CO$_2$-ECBM and CO$_2$ Sequestration Technology in Coal Seams of Qinshui Basin, China

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China United Coalbed Methane Co., Ltd.
China United Coalbed Methane Co., Ltd (CUCBM)

- State-owned company under the direct auspices of the State Council, including the State Plan, Finance, Science and Technology
- Exclusive rights for exploration, development and production of CBM in cooperation with foreign companies
- Professional company responsible for exploration, development, production and sale of CBM in China
China ECBM Project

Canadian International Development Agency (CIDA)

Ministry of Commerce (MOFCOM)

Canadian Climate Change Development Fund (CCCDF) (CA $5 million)

China United Coalbed Methane Corporation Ltd. (CUCBM) (CA $5 million)

3.5-year CA $10 million Project (Started March 2002)
Enhanced CBM Micro-pilot Test in the Anthracitic Coals of the Qinshui Basin, Shanxi Province, China
Activities in South Qinshui Basin

- 830 wells and more than 660 2-D seismic lines have been completed by CUCBM. (Up to May, 2007)
- 3 CBM pilots have been set up.
- 1 National test field for CBM development has been confirmed.
- 1 Z-pinnate System has been tested.
- 1 CO$_2$ micro-pilot
First Micro-Pilot Test
Qinshui Basin

- The first micro-pilot test was successful
- CMG’s GEM CBM Model has been validated based on successful history match of the micro-pilot field data
- Prediction of the performance of CO₂-ECBM recovery process indicated that more than 4 times the average CH₄ production rate compared to primary recovery can be achieved
- CO₂ storage into high-rank anthracite coal seam in Qinshui Basin is feasible
- Design of multi-well pilot on site
Micro-pilot Test Goals

- To accurately measure data while injecting into and producing from a single well
- To evaluate the measured data to obtain estimates of reservoir properties and sorption behavior
- To use calibrated simulation model to predict the behavior of a larger scale pilot or full field development
Primary CBM Recovery Operation

Gas / Water Separator

CBM Production Well
Well TL-003 Primary Production History
Adsorption Isotherms

Qinshui Basin

Langmuir Selectivity = 1.2
Micro-pilot Test Design

- **Stage 1.** Inspection of wellhead equipment
- **Stage 2.** Isolation of #3 seam from #15 seam and install additional downhole and surface equipment
- **Stage 3.** Initial production testing to determine baseline reservoir properties
- **Stage 4.** Intermittent injection of 200 t CO$_2$ and followed by a 30 days shut-in period
- **Stage 5.** Production testing after the CO$_2$ injection period
- **Stage 6.** The final shut-in test
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Target Coal Seam Well for Field Test

- No. 3 seam – Shanxi Formation
  - Age: Carboniferous Permian coal
  - Depth: 478 meters
  - Average thickness: 6 meters
  - Reservoir temperature & pressure: 25°C & 500 psi

To isolate seam from lower No. 15 seam, a bridge plug set in TL003 well at 573 meters
Well Configuration

- Downhole gauges
- Perforated pup
- Nogo seating nipple
- pump
- wellhead

Cable to Surface Readout

244.5mm surface casing at 39.73m

Perforations for #3 Seam
471.85 - 478.50 m

NOGO seating nipple
2.4 m Perforated pup joint

Blanking sub with Prism pressure transducers at 498.47 m

Top of Bridge Plug at 573 m

Perforations for #15 Seam
Downhole Gauge Installation

- Installed 2 sensors
  - 0 – 1500 psi range
  - 0.025% full scale accuracy
  - 0.0003% resolution
  - 120 C temperature
- Signals transmitted via multi-conductor electro-mechanical wireline cable
- Surface Readout
  - Live data readouts
  - 1M data points storage capacity
On-line Gas Chromatograph

- Capable of measuring produced gas composition “on-line”
- Separates and quantitates:
  - CO₂, CH₄, O₂, N₂, C₂-C₄, H₂S
- Analysis every 5 minutes initially & decreased to 1/hr as pilot continues
- Baseline Composition: CH₄ - 96.3%, CO₂ - 0.5%, N₂ - 3.67%, C₂ - 0.01%
TL-003 Wellsite & Wellhead

