International Workshop on Underground Coal Gasification

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Summary of Papers

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DTI's Cleaner Coal Programme

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Executive Summary

73 Delegates attended the International workshop on underground coal gasification (UCG), which was organised to present the current results on the Department of Trade and Industry (DTI) Initiative on UCG, and establish the interest overseas in UCG for future collaboration and exploitation. More than a quarter (21) of the delegates came from overseas, international organisations (2) and the UK representation included Government (15), UK Industry (28), and Academia (7).

The UK initiative on UCG, supported by the UK DTI, has included feasibility studies of coal resources in the UK, directional drilling, environmental, legislative and planning issues, economics and public perception. An initial search has been made for a trial site, and proposals have been made about how a trial in a deep coal seam in the UK should be undertaken, and possible target locations have been identified in Northern Ireland, and mainland Britain. The various studies presented as part of the DTI initiative showed that UCG in the UK is feasible from a planning and environmental perceptive, and offers considerable potential as a future method of indigenous coal exploitation. Public acceptance of the technology needs to be secured through a series of well-run and transparent field trials. UK expertise in UCG and the related technologies has been enhanced as a result of these studies.

The overseas delegates provided ample evidence that interest in UCG is growing significantly in coal producing countries. China has the greatest activity with eleven demonstration trials either completed or underway. Australia has the commercial development at Chinchilla, Queensland and a broad programme of evaluation at CSIRO. In Europe, Slovenia is evaluating and developing UCG technology for a possible future demonstration at the Velenje Colliery, and Russia, is revisiting its previously extensive expertise, and considering advanced power projects using UCG fired gas turbines. Japan has an on-going programme of evaluating UCG technology.

Other coal producing countries are considering the feasibility of importing or developing UCG technology to exploit coal resources, and several, like India, Pakistan and South Africa are reported to be evaluating the commercial UCG technology demonstrated at Chinchilla.

There is also ample scope for international collaboration on UCG, and a number of delegates suggested that collaborative programmes should be developed. Exchanges on UCG between countries are still mostly bilateral but opportunities exist for a full-scale international collaborative programme, for countries that wish to take the initiative.

The Workshop achieved its objectives and demonstrated to the UK DTI the growing interest and commercialisation of UCG worldwide. The results will provide a major input to the forthcoming review of UCG in the UK.

Introduction

The UK DTI is undertaking an initiative to investigate the potential of UCG as a future method of coal exploitation in the UK. The aims of the workshop were to:

- Establish the current worldwide state of the art of UCG for decision makers in Government and Industry
- Disseminate DTI supported work on UCG to date and provide export consultancy opportunities for UK industry with skills in the specialist and supporting technologies (UCG, power generation, gas processing)
- Advance the commercial exploitation of UCG in the UK and elsewhere and identify areas for collaboration with UK Industry, academia and overseas organisations

The workshop took place over two days under five working themes. The following is an outline of each presentation. The slide presentations of each speaker are also available in pdf format on CD Rom.

Theme 1 – UCG world perspective

Chairman, Bronwen Northmore, Director, Coal & New Energy Technologies, DTI

1. The Exergy UCG Technology and the Chincilla IGCC project

Dr Michael Blinderman, Ergo Exergy Technologies, Inc., Canada

This presentation outlined the UCG project, which has been demonstrated by a private consortium in Chinchilla, Queensland, Australia, and is now being promoted as a commercial development. About 35,000 tons of coal has been gasified and 80Mm3 of product gas has been produced over a period of 30 months. Gas clean-up and a gas turbine are planned for installation mid 2004. Calculations show that the economics of the process are highly favourable compared with competing methods of coal exploitation, and the environmental requirements have been met in all cases. A case study suggests that Canadian greenhouse emissions Kyoto targets could be met if substantial UCG and CO_2 sequestration were added to the energy mix. In conclusion, the process is clean, proven and is being considered for power projects in Australia, S Africa, India and Pakistan.

