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CLEAN ENERGY FROM UNDERGROUND COAL GASIFICATION

Promoting commercially viable UCG in China

PROJECT SUMMARY 290

CLEANER FOSSIL FUELS PROGRAMME

OBJECTIVES

- To compare state-of-the-art underground coal gasification (UCG) developments in China with the UK.
- To examine UCG site selection constraints and environmental issues.
- To appraise options for gas cleaning, downstream processing and utilisation.
- To examine use of the product gas in gas turbine power generation systems.

SUMMARY

UCG is a technology which can exploit the energy in coal whilst avoiding the environmental problems at the surface that are associated with coal mining, disposal of mining waste and coal combustion. In the process of UCG, water/steam and air or oxygen are injected into a coal seam. The injected gases react with coal to form a combustible gas, which is brought to the surface and cleaned prior to utilisation.

In the UK, UCG technology could enable deep coal resources that are uneconomic to mine conventionally to be exploited. In China, the technology is aimed at recovering energy from residual coal pillars in mined areas and gasification of coal seams at shallow depths. Despite the differences in approach between the UK and China, there are many areas of common interest and opportunities for technical exchange which would benefit both countries.

There are two distinct UCG approaches being developed in China, both of which differ from the remote access, surface to in-seam directional drilling method being pursued in the UK. These are the undersurface gasification (UG) method and the long tunnel, large section, two-stage method.

Figure 1. Undersurface gasification (UG) test site in China

Performance, safety, environment, process control, gas cleaning, marketing and finance issues will require further attention in China before commercialisation can become a reality. However, continuing laboratory and field research is aimed at achieving this goal. The deep UCG method envisaged for application in the UK would avoid many of the problems which limit the technologies used in China.

BACKGROUND

Coal is the most important energy source in China, but the Government is concerned about the pollution caused by burning coal and the environmental damage caused when mining it. UCG is seen as a "clean coal technology" which can reduce these problems.

Construction of in-seam gasifiers in China involves the use of underground mining methods in contrast with the approach envisaged for the UK, which will be fully remote, relying on guided drilling to construct the injection boreholes, production wells and the in-seam gasifier.

Recent work in the UK and in Europe has focused on the development of UCG using advanced guided drilling techniques, to remotely access from the surface extensive deep coal resources that are uneconomic to mine conventionally. Field trials at Thulin in Belgium (1979-1987) and subsequently at El Tremadal in Spain (1993-1998) demonstrated the technical feasibility of UCG at depth. These trials involved the drilling and linking of two wells, an injection well to feed the reactant gases to the gasifier and a production well to carry the product gases to the surface for processing and use.

Optimisation of reaction conditions in deep, drilled systems might produce gas with a heat value of 16MJ/m^3. Air-blown underground gasifiers in China produce gas with a heat value in the range 4 to 6MJ/m^3 and a two-stage system can produce gas of 12 to 14MJ/m^3 containing up to 50% hydrogen. Although elevated depth and pressure are not pre-requisites for a high quality gas, the benefit is in higher mass flows and hence greater efficiency of energy transmission to the surface.

In the UK, the UCG product gas will be principally used for power generation. In China more diverse gas uses are being considered including domestic cooking and heating, power generation and chemical synthesis to reduce reliance on imported petroleum products.

Many UCG trials have been carried out in China, funded both from government and private sources. Technical uncertainties remain, but with further investment in R&D, full-scale commercial demonstration may soon be practicable. If successful, UCG is likely to be widely replicated throughout China.

BENEFITS OF UCG TECHNOLOGY

Environmental

UCG potentially offers benefits to the environment over conventional coal mining and combustion through:

- reduced mine spoil and ash disposal
- reduction in emissions from coal burning
- reduced greenhouse gas emissions from coal mining
- less materials transported
- smaller land area occupied
- reduced process water requirements
- minimal mine-water recovery and surface hazard liabilities on mine abandonment.

Taking into account possible reductions in methane emissions if UCG replaces longwall coal extraction, CO_2 emissions from pulverised coal-fired power plant and UCG-fired steam plant will be generally similar. Use of combined cycle plant will reduce the emissions significantly.

Researchers in China have suggested that CO_2 in the UCG product gas can be absorbed using waste alkaline solution and then fixed into a high calcium coal ash for filling into the UCG cavity. Thus, the greenhouse emission impact would be reduced and the heating value of the product gas per unit volume increased.

The detrimental sub-surface environmental impacts of the UCG process are considered to be fairly low, as the main product of the process is gas and by-products are either left in the ground, or they can be removed by conventional processes or even re-injected back into the coal seam. Phenol residues can be flushed owing to its relatively high water solubility and the water would then be treated. No serious groundwater pollution problems have been detected in any trials.

