European UCG Case Study

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Outline of Presentation

- Background to the European Trial
- Objectives, Planning & Site Selection
- Drilling and Completion of Wells
- Gasification Results
- Conclusions and Future Prospects
US Programme Conclusions - 1989

Conclusions

- Field tests have unequivocally established the technical feasibility of UCG in coals at moderate to shallow depths using air or steam/oxygen as the gasification agent.
- The CRIP process appears to offer a method of positive control of the progress of gasification and provides a means to generate new cavities as needed.

To be resolved

- Feasibility of gasifying seams greater than 500m
- Behaviour of the most commercially attractive seams i.e. seams are the very thick seems >15m.

- Thorsness & Britten 1989
Background to European UCG Trial up to 1990

• Developing Technology from U.S and oil & gas industry - CRIP, in seam drilling, use of oxygen.

• Thulin Trial (1979-87) - 860m depth, high CV gas.

  – Evaluated previous trials
  – Undertook economic evaluation and considered that UCG in thinner and deeper seams feasible
  – proposed two trials over a 15 year period at increasing depth.
Technical Objectives of the EU Trial

- Demonstration of Long In-seam Drilling
- Construction of a Competent gas Circuit between Injection and Production Wells
- Demonstration of Adequate Coal Conversion
Configuration Selection for UCG Trials

CRIP configuration proposed for UK & Australian Tests

Configuration European Trial

Sasol Scheme
In-Seam Configuration and Project Plan

- **Preparatory stage**
  - Geology and coal evaluation.
  - drilling, completion of boreholes,
  - surface equipment.

- **Gasification activities**
  - drying, pressurisation, ignition of the coal
  - development of cavity by means of the CRIP manoeuvre.

- **Postburn activities**
  - Determine cavity shape by drilling
  - validate gasification models used for process control.
  - Site restoration.
Location of Test Site in Teruel, Spain
**Geological Data of Test Site**

**Characteristics**

- Two dipping coal seams 7 to 14 m apart
- Depth of 500-700 metres
- Seam thickness 1.9 to 7.0 metres
- Thin layer of clay under both seams - sand layers above the coal were known but manageable.
- Tectonic framework highly favourable to gasification (Isolation by faults)
Coal Seam & Strata Characteristics

**Hydrogeology**
- Floor Thick Limestone
- Roof 15m of Sand
- Permeability's
  - Coal: 1.96mD,
  - Sand Strata: 17.6mD
  - Limestone: very low
- Drainage upwards and to N. East
- Aquifer location and protection favoured upper seam

**Coal Analysis**
- Sub-Bituminous C
- Vitrinite Reflectance 0.36%–0.43%
- Proximate Analysis
  - Moisture 45%
  - Ash 18%
  - Volatile Matter 26.5%
- Total Sulphur 7.3%
- HHV 18095kJ/kg
Overview of Test Site showing the 3 Operational Areas
UCG Production Area

Wellhead Area

Instrumentation Cabin

Combustor

Flare
Cross Section of Exploratory Wells
Well Layout for Trial

FIGURE 5: Well Layout
Drilling of Directional Well
Injection Well Completion
Production Well Completion
On-Line Software tools for UCG Operations

- Mass Balances
- Gasification analysis
- Water ingress rates
- Cavity dimensions
- Laboratory analysis of post gasification coal samples
  - XRD, SEM
  - Coal chemistry & petrology,
  - Reflectance
  - Mineralogical analysis

Control Room Spanish UCG Trial
# Sequence of Operations

<table>
<thead>
<tr>
<th>Start up Pre-gasification Stage</th>
<th>1st Gasification Stage</th>
<th>Stand By</th>
<th>Modification to Surface Plant</th>
<th>2nd Gasification Stage</th>
<th>Final Gasification Operations</th>
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<tr>
<td>30/06/97 to 10/05/97</td>
<td>21/07/97 to 29/07/97</td>
<td>29/07/97</td>
<td>07/08/97</td>
<td>17/09/07</td>
<td>01/10/97</td>
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<td></td>
<td>1st Ignition</td>
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<td>2nd Ignition 01/10/07</td>
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<td>3rd Ignition 04/10/97</td>
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**Ignition Dates:**
- 1st Ignition: 29/07/97
- 2nd Ignition: 01/10/97
- 3rd Ignition: 04/10/97
Key Results from European Trial

- Coal Affected: 290 tons
- Product Gas: 490 tons
- Peak Power: 8MW
- Gas Composition (dry N$_2$ free):
  - Hydrogen: 27%
  - Carbon Monoxide: 14%
  - Methane: 14%
  - Carbon Dioxide: 45%
- Calorific value of product gas (LHV): 10.9MJ/m$^3$
Composition of Product Gas

