h there was gasified amount of 214 kg of coal in experimental gasifier with average rate of 3.4 kg/h. The air, was the primary gasification agent in the experiment and its total volume was 661 $Nm^3$. Oxygen was used only in a short period of the experiment. The produced gas reached an average calorific value of 3.27 $MJ/Nm^3$. The calorific value was slightly higher (4.13 $MJ/Nm^3$) when was using oxygen as gasification agent. This article talks not only about the analysis of the achieved results from UCG but also used experimental gasifier, input supply system of a gasification agent, and monitoring system.



## 1. Introduction

Underground coal gasification converts coal to gas while still in the coal seam (in-situ). Gas is produced and extracted through wells drilled into the unmined coal-seam. Injection wells are used for injection of the gasification agents (air, oxygen, or steam) to ignite and as a fuel for the underground combustion process. Another production wells are used to bring the syngas to surface (see Fig. 1) [1–3]. The high pressure combustion is conducted at temperature of 700–900 °C, but it may reach up to 1500 °C [1,2]. The process decomposes coal and generates $CO_2$, $H_2$, CO and small quantities of $CH_4$ and $H_2$ S [2]. As the coal face burns and the immediate area is depleted, the gasification agents injected are controlled by the operator [1].

The effectiveness of coal transformation on syngas depends on more parameters. Of course, it will depend on structure of process control. Economy of UCG depends on controlling too. Automated process control of UCG has advantages such as the ability to achieve greater control accuracy, the ability to switch between manual and automatic process control and especially the possibility of implementing relatively complex control algorithms as well as nonlinear functional dependencies and the possibility of easier communication with other management levels. The principle of automatic process control of UCG is dependent on the nature of information obtained from the system, the possibility of identification of controlled process and the goal that is pursued by the automatic control. UCG process is difficult to identify and manage considering that the process takes place in a several stages and during operation there are changes of underground coal gasifier (e.g. cavity enlargement, shift of combustion front, gas leaks, cracks, ground water, etc.). We say that the measurement of the process variables, process identification and finally automated process control takes place under conditions of uncertainty. In automated control of UCG can be used algorithms for gasification agents flow rate stabilization, stabilization of oxygen concentration in syngas (control of underpressure) and optimal control that uses the methods of continuous extreme finding e.g. maximization of syngas calorific value or selected component concentration in syngas [4]. Water inflow can be controlled by maintaining an appropriate pressure level in the georeactor in relation to hydrostatic pressure. For the monitoring of the UCG cavity development, a number of geophysical techniques were applied, i.e.: geothermal method, vertical electroresistance sounding, georadar method, gasometry, radon radiometry. The database of measured environmental risks helps in decision and control processes of UCG. The control system can automatically stop any gas leaks or reduce the performance of the gasifier if any environmental pollution occurs. The use of automated signaling and warning devices is granted. Use of