Economic

Substitution of UCG for conventional coal mining could offer benefits from:

- lower-cost power generation
- a new energy source for declining mining areas in need of economic stimulation
- a larger exploitable coal resource.

Occupational safety

UCG is inherently safer than coal mining where remote operational methods are employed and could be less hazardous than conventional coal mining in China, where underground control methods are envisaged, provided suitable designs and management systems are employed.

UCG IN CHINA

China carried out its earliest UCG tests in 1958. Progress in the 1960s was limited by the drilling technology and lack of funds. Later, trials were carried out under the auspices of China University of Mining & Technology (CUMT, established 1985) and also under the former Coal Ministry. Since 1984, various national development plans have included UCG science and technology projects. The China Ministry of Science and Technology (MOST), has recently allocated approximately £1.2 million to CUMT and Xinwen Mining Group to undertake laboratory and full-scale trials to improve UCG control technology.

The identified UCG resources in China consist of unworked coal and pillars in working and closed mines of some 30 billion tonnes. If the European deep drilling technology is shown to be feasible, the accessible UCG resource could increase to 300 billion tonnes.

There are two distinct UCG approaches being developed in China:

- undersurface gasification (UG)
- long tunnel, large section, two-stage.

Undersurface gasification (UG) method

UG is an extension of mining, developed by Professor Chai, in which each gasifier district is controlled independently from underground to ensure optimum performance. The original infrastructure of shafts and mine roadways are used to access the gasifier and incorporate gas pipework. Underground access is maintained at all stages of the operation. Large numbers of the producing districts are envisaged forming a "gasification colliery".

Future designs allow for the drilling of injection wells into the gasifier from a rock gallery beneath the coal seam, which will improve gasifier control and safety as shown in Figure 2. Shaft connections between the rock galleries and gasifiers would be sealed prior to operation to further improve safety.

Long tunnel, large section, two-stage UCG method

This method was developed by Professor Yu Li and the Underground Gasification Engineering Research Centre at the China University of Mining and Technology (CUMT), Beijing. Conventional underground mining methods are used to develop the gasifier. The layout is similar to a longwall district but with injection and production boreholes drilled at the gateroad ends (Figure 3). Additional boreholes are drilled to enable the air injection point to be adjusted to control the movement of the gasification face. The system is monitored and operated remotely from the surface.

Long tunnel, large section refers to the structure of the gasifier which is a 3-4m^2 coal mine roadway around 200m in length.

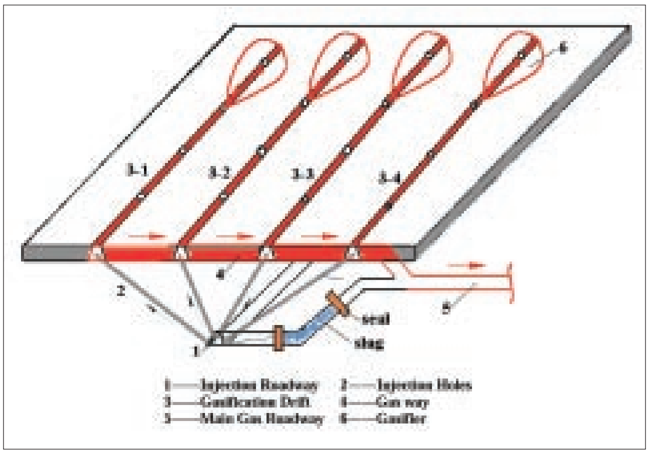

Figure 2. The room-and-pillar UG concept

The two-stage process involves an air-blown first stage to raise the temperature of the reactor, then an injection of steam which decomposes on contact with the heated coal to form hydrogen and carbon monoxide.

Gasification control involves increasing, decreasing, pulsing or reversing air flow, and a stable gas quality can be difficult to maintain. The difficulty is compounded by a lack of suitable monitoring provision in the gasifier. Discontinuous processes, such as two-stage pulsing of air injection are inefficient, as low quality gas (4MJ/m^3) is intermittently produced which either needs enrichment, or is simply vented. A storage tank is needed to ensure a constant supply of the higher quality gas (11MJ/m^3).