Gas Composition on Dry N2 Free – 1st Gasification

Gas Composition on Dry N2 Free–2nd Gasification
Product Gas Quality

Gas Quality on Dry N2 Free Basis– 1st Gasification

Gas Quality on Dry N2 Free Basis– 2nd Gasification
Water Production and Concentration
Energy Balance for the Coal
Power (MW) and LHV (MJ/m³) of the Syngas Produced Gas

Courtesy Chappell & Mostade, 1998
Site Hydrogeology for European Trial

- Injectability tests in Exploratory Wells
- Drainage upwards and to N. East
- Permeability's
  - Coal: 1.96mD, Sand Strata: 17.6mD
  - Limestone: very low
- Aquifer location favoured upper seam
Underground Contamination

• Rapid pollutant decay in extracted water from cavity.
• Gas losses significant due to sand roof but no gas at control monitoring points.
• Hydrogeological study has established
  – low dispersal rates.
  – impact on aquifers remote.
• Contamination risk was insurable.
CO$_2$ Capture from UCG Field Trial Syngas

Capture Advantages of UCG (in deep seams)

- Suitable for pre-combustion capture (CHEAPER CO$_2$ SEPARATION)
- Oxy-fuelled Process - burning gas produces only CO2 and water (CHEAPER SEPARATION)
- High Pressure Process - Smaller Plant & Pressure energy for power (up to 20%) available. (Cost Savings)
- Gas suitable for producing H$_2$/methane mixtures- easier gases for transmission and storage than pure hydrogen (Greater Flexibility)
Post Gasification Drilling Trajectories
Shape of Cavity in European UCG Trial
Why did it Stop so Soon?

DTI Summary 1999

- A blockage occurred in the macaroni supply tube carrying TEB and methane to the burner, which was impossible to unplug. This led to a delayed ignition which created an underground explosion and damaged the injection well. A sudden loss of well pressure, a few hours later, stop.

- The abrupt end of the channel gasification test led to its abandonment, in spite of the second injection well being ready for operations. Success was considered unlikely.

Chappell & Mostade 1998

- At 5.00 a.m, a sudden and significant decrease of the injection well pressure occurred, in consequence of a loss of integrity of the injection well. It was decided at this point to terminate the second gasification phase.
Conclusions from the Trial

- Two successful ignitions, and seven manoeuvres of the coiled tube were performed. Coiled tubing is satisfactorily for moveable injection.
- Directional drilling met the objectives of process well construction, although further improvements in accuracy are required.
- Gasification at greater depth enhances methane formation and cavity growth.
- The production gas had a quality and heating value comparable with surface gasification and usable for chemical and power production.
- The process is controllable and the engineering completion of the injection and production wells operated satisfactorily.
- The gasification process appeared to be highly responsive to changes in oxygen rate and, the process can be stopped and restarted.
- No evidence of contamination spread beyond the cavity or subsidence was observed.
Lessons Learnt

- Feasibility of UCG at 550m was demonstrated.
- Investment in site exploration and the need for thorough evaluation of the hydro-geological conditions is essential prior to process well construction.
- Directional drilling was successful engineering completions worked satisfactorily& important user experience was obtained.
- Environmental effects minimal with correct site selection and good operational control.
- Economics largely dependent on drilling and exploration costs.
- High water ingress into the cavity hindered the full development of the first gasification operation, required plant modification, and created both delays and extra costs.
Future Prospects from the First EU Trial

- Advantages of UCG at great depth, in terms of gas quality and cavity growth, are substantial.
- The technical outlook for underground gasification at intermediate depth has improved significantly as a result of this trial.
- A number of technical questions have been resolved, and the success of future UCG projects has been increased.
- Factors such as drilling technology & the need for environmental processing are moving in favour of UCG.
- Underground gasification has inherent environmental benefits in terms of gas processing and CO2 removal, and deep UCG is likely to have minimal effect on ground contamination.
Post Script to the Trial

- The UK Government conducted an extensive feasibility study of UCG (1999-2005) and concluded that UCG with CCS had the potential as an effective option for UK energy supply, and initiated the Firth of Forth study.

- The semi-commercial EU trial in deeper coal did not follow on as planned, but EU after a gap of 7 years is re-engaging in UCG with CCS (2007).

- A good number of major feasibility studies and trials are now underway around the world, driven by energy prices, security of supply and the revival of coal. Most studies and regulators, are favouring UCG in deeper seams.