What is Gasification?

Gasification is the partial combustion of Coal with $O_2$ and water.

Underground coal gasification is like other coal gasification techniques (Sasol® FBDB™), except that the geological strata form the reaction vessel and groundwater is used as process chemical.

This lowers cost, but adds a level of complexity to analysis of the process behaviour and leads to extra uncertainty due the geological environment.
What is UCG

Underground Coal Gasification (UCG) is a cost-effective environmental friendly solution for resource recovery in areas beyond the technical and economic confines of conventional mining.

Employing a series of wells, UCG converts in-situ coal into product gas, thus eliminating the expense of:

- Mining
- Blending
- Stockpiling
- Reclamation
- Road transport
- Screening
- Fine coal losses and dust pollution
- Surface gasifier operation and maintenance
- Ash handling
THE UCG PROCESS - i

The process involves the drilling of two or more boreholes into the coal seam.

Presented with kind permission of:

ergo
The coal is ignited, and combustion is maintained by injecting air or oxygen and/or steam through one of the boreholes.
The resulting pressurized gases are contained within the seam by overlying impermeable rocks and water pressure in the surrounding coal and overburden.

Presented with kind permission of:

ergo
THE UCG PROCESS

ground level
water table
overburden
coal seam

air in
gas out

The hydraulic gradient is maintained into the cavity

Presented with kind permission of:

ergo
Quick Process Description

- UCG involves injecting steam and air or O$_2$ into a coal seam from an injection well. The injected gases react with coal to form a combustible gas which is brought to the surface in a production well, cleaned and used as a fuel or chemical feedstock.

- To facilitate flow of the gas through the coal seam from the combustion zone to the production well, a “link” is created by using directional drilling.

- At the initiation of a UCG operation, ignition wells are used to provide ignition agents (e.g. propane or LPG, burning wood or coal, ammonium nitrate fuel oil (ANFO), explosives like thermite, diesel and other fuels, air/steam/oxygen, etc.) to initiate combustion.

- Once combustion is established in the coal seam, the injection wells inject O$_2$ to sustain and control the combustion rate.

- A cavity is formed as the coal burns and the roof collapses / goaf. This results in lateral growth and is allowed to continue until the product gas quality deteriorates.
Quick Process Description

• Between the combustion zone and the production wells, the gas flows through the coal seam and is enriched by products of the reactions and pyrolysis.

• When the quality of the product gas falls, fresh coal is ignited further along the injection well. The Injection Wells are often moved in order to “guide” the combustion process between the wells and thereby create the desired link between the reaction zone and the production well.

• The greater the lateral growth, the longer the life of a gasifier and the more cost-effective the operation.

• Once the coal within the underground gasifier has been exhausted, new injection and production wells are drilled and the process is repeated.
Worldwide distribution of UCG sites
Gorgas, USA - 1950’s
Angren, Uzbekistan

[UCG - 1956 to present, 100 MWₑ, gas + coal]
### Former-Soviet Union UCG R&D

UCG R&D started in the 1930’s, went commercial in 1950’s

<table>
<thead>
<tr>
<th>UCG plant</th>
<th>Coal rank</th>
<th>Thickness</th>
<th>Depth</th>
<th>Dip</th>
<th>Net Heat Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lisichansk</td>
<td>Bituminous</td>
<td>0.44 - 2.0</td>
<td>60 - 250</td>
<td>38- 60</td>
<td>20.1 -23.0</td>
</tr>
<tr>
<td>Yuzhno-Abinsk</td>
<td>Bituminous</td>
<td>2.2 - 9.0</td>
<td>130 -380</td>
<td>35 - 56</td>
<td>28.9 - 30.7</td>
</tr>
<tr>
<td>Podmoskovnaya</td>
<td>Lignite</td>
<td>2.5</td>
<td>30 -80</td>
<td>0</td>
<td>11.8</td>
</tr>
<tr>
<td>Angren</td>
<td>Subbituminous</td>
<td>3.0 - 24.0</td>
<td>110 -250</td>
<td>7</td>
<td>15.3</td>
</tr>
<tr>
<td>Shatskaya</td>
<td>Lignite</td>
<td>2.6</td>
<td>30 - 60</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>Sinelnikovo</td>
<td>Lignite</td>
<td>3.5 - 6.0</td>
<td>80</td>
<td>0</td>
<td>8</td>
</tr>
</tbody>
</table>
Huntley, NZ
Rawlins 2, USA 1980
A Look at Steeply Dipping Bed (In Situ Energy - ISE)
Zhangzhuang UCG Station
XinAo Group, China, 1990 to present
The sketch of the "long-tunnel, large-section, two-stage" gasifier

An Overview of The Chinese Programme On UCG By LIANG JIE (Underground Gasification Engineering Research Centre for Coal Industry - China University Of Mining & Technology)
Rocky Mountain, US Trials 1987-1990

• 31 tests involving DOE, Gulf, Texas A&M, GRI, ARCO
• Two technologies developed
  – Steeply Dipping Beds
  – Moveable Injection = CRIP
• Rocky Mountain Trial, 14,000 tons of coal 93 days
Joint European Trail, Spain
• ELW is 2 directionally drilled wells that intersect at an angle of 30°.
• Combustion was started at the intersection point from a vertical borehole, but it was assumed that in future this could be done through one of the directional boreholes.
• One directional hole is used as injection hole and the other as Production hole.
• Gasifier life was short lived as chamber dies as it reached maximum sustainable size.
• Once dead it could not be started again.
Well Layout for Spanish Trial (CRIP)
THE CHINCHILLA PROJECT
Queensland, Australia