2. Overview of the Chinese Programme on UCG

Dr Liang Jie, China University of Mining & Technology, China

Eleven trials of UCG in specially constructed tunnels and galleries have been undertaken in China, since the mid-eighties of which five are currently in operation. The tunnels are connected to surface by vertically drilled holes, and high CV and hydrogen are achieved by alternating steam and air in a two-stage process. The UCG Research Centre, CUMT, provide theoretical and laboratory support to the Mining Companies who carry out the trials. Market prospects for UCG in China are considered "very bright". Dr Liang proposed international collaboration in deep UCG, pollutant studies and UCG gas utilisation.

3. Lessons from the European Trial for deep UCG

Dr. Michael Green, Independent Consultant to DTI, UK

The European trial (1992-1998), initiated as a result of the European Working Group on UCG, took place at a depth of 550m using directional drilling from surface to construct the process wells. 490 tonnes of coal were gasified over 11 days with O2/water and a maximum power of 8MWt. Water ingress and injection well blockage caused premature closure, but cavity growth and controllability were good. Lessons were learnt for future deep trials about site selection and drilling, but the trial confirmed the performance advantages of deep UCG.

4. UK Initiative on UCG.

Peter Sage, Future Energy Solutions, AEA Technology plc, UK

The UK initiative (1999-2005) is aimed at evaluating UCG as a future option for the UK, based on the success of the European UCG trial in deep coal seams. Feasibility studies include UK coal resources for UCG, review of sites, directional drilling, economics, environmental and legislative issues and public perception of UCG. Next stage is an independent review of the UCG programme, due at the end of 2003, and possible directions for the future programme were identified.

5. Technological Advances in UCG.

Dr. David Creedy & Kevin Garner, Wardell Armstrong Ltd, UK

The technology available for UCG is highly varied and must be adapted to the local site and economic conditions. Comparisons were drawn between shallow and deep UCG, the options were considered for directional drilling and reference was made to the choice of gas cleaning for power generation. The key issues for UCG commercial development, now close in China and elsewhere, are:

- Gasifier construction
- Control of UCG process
- Gas cleaning requirements
- End use options
- Environmental consideration
- Costs
- Effective management

6. UCG Studies in Japan.

Professor Sohei Shimada, Tokyo University, Japan

Following a trial and laboratory modelling of UCG in the 1960's, Japan renewed interest in UCG in the 1990's and identified a potential site in Hokkaido. Cost analysis suggested production costs of $29-35/ GJ, which is a similar price to natural gas in Tokyo. JCOAL is currently reviewing the technology of UCG, and the paper concludes that both on and offshore UCG are targets. International collaboration on UCG is a good solution.

Discussion on Theme 1

Q. What is the limit on size of a UCG project?

A. Michael Blinderman, indicated that there is no size limit to UCG, but maximum output of a single gas turbine is 400MWe.

Q. What was the cost of the European Trial?

A. Michael Green answered £11.7M.

Q. Andrew Beath asked Michael Blinderman about turning down UCG output to match demand.

A. Michael Blinderman said that 70% turndown could be achieved (i.e. reduce to 30% of maximum/normal output). He added that for emergency outages, stoppages of 1-2 days can be tolerated (but not months).

Q. What variation in quality can turbines operating on UCG gas tolerate?

A. Michael Blindermann said about +/- 10% variation in Wobbe number, but the gas from Chinchilla has a standard deviation of 6.5%.

Q. Alex Galloway (UK Coal) asked about environmental issues related to controlled shutdown.

A. Michael Blinderman said that a strategy for controlled shutdown is required, in which case he did not see it as an issue. The Chinchilla project had met all environmental conditions imposed by the regulators in Australia. The appearance of the site is very important.

Q. Ken Fergusson (Combustion Engineering Association) expressed interest in the competence of the roof and the transfer of pollutants.

A. In response Dr. Blinderman indicated that roof collapse is part and parcel of the Chinchilla process.

Kevin Garner (Wardell Armstrong) added that subsidence is necessary to extend the volume of the gasifier.

Michael Green added that post the Spanish trial post -investigation showed that there had been collapse of the cavity to a height of about 10-15m.

Q. A delegate from Arc Electrical, India commented that speakers had said UCG was there and was economic so why is it not commercial?

A. Peter Sage referred to the long gestation periods to full commercialisation for major technologies (he quoted pulverised fuel firing as an example). He also referred to environmental drivers now emerging and the low cost and high availability of oil and gas in the past.

