Session 2A: Behaviour prediction

Supported by the Australian Government through the
Asia Pacific Partnership (AP6) Coal Mining Task Force

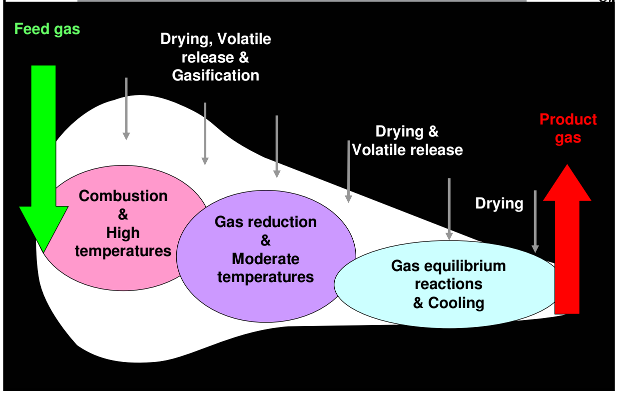
12th November 2006
Kolkata, India

Behaviour prediction

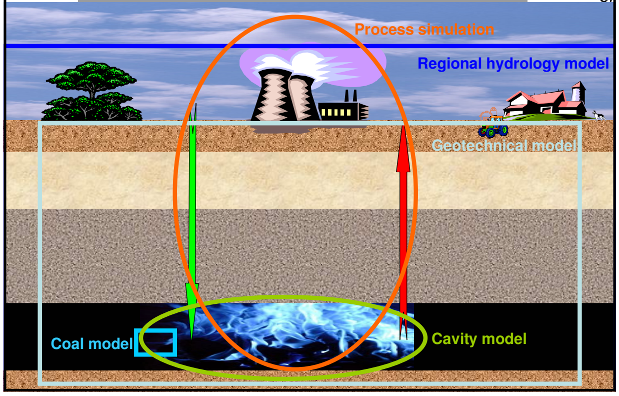
One of the key problems with past UCG operations has been the difficulty in understanding what is happening. Many months of data analysis and modelling was required to interpret results from some experimental trials.

Modern computing allows the opportunity for real-time assessment of the reactor behaviour, if suitable models can be developed.

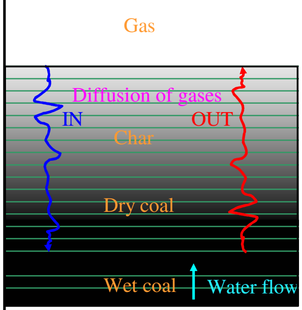
UCG reaction processes



Modelling



Coal Model



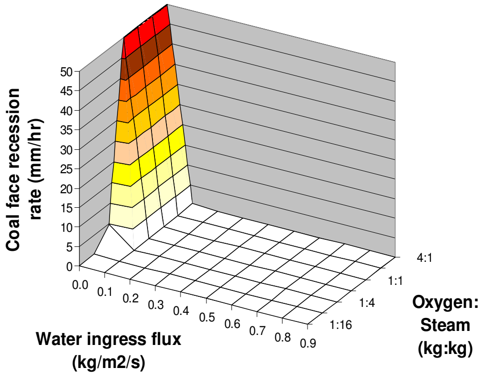
The coal model represents lump coal reacting with a hot gas.

Included in the model are:

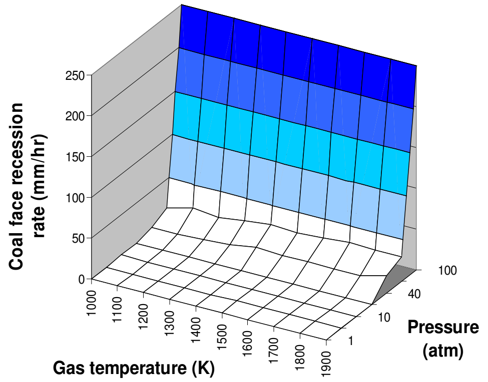
- ❖Reactions
- ❖Gas diffusion
- ❖Water flow
- ❖Drying
- ❖Heat transfer
- ❖Coal structural changes

Output is used in the cavity model.