- pilot scale
- operating Nov 1999 – Apr 2003 (in conservation mode at present)
- conversion to CTL proposed
- little visible infrastructure
- no groundwater /surface contamination *
- no surface subsidence
- 1 week shutdown possible i.e. peaking capability with CCGT
- 100% availability
- 95% coal usage
- 75% energy recovery

* By independent audit by Golder Associates, for Australian EPA

Presented with kind permission of:
Chinchilla, (1999 to present)
And then a stone’s throw from us…
Eskom Surface infrastructure

Eskom UCG Demonstration Site

Majuba power station with the UCG site in the foreground

UCG gas burners at Majuba power station

500mm NB pipeline for transporting UCG gas to Majuba power station

Picture by: Eskom
The gas-treatment plant at Majuba
UCG Schematic model
Technology diagrams

**Vertical Wells**
- Air
- Exhausted Holes
- Product

**CRIP (Controlled Retracting Injection Point)**
- Air/Oxygen
- Product
- 2nd CRIP reactor
- 1st CRIP reactor

**Steeply Dipping Bed**
- Product Gas
- Air/Oxygen

**Tunnel**
- Steam
- Air
- Product
- Flame front movement
- Mined tunnels
Long-wall mining thinking applied to UCG
New production methods simulate a Long-wall mining method for a continuous supply.
Why Air vs. O₂

<table>
<thead>
<tr>
<th>Process</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air-blow UCG</td>
<td>45.4 %</td>
</tr>
<tr>
<td>Oxygen-blow UCG</td>
<td>46.5 %</td>
</tr>
<tr>
<td>UCG with CO₂ separation</td>
<td>39.8 %</td>
</tr>
<tr>
<td>Conventional coal</td>
<td>~37 %</td>
</tr>
<tr>
<td>IGCC</td>
<td>~45 %</td>
</tr>
</tbody>
</table>

Oxygen is better for:

- Increased CO:CO₂ ratio
- Improves CV
- Improved gasification stability
- Better cavity growth
- 60% reduction in volume of compressed gas injected into seam
Isothermal Flow Modelling
Variability in historical data

Product gas, volume% (dry)

Gas calorific value, MJ/m³ (dry, STP)

Other
Carbon dioxide
Hydrogen
Carbon monoxide
Methane
Calorific value
Another way of looking at it...

- Surface (Air)
- Surface (Oxygen)
- Underground (Air)
- Underground (Oxygen)
- Underground (Steam)
- Natural gas

Carbon monoxide

Major combustible gas concentrations only

Synthesis gas

$H_2:CO = 1:1$

$H_2:CO = 2:1$

Hydrogen

Methane
Opportunity definition for UCG

1. Utilisation of isolated deep coal reserves which can not be otherwise economically exploited

2. Increased efficiency of fossil fuel use (up to 95%)

3. Extension of mine life through optimal coal utilisation

4. Reduction of environmental footprint (no coal or ash handling required)

5. Mining-related hazards are avoided
Current above ground gasification processes

Coal Mining
Coal seam
Coal exploration & drilling

Coal
Steam, oxygen or air
Ash
Syngas for electricity generation

Ash dump
With UCG, the same coal gets gasified

Coal exploration & drilling

Coal seam

Oxygen or air

Syngas for CTL or electricity generation

Ash

Surface
Above ground versus under ground
The electricity generation process

GASIFICATION & PROCESSING

Potential for CO₂ removal

GAS CYCLE

Power

Steam cycle

Feed Coal Feed Gas Feed Water

Gasifier

Liquid waste

Feedwater

Solid waste

Clean gas

Gas cleaning

Compressed air

Combustor

Hot gas

Air

Power Out 1

Gas turbine

Compressor

Exhaust gas

Power In 1

HRSG

HP steam

Power Out 2

Steam turbine

FLUE gas

Condensate

Cooling water

LP steam

RCY-1

Compressed air

GAS CYCLE

Power

Steam cycle

Feed Coal Feed Gas Feed Water

Gasifier

Liquid waste

Feedwater

Solid waste

Clean gas

Gas cleaning

Compressed air

Combustor

Hot gas

Air

Power Out 1

Gas turbine

Compressor

Exhaust gas

Power In 1

HRSG

HP steam

Power Out 2

Steam turbine

FLUE gas

Condensate

Cooling water

LP steam

RCY-1
Low Cost Low Emission Power

- Surface Coal Gasifier IGCC with Shift & CO₂ removal from syngas
- Surface Coal Gasifier IGCC with CO₂ removal from syngas
- Surface Coal Gasifier IGCC using untreated syngas
- Natural Gas Combined Cycle
- Conventional PF Coal
- UCG-IGCC with Shift & CO₂ removal from syngas
- UCG-IGCC with CO₂ removal from syngas
- UCG-IGCC using untreated syngas

TARGET OPTION

Greenhouse emissions, tCO₂/MWh
Cost of electricity, $/MWh