Alan Singleton made a similar comment about the US.

Theme 2 – Advances in the Science and Technology of UCG

Chairman, Dr.Cliff Mallett, CSIRO, Australia

1. Advanced drilling techniques for UCG

Peter Jackson, IMC Geophysics Ltd, UK

Directional drilling in coal is used extensively for degasifying, CBM production and exploration ahead of mining in S Africa, the US and Australia, where the techniques of under balanced drilling, pressure monitoring, steerage and intersections have been extensively practised. The unreliability of inseam drilling experienced by British Coal and the European UCG trial has largely been overcome, and the equipment choice is now much greater. Nevertheless, the accuracy required for UCG drilling is higher than the other applications, and trials in UK coals are still required. Site exploration using 3D seismic is an important prerequisite for the drilling of UCG process wells.

2. UCG laboratory and theoretical simulation studies in China

Dr Lui Shuqin, China University of Mining & Technology, Beijing

The laboratory simulation of UCG is being undertaken in a coal-filled chamber (4m x 1.2m x 0.5m), in which a 100mm borehole represents the inseam gasification tunnel. High-pressure oxygen, steam and air are introduced, the bed is fully instrumented with thermocouples and gas analysis determines the product gas composition. Tests results on three types of coal (lignite, fat coal and lean coal) with two-cycle operation (air and oxygen/steam) have been undertaken, and early results for the temperature fields, showing the movement of the reactor zone, were presented. Rock properties, and cavity pollution concentrations are being investigated in the laboratory tests.

3. Mathematical modelling of UCG processes

Greg Perkins, University of New South Wales, Australia

A suite of models ranging from the classic 1D representation of gasification through to 3D dynamic CFD has been investigated in this PhD study. Initial confidence was established by validating the 1D results against moving bed surface gasifiers. Steady state CFD modelling of the conditions of the Rocky Mountain trial provided gas concentrations in the cavity (O2, CO, CH4, H2 and temperature) for 10, 30 & 50 days, which were compared with experimental data, showing reasonable agreement. Dynamic modelling gave insights into the mechanisms of cavity growth, which can also be observed in field results. UCG is complex physical process and this hierarchical approach is useful and necessary to understand and capture the most important physics of UCG.

4. A review of UK coal resources for both New and Conventional Technologies

Neil Jones & Sam Holloway, British Geological Survey, UK

The study established coal resource criteria for UCG, and other exploitation criteria, and used the extensive database on UK coals to identify and map (1:100,000 scale) suitable areas for UCG in the UK. 4,000 km^2 or 10% of the onshore coal resource were verified as suitable for UCG; the largest areas are in Eastern England, Cheshire Basin, and the Midland Valley of Scotland. These represent 11BT or 426 years at current UK consumption.

5. Coupled geotechnical and thermal modelling for the prediction of UCG cavity growth

Dr Ting Ren, D Whittles & DJ Reddish, Nottingham University, UK

FLAC is a commercially available computer model for modelling structural characteristics of underground rock formations. It can also incorporate temperature and permeability effects, and has been used successfully for predicting the rock behaviour of long wall mining (particularly under sandstone aquifers). The programme was used to predict roof failure, subsidence and temperature profiles above UCG channels. Further results were derived for two parallel UCG channels, showing the interaction between them.

Discussion on Theme 2

Q. Ken Fergusson and Gerwyn Williams expressed surprise that no good UCG resource availability had been identified in South Wales.

A. Neil Jones explained about the extensive historical mining operations tended to eliminate most onshore areas of S Wales, although offshore would be different.

Q. A delegate asked what is the vertical extent of the influence of UCG channels on overlying strata?

A. David Reddish answered that the effect is highly dependent on geological conditions, but his experience from long wall mining is that most effects diminish at 100m. A debate then ensued about the criterion regarding a minimum separation of 100m from aquifers.

Q. Michael Green asked what are the coring requirements for the rock laboratory testing of samples?

A. David Reddish indicated that standard coring is satisfactory to collect the samples, but the tests are normally conducted with dried samples. The heating of samples during testing is difficult.

