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Underground coal gasification – Part I: Field demonstrations and process performance

Greg Perkins

Martin Parry Technology, Brisbane, 4001 Queensland, Australia

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ABSTRACT

Underground coal gasification can convert deep coal resources into synthesis gas for use in the production of electricity, fuels and chemicals. This paper provides a review of the various methods of undertaking underground coal gasification and observations from demonstrations of the process in the field. A general representation of the underground process is presented, along with an identification of the various zones and associated governing phenomena. The main factors affecting the performance of underground coal gasification, such as coal rank, depth and thickness and oxidant composition and injection rate are examined in detail. A brief assessment of the economic and environmental considerations relevant to underground coal gasification projects is presented. Finally, guidelines for site and oxidant selection are provided based on the learnings from prior demonstration projects.

Contents

E-mail address: greg.perkins@martinparry.com.au

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1. Introduction

Underground coal gasification (UCG) is the process of converting hydrocarbon materials into synthesis gas in-situ. Underground coal gasification is sometimes referred to as in-situ coal gasification (ISCG). The process has been developed over more than a century, though only a few projects currently operate on a continuous basis. Various articles and studies indicate that UCG is technically feasible and economically attractive as a method to utilise the energy of deep coal resources (e.g. [1–6]). Recent reviews on the fundamentals, applications and modelling have been reported by Bhutto et al. [7], Shafirovich et al. [8] and Khan et al. [9], respectively. Fig. 1 shows the worldwide locations of UCG commercial and demonstration projects as well as areas that are thought to be prospective for carbon sequestration.

In its simplest form UCG involves: i) drilling an injection well into the coal seam and linking it with a production well, ii) igniting the coal seam and iii) injecting an oxidant (e.g. air, oxygen/steam etc.) and iv) recovering syngas from the production well. In practice, the process involves performing coal gasification within an open system located hundreds of metres below ground and controlling it though a limited number of injection and production wells to convert and extract the hydrocarbons. Like surface coal gasification, underground coal gasification, requires high temperatures, management of dangerous fluids such as pure oxygen and handling of hot raw products of syngas, tars and produced water. In addition, the process is undertaken in a geo-reactor, wherein the natural surrounding strata are used to contain the process and provide adequate barriers to ensure isolation, in terms of chemical, thermal and mechanical impacts.

The treated product syngas from UCG can then be used in a variety of processes such as:

- combustion of syngas in a combined cycle gas turbine to produce electricity (e.g. [10,11])
- conversion of syngas into synthetic crude oil to produce naphtha, diesel and kerosene via the Fischer–Tropsch process (e.g. [12])
- conversion of syngas into methanol, which may be further refined into dimethyl ether (a potential transport fuel), olefins and acetic acid
- conversion of syngas into hydrogen to produce ammonia and urea or for use in fuel cells (e.g. [13–15])
- conversion of syngas into synthetic natural gas, via the methanation reaction

Fig. 2 shows a schematic of the important products that can be made with UCG. Carbon dioxide may be separated from the syngas and used for enhanced oil recovery (EOR) or sequestered in geological formations in so-called carbon capture and storage (CCS) projects.

The focus of this paper, which is Part I of a two-part series, is on describing the main methods of undertaking underground coal gasification, summarising the results of field demonstrations, analysing the factors which affect the process performance and reviewing the economic and environmental considerations of developing projects. In Part II of the series, a detailed examination of the fundamental phenomena in various zones of the process is performed, including at the cavity sidewall, in the permeable bed of ash and char, in the void spaces and in the near- and far-fields surrounding the active gasification zones.

2. Underground coal gasification methods

The main methods for underground coal gasification are:

- chamber method
- stream method
- linked vertical wells method
- controlled retracting injecting point method
- steeply dipping beds method

The dependent variables in underground coal gasification are shown in Table 1. Like mining and oil and gas extraction, site selection determines most of the important independent variables which determine the technical and economic performance.

A schematic of several of the methods is shown in Fig. 3. Several other methods, such as the blind-borehole method, a small-bore method and the long tunnel system of gasifying manually-mined channels have also been trialled [17–20]. Table 2 provides a summary of significant underground coal gasification projects worldwide since the 1930s.

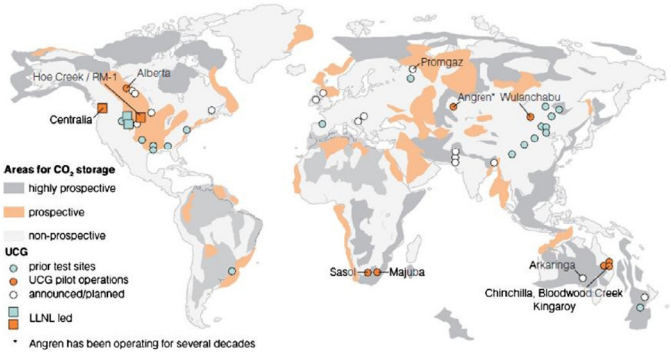

Fig. 1. Summary of the underground coal gasification sites, including prior test sites, pilot operations and areas thought to be prospective for CO_2 sequestration (from Couch [16]).