Instrument Trailer

Well head with Downhole gauge packoff
Micro-pilot Test Design

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Project Steps

- Well TL003 identified for CO$_2$ micro-pilot test, July 2003
- Downhole gauges installed to measure reservoir pressure & temperature during micro-pilot, Oct. 2003
- Well put on primary production to establish baseline information - Gas production 450m$^3$/day and water 0.9 m$^3$/day, Oct, 2003- Feb. 2004
- Shut-in/Buildup test for permeability (12 md)
- Installation of gas chromatographic equipment for on-line gas compositional analysis, Nov 2003
- Procurement of CO$_2$ pump to inject CO$_2$, Feb 2004
- CO$_2$ source secured- Zhongyuan Oilfield located in Henan province, Jan 2004
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**CO₂ Injection Strategy**

- Goal is to inject 200 tonnes into reservoir over a 12 day period. Each truck can transport 18 tonnes of CO₂.
- Injection rate to be maintained below reservoir fracture pressure (1100 psi).
- Estimate average injection rate of 30L/min over 8-10 hr period.
CO2 Pumping Equipment

- National Oilwell N30 triplex pump
- Toshiba Variable Frequency Drive (VFD)
- Low & high pressure shut-down switches
- High pressure relief valves
- Flow stabilizers
- Flow meter & totalizer

Pump Skid testing at TL-003 well in Qinshui basin
Completion of Field Micro-Pilot

- CO₂ pumping equipment shipped to China
- Pressure tested well before CO₂ injection
- Injected over 192 tonnes of CO₂
- CO₂ soak for 30 days
- Production for 60 days measuring gas composition, pressures and flow rates
- Well shut-in/pressure build-up for final permeability estimate
- Micro-pilot test engineering evaluation and numerical model historymatch and prediction
Cooling Down the System
Injecting Liquid CO$_2$
Bottom-hole Pressure Response During CO₂ Injection

![Graph showing bottom-hole pressure response during CO₂ injection from 3 April to 3 May. The graph displays fluctuations in pressure over time.]
Injectivity versus Cumulative CO$_2$
Micro-pilot Test Design

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Bottom-hole Pressure During Final Production Test

![Graph showing pressure buildup](image)
Time 0 = April 6, 2004

Symbols: Field Data
Curves: Numerical

Well Shut-in
Gas Composition During Final Production Test

Date


Gas Composition, volume percentage

CO2
CH4
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Results

- All six stages of the micro-pilot test were successfully completed.
- The average pressure of seam #3 is 1,241 kPa at a depth of 472 m.
- Absolute permeability of the coal seam prior to CO$_2$ injection was 12.6 md, which was based on an effective permeability of gas of 2 md and a gas saturation of 40.8%.
- 192 metric tonnes of CO$_2$ was injected.
- The injectivity stayed relatively constant while the estimated permeability reduced substantially during injection (from 12.6 md to 1.4 md after injection).
Reservoir Simulation

- Obtain a credible numerical model which can reflect the characteristics of the coal reservoir with the micro-pilot test
- Design the multi-well pilot test with the numerical model and further calibrate the numerical model
- Commercial development design with the established numerical model
The History Match of the Micro-Pilot Test

- Micro-pilot test data such as BHP and production gas composition have been successfully matched.
- CMG’s CBM Model has been validated and can be used to predict field-scale ECBM recovery performance.
- Prediction from the successful history match numerical run could be used to study the micro-pilot test process mechanisms.
Multi-Well Pilot Test
Reservoir Simulation Model

Depth from TL-003 Wellhead (m)

Seam #3

Water Zone
Seam #15

FZ-008
FZ-002
FZ-003
Injector

N
Multi-Well Pilot Test

Cumulative Methane Production

![Graph showing cumulative methane production over time for Primary CBM and ECBM.]
5-Spot Field Pilot Test Prediction

CO₂ Inventory

- Start CO₂ Injection (5.6783 years)
- Time 0 = March 16, 1998
- After 6 months CO₂ Injection
- CO₂ Stored
- Cum. CO₂ Injection/Recycled (kg)

Start CO₂ Injection (5.6783 years)
Summary

• The single well micro-pilot test as conducted in the South Qinshui TL-003 well has been completed successfully and has met all the technical objectives of the micro-pilot test.

• Successful history matching of the dataset from the micro-pilot and use of the calibrated numerical simulator to predict the multi-well pilot performance will establish the level of production enhancement compared to primary production, and whether substantial CO$_2$ storage in the coal seam is feasible.
Thank You