Theme 3 – Environment

Chairman Dr Keith Burnard, Manager DTI Cleaner Fossil Fuel Programme

1. Environmental and legislative issues of UCG in UK

Jenny Kirton, WS Atkins

This study, which was supported by the DTI initiative on UCG, reviewed past UCG trials and examined the potential environmental issues of UK in relation to groundwater effects, subsidence, surface impacts and air emissions. Consultation with the Regulatory Authorities has identified the concept of 'Permanently Unsuitable' groundwater, i.e. designated areas of already poor water quality, as potentially suitable locations for UCG activities. UCG is a prescribed process under IPPC Regulations for which aquatic and air emission limit values (ELV's) will be set. The study is currently preparing a best practice guide for UCG.

2. UCG site selection in the UK - The issues

Kevin Pickup, The Coal Authority

The paper described the Coal Authority's initial search for a UCG trial site in the UK, and its subsequent detailed examination of four specific sites from the standpoint of coal geology, hydrogeology, environmental issues and planning. All the sites had well known coal geology, and were suitable for the proposed drilling and gasification trials. A methodology based on potential pathways was developed for assessing the hydrogeological risk, and a matrix scoring system for the planning issues was developed. It was concluded that extensive site investigation would be required for a UCG site, and planning issues would be a departure from the development plan and would be more complicated without specific Government guidance.

3. The geomechanics of UCG and CO_2 sequestration. Threat or opportunity?

Professor Brian Smart, Heriot-Watt University

The presentation makes the case that geomechanical modelling of the disturbed region above a UCG cavity will lead to better design decisions on well positioning, and lead to an improved understanding of cavity growth dynamics. A commercially available stress mode from the oil and gas industry, VISAGE can be used to model the stresses and the discontinuities as the cavity develops, and these can be coupled with reservoir fluid flow models such as ECLIPSE. Examples were shown of the modelling of oil and gas reservoirs, and a flow chart was presented on how they could be applied to processes like UCG and CO_2 sequestration.

4. Environmental risks in UCG

Rusty Mark, CSIRO, Australia

This presentation drew on published work on public perception issues, and how it could be applied to the benefit of a new process like UCG. The upside of UCG, in the Australian context, is the potential for cleaner energy from domestic sources, liquid fuel production from coal and the potential for CO_2 removal. These have to be offset against the 'dread of the unknown', which was a feature of nuclear power. It is necessary to balance the requirements of the project against local interests and known versus unfamiliar risks. It has to be done right, and Government Policy must be transparent.

5. A pilot study of public perceptions of UCG

Simon Shackley, Alexander Reiche and Sarah Mander, Tyndall Centre for Climate Change Research, UMIST

This pilot study took place using a focus group already familiar with CO_2 and climate change issues, and a key conclusion is that UCG should be presented in the context of a low carbon energy solution, i.e. with its CO_2 capture benefits and potential for hydrogen production. UCG, nevertheless, is perceived as relatively high risk with little benefit to local communities. They recommend that mastery of the technology takes place in remote areas if possible, and a strategy of transparency and local contact is maintained throughout the development project.

Discussion on Theme 3

Q. Ken Fergusson referred to the link between UCG and CCS. He stated that the earlier study on carbon dioxide storage had not referred to 'permanently unsuitable' water and this had been an omission. He also referred to the gas tightness of the cavity and its potential usability for long-term carbon dioxide storage.

A. In response Brian Smart said that the concept is a rubbleised zone for carbon dioxide storage which includes the cavity and the stressed area above: only site specific analysis could determine if this zone could be gas tight over 100's of years.

There then followed a discussion about prospects for carbon dioxide sequestration into caverns and into coal measures.

Michael Blinderman, made a distinction between dense phase storage of CO2, and their own ideas of storing lower pressure gaseous CO_2 in the spent cavity, surrounded by the existing impermeable strata.

Sam Holloway's views were also solicited. He was sceptical about the CO_2 remaining in the cavity but others pointed out that carbon dioxide would preferentially and permanently adsorb onto and displace methane from coal pores.

Professor Smart thought that carbon in the cavity is essential.

Gerwyn Williams (UK Onshore Gas Corporation) asked Kevin Pickup about grid connection charges.
He quoted a range of circa. £0.3 to 2.0 million.