Predictions from the coal model -Impact of reactant gas mix and water



Predictions from the coal model -Impact of pressure and temperature



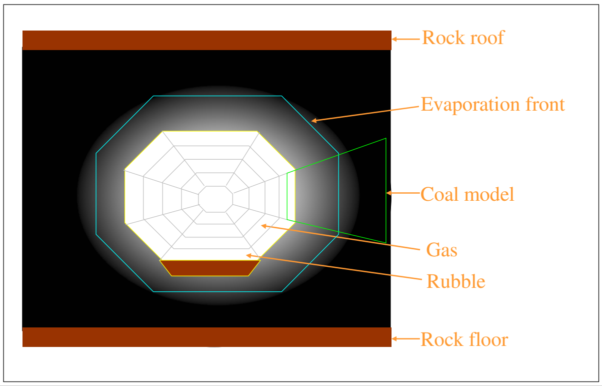
Use of the coal model

- ❖Does not provide standalone predictions relevant to UCG as it neglects many of the gas flow and heat transfer features of real cavities
- ❖Makes spot predictions of coal behaviour under pseudo-steady state conditions to feed into more complex models
- ❖Can be used to predict the general operating regimes that are desirable for efficient gasification

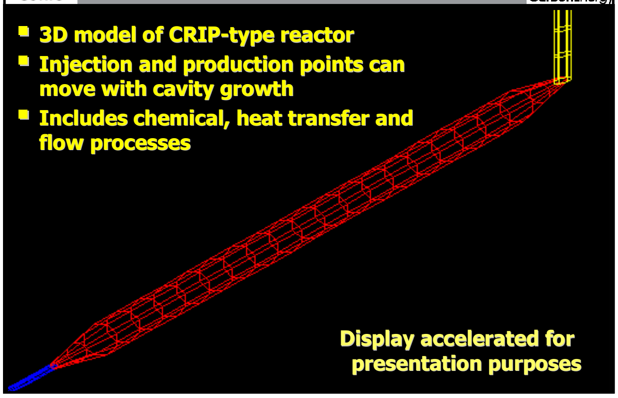
Elements of a cavity model

- ❖ Coal & char reactions
- ❖ Coal/char structural changes
- ❖ Gas flow and reactions
- ❖ Water flows and evaporation
- ❖ Heat transfer
  - o Conduction,
  - o Convection
  - o Radiation
- ❖ Rock & coal breakage and collapse
- ❖ Resizing of the matrix with growth

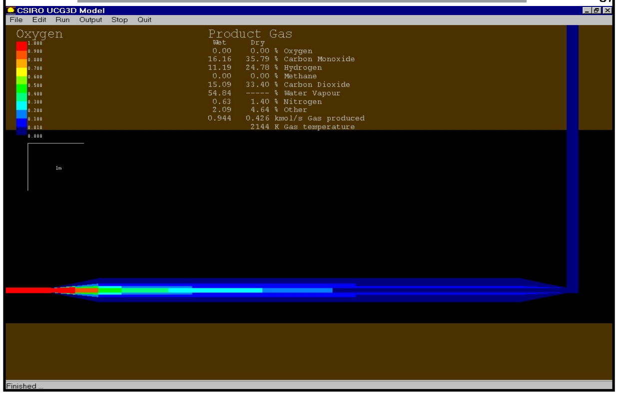
Model of Cavity Growth



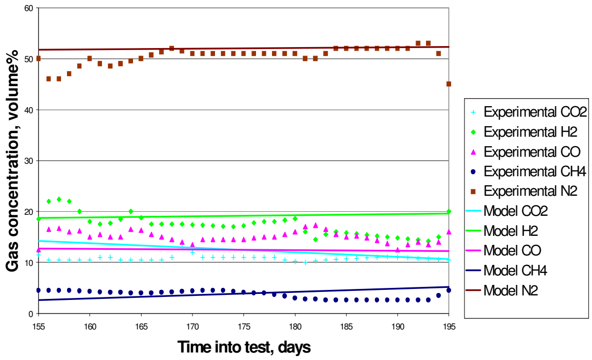
Cavity model operation



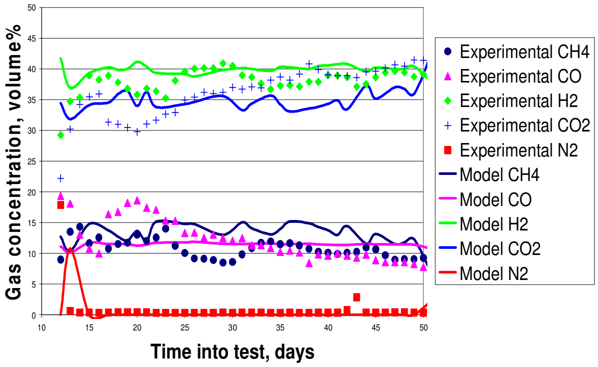
Specific gas concentration prediction from cavity model