UCG theory and scale model testing

The UCG Engineering Research Centre, at CUMT's Beijing campus, has been responsible for much of the theoretical and

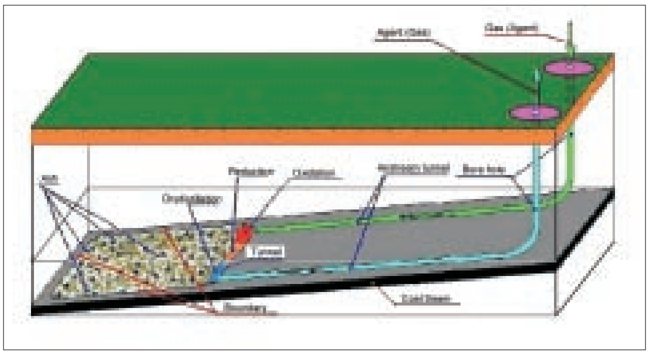

Figure 3. Schematic of the long tunnel, large section UCG arrangement.

modelling work underpinning the advancement of UCG technology in China. CUMT has developed theoretical models for simulating UCG processes and constructed laboratory rigs for physical UCG testing. Studies have been carried out on cavity growth and gasifier control technologies, using both air and oxygen steam injection on bituminous and lignite coals. A new advanced test rig has recently been completed.

Utilisation of the products of UCG

The uses of UCG product gas being studied in China include chemical feedstock, industrial fuel, city gas and power generation. Chemical processes which could use UCG gas, including synthesis of ammonia, methanol, di-methyl ether and petroleum, are also being examined.

OBSERVATIONS AND FINDINGS

Basic studies

A coupled geotechnical thermal model was developed which indicated that the overburden mechanical properties play a dominant role in cavity growth, overburden collapse and subsidence. Surface subsidence will be less with UCG than with conventional coal mining. Initial laboratory tests at the University of Nottingham indicate that mudstones and siltstones can be highly affected and fractured by thermal stress while sandstone will remain largely intact.

Site selection

The principal problems of gasifier control and environmental risk in China are related to uncontrolled water flows into the gasifier and lack of containment. The most critical technical factors relating to site selection are therefore:

- no major aquifer in contact with the target seam
- effective sealing of boreholes and shafts linking the gasifier with the surface
- avoidance of de-stressed mining zones where mining-induced fractures could allow gas leakage to the surface, resulting in pollution.

Gasifier control

Stable gasification has sometimes proved difficult to achieve and UK engineers have suggested various options for varying the point of injection into the gasifier to improve the degree of control.

Uncontrolled water inflow can be a problem, making the hydrogen content of the product gas unpredictable, which could compromise the intended use. A gas turbine will run using air-gas provided the hydrogen content is relatively stable and does not exceed 15%. Combustor redesign will be necessary for the high hydrogen content gas produced when oxygen and steam is injected, or if the two-stage method is employed. A gas turbine designed for a low hydrogen application will not be transferable to a high hydrogen situation.

Oxygen and steam injection could ensure more stable gasification conditions but the financial implications need further examination.

Gas cleaning and transport

UCG fuel gas requires cleaning before use to prevent polluting emissions and damage to plant. Cooling of gases leaving the gasifier, especially where long underground pipelines are involved, will allow condensation of tars, ammonium compounds and alkali salts which could cause blockages. The acidic gases will be highly corrosive and could lead to failure of pipelines, valves and other components. Some underground gas treatment may therefore be necessary.

POTENTIAL FOR FUTURE DEVELOPMENT

There is considerable potential for future development of UCG in China and projects are in preparation to demonstrate various chemical uses as well as the viability of medium-scale power generation using gas turbines. However, further work is still needed to assess the practicality and commercial viability of using oxygen and steam injection to achieve stable gasification conditions. Detailed data on the quality and variability of UCG product gases is also needed to facilitate design of cost-effective gas cleaning systems and wastewater treatment processes.

CONCLUSIONS

- Commercially viable technology must enable a gasifier to be constructed and operated to deliver gas of a pre-determined quality to match the precise requirements of the user. This is not yet possible in China.
- Deep UCG using oxygen could enable China to achieve larger-scale projects with fewer environmental and safety problems, higher efficiencies and the opportunity to exploit deep coal that is uneconomic to mine.
- There is considerable synergy between the UK programme on UCG and the development of UCG in China and it is recommended that the collaboration established during this project is continued.

Further information on the Cleaner Coal Technology Programme, and copies of publications, can be obtained from:
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COST

The total cost of the project was £347,900 with the Department of Trade and Industry contributing 47%, the UK participants and UK industry 32%, and China, 21%.

DURATION

22 months - May 2001 to March 2003

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Additional contributors include Alkane Energy, BOC Gases, Edeco, Dr M Green, FES, First Renewables, Arbre Energy Limited, Henan Coal Research Institute, Feicheng Mining Group, Bureau of Xinmi Electricity, Chaoguang Coal Mine and Tengzhou Construction Group.

FURTHER INFORMATION

For further information about this project see project report number COAL R250 available from the Helpline.

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