Trudie Mansfield (DEFRA) in a question to Simon Shackley, asked what if you can't link UCG with CCS?

In response Simon said you can still link them but not in the same place.

David Watt (Antrim Coal) said that wherever you're proposing storage you must have a 'capped' reservoir.

The subsequent discussion suggested that this is not necessarily the case.

Theme 4 – Utilisation of UCG Gas.

Chairman, Professor S Shimada, Tokyo University

1. Combined cycle power generation from UCG gas

Greg Kelsall and David Abbott, ALSTOM Power plc

The presentation reported on the range of development work on gas turbines by Alstom for low to medium CV gas in the range 2 to about 14MJ/m3, and power outputs range from 4MW (typhoon) to 250MW in combined cycle operation. Examples were presented of gas turbines operating on gasified refinery residue (Falconoara Italy), blast furnace gas (Bao Shan Steelworks, China) and biogas (Varnamo Sweden). Enquiries have also been received from the UCG projects at Xinwen (5MW GT), Xinme (9MW CCGT) and Yima (400MW CCGT) with gases in the range 3 – 10 MJ/m3. An outline of the technical developments in gas turbine combustor and the gas cleaning requirements was presented. It concluded that UCG is a potentially significant market for gas turbines, the work already undertaken on low to medium CV gases is applicable and low emission levels can be delivered.

2. Feasibility study of UCG in Velenje, Slovenia

Franci Lenart, Gorazd Berčič, Alenka Zapušek, Igor Veber and Marijan Lenart

The Velenje Colliery in the NE of Slovenia covers a large area (8km x 2km) of very thick lignite (60 – 168m thick) at about 400m depth from surface. The Eastern area is being mined at about 4Mt/yr, but large areas of high ash coal remain intact and two areas ((Tičnica and Leženj) are being assessed as test areas for UCG. Detailed geological and hydrogeological data suggests that despite the presence of an important aquifer, below, and minor (apparently unused) aquifers above, the site areas may be suitable for UCG. The geological study has been backed up by X Ray diffraction of the coal and thermal analysis of the coal. Parallel research on the underground gasification process has produced a method for on-line analysis of the UCG process.

3. Process studies for clean electricity and liquid fuels from UCG

Dr Andrew Beath, CSIRO, Australia

CSIRO expertise in UCG includes site selection, project development and modelling, and economic evaluation for power generation and the production of liquid fuels. Process modelling suggests coal seam depth and thickness affect gas quality to different degrees depending on whether the process is air or oxygen blown. An economic analysis based on the EPRI model shows that UCG is a viable method for the economic production of electricity and synthetic liquid fuels. Process flow sheets are provided for combined cycle UCG with and without CO_2 capture. The economic analysis shows that UCG has lower costs, particularly capital costs than competing coal processes like surface gasification and furthermore, CO_2 capture can be achieved more economically.

4. UCG in Russia and prospects for electric power production in gas-electric complexes

Dr A.A. Kuznetsov and Dr V.K. Kapralov, NMRC, Skochinsky Institute of Mining

The presentation described the operating experience of six UCG Stations in the former Soviet Union, which together have produced around 40Bm3 of product gas since 1962. Modifications to the process to reduce drilling and improve process efficiency were tested at Angrenskaya, Uzbekistan, and the results were incorporated in a new economic analysis, which showed that there are economic advantages for power generation over other forms of coal utilisation including surface gasification. Finally the case for high pressure UCG is made.

Discussion on Theme 4

Q. Peter Jackson asked why UCG in Russia had stopped?

A. Michael Blindermann explained that the arrival of cheap natural gas had been the main cause, but money for development had not been available after about 1995. Dr Kuznetsov is the only person in Russia who is supported to work on UCG.

Q. Greg Kelsell was asked about developments of small gas turbines like the Typhoon.

A. He said that the technology is still owned by Alstom, but manufacturing (at Lincoln) had been transferred to Seimens. Applications would need to be discussed with both companies.

Theme 5 – Commercialisation and the future.