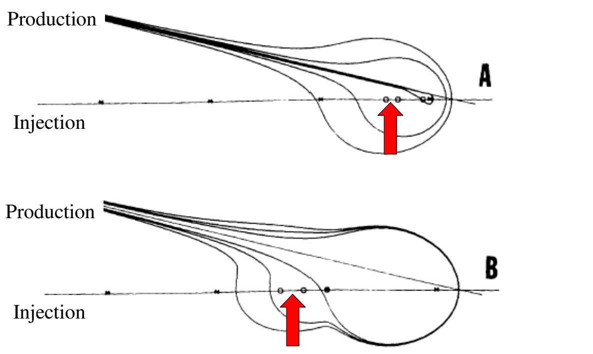
Hanna II trial (1975) - Air-blown, Vertical wells



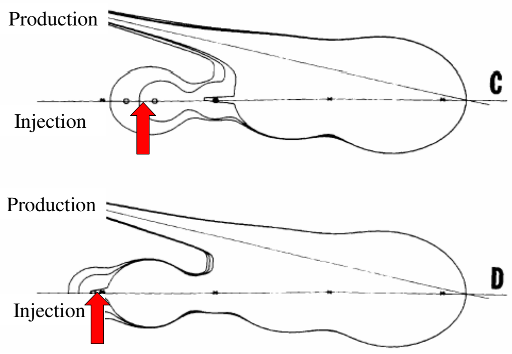
Rocky Mountain 1 trial (1987-88) -Oxygen-blown, Knife edge CRIP



Cavity growth (Experimental) 1



Cavity growth (Experimental) 2



Model performance

Predicts accurately:

- Cavity volume changes
- Product gas composition and flow

Hindrances to model performance:

- Requires detailed site information
- Experimentally, the cavity shape was affected by uncontrolled shortening of the 'CRIP' and an undetected fault running through the site

Physical site changes

Modelling of other side of UCG, the physical site changes, will be discussed in a later session.

In the cavity modelling, simplified models are used for roof collapse and hydrological flows and these are 'tuned' using output from the more complex and specialised geotechnical and hydrological models.

Session 2B: Process performance & economic viability

Supported by the Australian Government through the Asia Pacific Partnership (AP6) Coal Mining Task Force

12th November 2006

Kolkata, India

Historical utilisation of UCG gas

- ❖Most Soviet-era UCG produced a fuel gas for use as supplementary fuel in coal-fired boilers, so gas specification was not stringent
- ❖Chinese UCG is commonly used for domestic fuel gas, but has been used for hydrogen production and as a synthesis gas for ammonia production
- ❖Rawlins II trial in the USA demonstrated reliable synthesis gas production and a subsequent (failed) commercial plant at the site was intended to synthesis methane

Modern applications for the UCG

❖**The product gas can be used as a:**

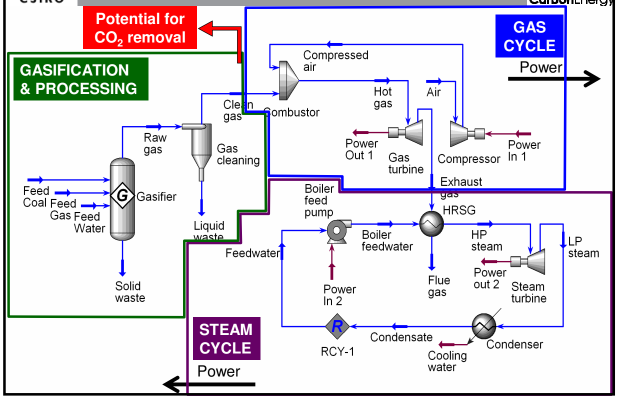
- FUEL
  - Electricity production via gas turbines
- SYNTHESIS FEEDSTOCK
  - Production of chemicals (eg. fertilisers)
  - Synthesis of liquid fuels (Fischer-Tropsch)

Electricity generation

Underground coal gasification can provide a fuel gas that is suitable for use in modern gas turbines after cleaning.