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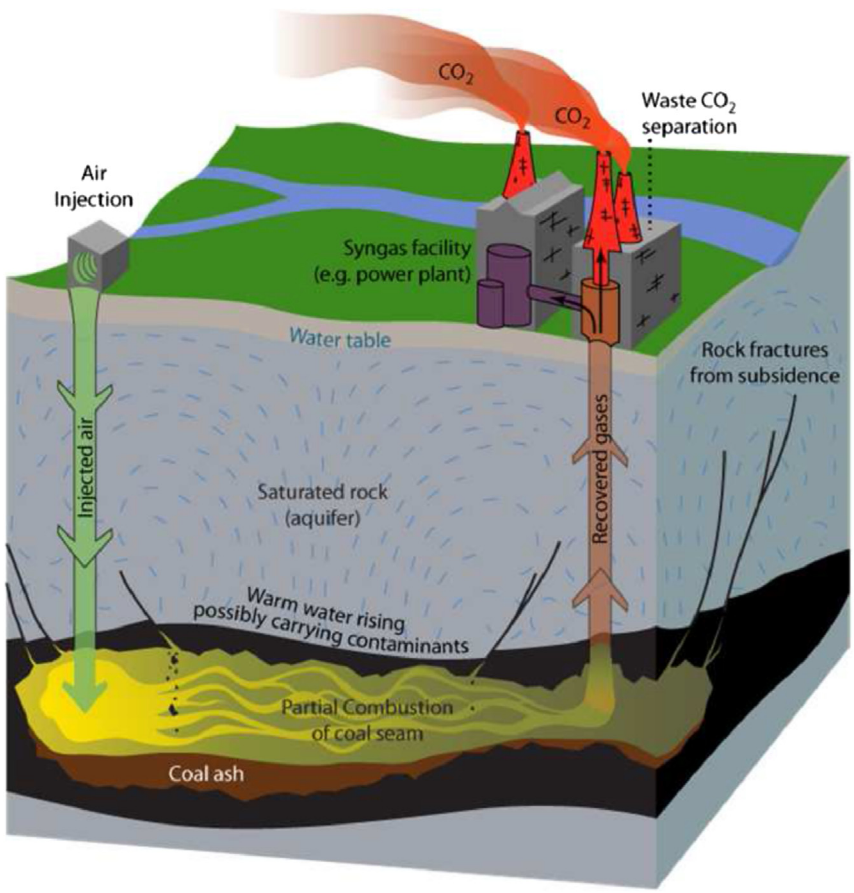


**Fig. 1.** Principle of the UCG process.

machine ventilation devices can rapidly dilute gases emitted in the UCG zone. Leaked gas should be completely eliminated or diluted with air below the explosive range as quickly as possible. For monitoring pollution in vulnerable areas as appropriate path seems to be the use of correlation spectroscopy of gases.

In industry gasification is needed to include detection of $CO_2$, CO and $CH_4$ migration from underground and to detect leakage to surface. Computational fluid dynamics (CFD) simulations are playing an important role in the designing and commissioning of gasifiers. CFD simulations are becoming popular to provide an insight into thermal and chemical conversion of the coal as it travels through the gasifier and effect of hydrodynamics on these processes. The syngas composition is possible to predict by utilization of thermodynamic model that was presented in Ref. [5].

As coal differs considerably in its resistance to flow, depending on its age, composition and geological history, the natural permeability of the coal to transport the gas is generally not satisfactory. Hydro-fracturing, an electric-linkage, and a reverse combustion may be used with varying degrees for high pressure break-up of the coal [2,3,6]. There are two different underground coal gasification methods commercially available shaft and shaftless UCG methods [7]. One of the methods uses vertical wells and a method of reverse combustion to open up the internal pathways in the coal. The process was used in the Soviet Union and later it was modified by Ergo Exergy. It was tested in Chinchilla site in 1998–2003. Another method that was developed by Lawrence Livermore National Laboratory in the USA creates dedicated inseam boreholes, using drilling and completion technology adapted from oil and gas production. It has a movable injection point known as CRIP (controlled retraction injection point) and generally uses oxygen or enriched air for gasification [3,6].

For verification of coal gasification technology in underground is necessary the whole system of gasification test in laboratory conditions [8–11]. For this purpose the experimental equipment for simulation of real underground coal seam was constructed. The similary equipment was published in Ref. [12]. In this work the research was focused on finding the amount and composition of gas produced from coal at different pressure conditions in the gasification ex-situ reactor. Pressure vessel was used as a gasification container - ex-situ reactor. The container was laden with subbituminous coal blocks that were ignited by an electric mechanism. Reverse combustion was supported with a gasification agents mixture ($O_2/N_2$), which was injected under a pressure of 200 kPa. Gasification experiments used K-type thermocouples for monitoring internal temperatures. Gasification process was controlled using the following parameters:

- flow of the gasification agents mixture,
- the composition of the gasification agents mixture,
- the pressure inside the ex-situ reactor.

The composition of the produced gas measured with a chromatograph and gas flow with a rotameter. In reverse gasification the combustion front moves in the contraflow of the gasification agent. The fuel for the combustion is gas, which is gradually released from the coal into the ex-situ reactor's area, while the porosity of coal is changing. A key knowledge for the reverse combustion is that the combustion reaction is limited to very thin