Chairman, Dr Michael Green

1. Commercialisation of UCG

Dr LK Walker, Director, Pict Energy Pty, Australia

The presentation outlined developments (and the cost) of UCG in the FSU, US, Europe and Australia, and identified the issues which have to overcome to commercialise the Chinchilla demonstration. The commercial benefits of UCG include 50% lower gas costs than natural gas, the availability of efficient power generation, sale of by-products and the option of CO_2 sequestration. It concluded with a plot of gas and oil prices over the last 30 years and suggested that the low prices in the 1990's, which made UCG difficult to promote during this time, are unlikely to return: hence a growing need for UCG.

2. Economic evaluation of UCG in UK Context

Dr George Marsh, Future Energy Solutions, AEA Technology

Power generation costs of UCG were developed using a standard economic model for plant sizes of 50MWe and 300MWe with the option of CO_2 capture for the larger plant. Combined cycle gas turbines provided the power generation, and the balance of plant was assumed to be the same as for surface gasification. The cost of raw gas from UCG was determined using a standard panel of bituminous coal 500m by 500m, which was accessed by a process well configuration using deviated drilling from the surface. Well spacing, cavity growth and various geometric factors were based on experimental results from previous deep coal field trials of UCG. Since most UK coal is located in rural areas, an allowance was made to transport the gas up to 100km to a brown field site where the power generation and gas cleaning plant would be located. While site-specific factors are likely to be important, the initial scooping study indicated that UCG costs are likely to be comparable or lower than IGCC.

3. Future plans: 5 minute presentations by key players

P Steemkamp of Eskom, S Africa presented himself as a potential buyer of UCG. He said that they had large quantities of unmineable coal and a growing energy demand - they want to buy UCG power plant. A particular target for UCG is the Matupo field (1.2BT), where they are considering using the gas for either co-firing into an existing power station or constructing a new station.

Alan Singleton of Energy Technology partners, USA reviewed US interest in UCG. The US field trial programme was extensive and reached technical and commercial credibility in the early 1990's. Lawrence Livermore Laboratories, Oil & Gas Companies and the US Dept of Energy were the major organisations involved. Low gas prices in the US halted the commercial development and a new company now succeeds Energy International, who held much of the know-how. He believes a revival of interest in the technology of UCG and gas to liquid fuel conversion is taking place

Cliff Mallett of CSIRO outlined the CSIRO programmes on UCG, which includes evaluation of suitable sites, modelling, environmental evaluation and end use of product gas. The programme also focuses on social issues of UCG and related technologies.

David Watt of Antrim Coal Company, Northern Ireland described the lignite deposits around Loch Neagh in Northern Ireland, and the current position with regard to open cast mining and its use for power generation, now and in the future. UCG of the deposits under the Loch is an option, which is held under review.

Gerwyn Williams of UK Onshore Gas Group outlined the opportunities for CBM exploitation in South Wales and suggested that many of the conditions are also appropriate to UCG, e.g. namely the availability of grid connections up to 20 MWe, basic REC studies and power purchase agreements. He also pointed out that the next step is directional drilling at the Pentreclwydau mining license area, which is also relevant to UCG.

4. Panel Discussion

With reference to the economics paper, there was a discussion about the degree of separation (100km) between ASU/gas turbine combustor and any UCG site. It was generally thought that this had disadvantaged the costings (25km may be more appropriate). Simon Shackley asked about the UCG location example close to Ellesmere Port/Runcorn and asked if this was a real prospect. Peter Sage indicated not at this stage.

The overriding message from the 5-minute presentations is that there are several potential customers for UCG (S Africa, Wales, N. Ireland and Scotland).

Paul Wilcox asked why there was not an UCG website. Keith Burnard (FES Programme Manager for the DTI Cleaner Coal Programme) said that all Programme Publications are placed on DTI website but that there is not a dedicated section for UCG.

Jeff Chapman commented that all work to date arises from either ‘command economies’ or from Government R&D initiatives. This prompted a fairly rapid response from Dr Blindermann who said that most of the running is currently with the private company with which he is associated.

Commenting on why there hadn't been significant private sector activity on UCG to date, Peter Steemkamp said that big companies need exhaustive due diligence before committing funds.

Cliff Mallett indicated that he would pursue with CSIRO the possibility of another International UCG Workshop in Australia in 2005. This was enthusiastically supported.

Close of Meeting