The power plant design is similar to that of the proposed IGCC plants using mined coal.

Combined cycle electricity generation



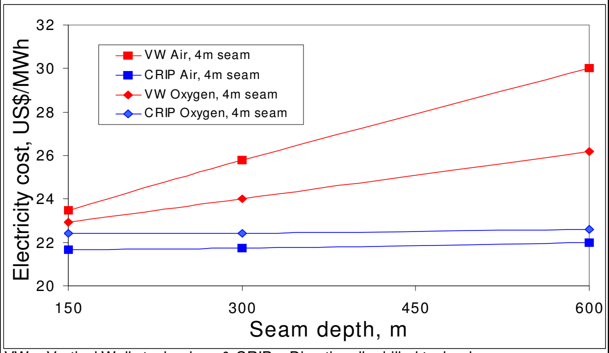
UCG and gas turbines

- ❖UCG product gas has a different composition for every site and varies significantly from that of entrained flow gasifiers for IGCC systems
- ❖This has an impact on the design of the turbine combustor and the turbine
- ❖Turbines are typically specified on mass flow, so the different gas composition can impact on operation

Process efficiencies for combined cycle electricity generation

Process	Efficiency
Air-blown UCG	**45.4 %**
Oxygen-blown UCG	**46.5 %**
UCG with CO_2 separation	**39.8 %**
Conventional coal	**~37 %**
IGCC	**~45 %**

Economics of Power Generation



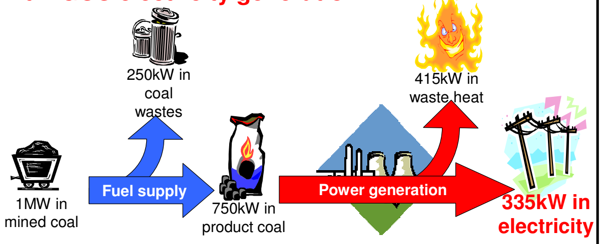
VW = Vertical Wells technology & CRIP = Directionally-drilled technology
Based on a 200MWe combined cycle plant

Resource utilisation efficiency

An alternative viewpoint is in terms of resource utilisation efficiency, so how does UCG compare with conventional mining and IGCC in resource utilisation efficiency?

Conventional resource utilisation efficiency

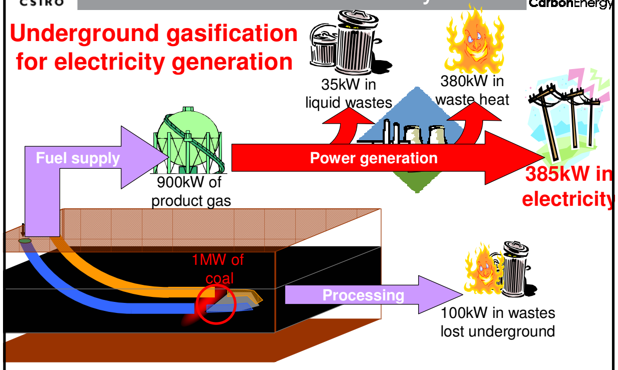
Conventional mining with IGCC electricity generation



Notes: - Underground mining losses range from 25-80% of the coal
- Transport and mining use approximately 5% of the coal energy

Underground coal gasification resource utilisation efficiency

Underground gasification for electricity generation



Note: - Underground gasification leaves 10-30% of the coal underground

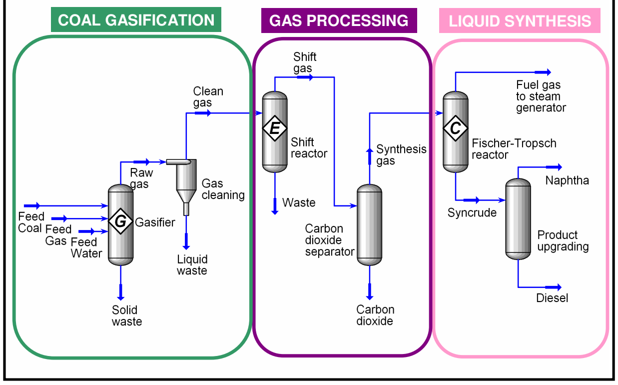
Comments on electricity generation

- **A simple option is to use UCG gas in existing coal-fired boiler plants – this will typically be limited to about 30% of the energy input coming from UCG, but allows for very flexible gas compositions**
- **Modern gas turbines can use UCG gas with minimal cleaning (simple removal of condensates) and can be cover a range of compositions, but efficiencies will vary**

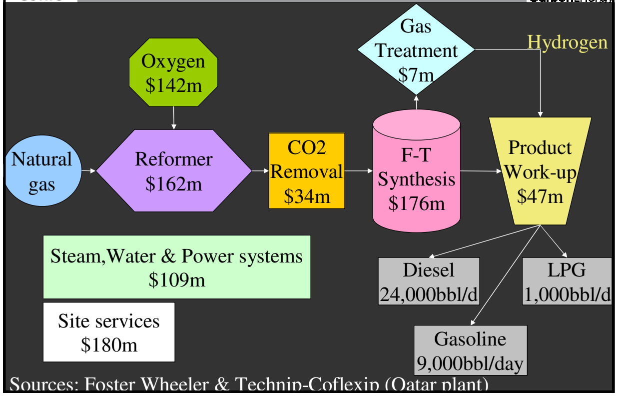
Liquid fuel synthesis

- ❖UCG is a low cost option for providing gas for Fischer-Tropsch synthesis of liquid fuels
- ❖This is a tempting process to consider due to the high value of the products, but the capital cost of the synthesis plant is very high

Application - Liquid Fuel Synthesis

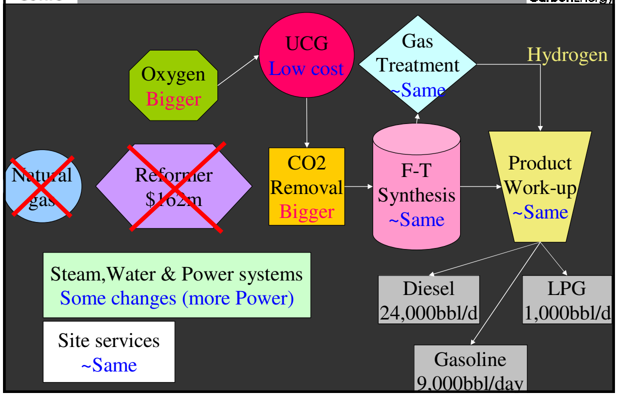


GTL Plant (SasolChevron)

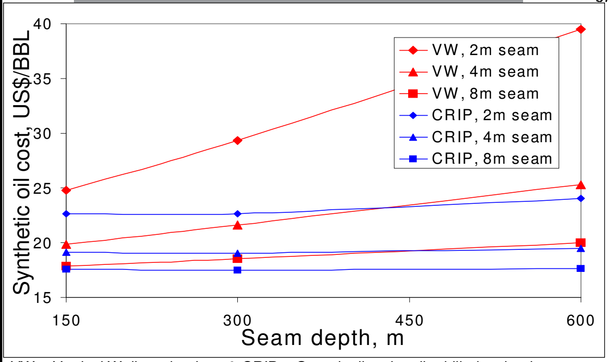


Sources: Foster Wheeler & Technip-Coflexip (Qatar plant)

UCG with GTL Plant



Economics of Liquid Fuel Synthesis



VW = Vertical Wells technology & CRIP = Generic directionally-drilled technology
Based on a 10,000 bbl/day plant

Comments on liquid synthesis

- ❖The gas specification for this process is much more stringent than for electricity generation and it will be difficult to convince financiers that UCG alone can supply a reliable gas feed
- ❖Large scale UCG with gas blending can maintain constant composition, but may lead to environmental problems

Comments

Process simulation is necessary for prospective plants using UCG as:

- ❖**Often the plant will have a tight integration between surface and underground operations**
- ❖**Differences between the UCG gas and conventional gases may have a significant impact on the surface plant operation**

The End

Supported by the Australian Government through the Asia Pacific Partnership (AP6) Coal Mining Task Force

12th November 2006
Kolkata, India