A preliminary evaluation of post-combustion CO₂ capture in a CSIRO pilot plant using MEA at Loy Yang Power in Australia

Fourth International Conference on Clean Coal Technologies (CCT2009)
Dresden, Germany, 18-21 May 2009

Yuli Artanto
Greetings.....

Safety First
安全第一
Sûreté
Utamakan Selamat
безопасность
Aims

• To obtain practical experience with real flue gases from a lignite fired power plant
• To test the performance of pilot plant under nominal conditions
• To assess the effect of operational parameters alteration on the performance of CO$_2$ absorption.
• To compare the results with simulation calculations

AUSTRALIA

- Stationary Energy: 52.30%
- Transport: 14.40%
- Fugitive Emissions: 6.30%
- Industrial Processes: 5.20%
- Agriculture: 16.40%
- Land use, Land-use change and forestry: 2.50%
- Waste: 3.00%

Total: 550 Mt CO₂e

VICTORIA

- Transport: 3.50%
- Industrial Processes: -3.50%
- Agriculture: 12.40%
- Land use, Land-use change and forestry: 16.30%
- Waste: 52.30%
- Stationary Energy: 16.40%

Total: 122 Mt CO₂e

Trend of Net GHG Emissions from Stationary Energy in Victoria

Brown coal in Victoria

- The Latrobe Valley situated in Victoria has a brown coal hub
- 33 billion tonnes easily accessible (400 billion tonnes in reserve)
- 500 years of supply at current rates of production
- Low in ash (incl. heavy metals), sulfur and nitrogen – but has a higher moisture content
- Foreseeable feedstock – generate electricity, liquid (transportation) and solid (export) fuels and chemicals
Electricity Generated in Victoria

94% of electricity is generated from power stations fuelled with lignite/brown coals

Conventional power plants in Victoria emit about 1,225 kg of CO₂/MWh

Potential capacity of Gippsland Basin deep saline aquifers: 33,300 MT (630 TCF or 275 years of Victorian emissions)
Succinct distance for production, CCS and consumption of electricity
Post Combustion CO$_2$ capture pilot plant developed by CSIRO in Australia

- Tarong power station
- Munmorah power station
- Loy Yang power station

Amines – black coal
Ammonia – black coal
Amines – brown coal
Latrobe Valley Post-Combustion Capture Project

Energy Technology Innovation Strategy (ETIS)

[Logos of Victoria, Loy Yang Power, National Research, CSIRO, CO2 CRC, International Power]
Pilot plant scale: 150 kg/h
Design CO$_2$ capture: 90%
Solvent base: MEA 30%
Commissioning: July 2008
Plant Specification

Absorbers:
- 200DN stainless steel pipe (211 mm ID)
- The column height: 9.4 m
- Total packing height: 3.7 m (2 x 1.35 m)

Stripper:
- 150DN stainless steel pipe (161 mm ID)
- Stripper height: 6.9 m
- Packing height: 3.9 m.

Pall ring packing, (i) packing size in every section is 160 mm, (ii) specific area of packing is 338 m²/m³ and (iii) packing factor (1/m) is 306.
Performance of pilot plant at different conditions using MEA-based solvent

Installation and commissioning

Performance of pilot plant at different conditions using blended & novel solvent

Applicability study for integration between PCC and (New/existing) power station

2008 2009 2010 2011
Experimental Program FY2008/2009

Campaign 01
• Handling the plant system correctly
• Fine tune nominal conditions using 30% MEA and real flue gas – as base line

Campaign 02
• The effect of changing operational conditions: flue gas rate (at constant gas/solvent ratio), solvent flow rate, reboiler temperature, stripper pressure
Experimental Program FY2008/2009

Campaign 03

- The effect of changing absorber temperature
- Temperature profile of absorber

Nominal conditions for fine-tuning test

- MEA concentration: 30%
- Flue gas rate: 150 m³/h
- Solvent rate: 0.34 m³/h
- Absorber inlet Temp.: 40°C
- Stripper Press.: ~0.6 bar(g)
- Reboiler Temp.: ~116°C
Loy Yang Pilot Plant (150 kgCO₂/hr)
Simplified Process Flow Diagram

- Flue gas (Knock-out drum)
- Flue gas pre-treatment
- Absorber 2
- Condensates and Particulates
- Make-up NaOH
- Spent NaOH recycled
- Absorber 1
- Treated flue gas
- Make-up
- Solvent make-up Tank
- CO₂ product
- Steam
- Condensate
- Reboiler (plate type)

Gas sampling point
Liquid sampling point
Three different approaches to determine %CO$_2$ recovery

**Treated flue gas based:**

$$100 \times \frac{CO_2^{\text{after pretreatment (toABS column 2)}} - CO_2^{\text{in treated fluegas}}}{CO_2^{\text{after pretreatment (toABS column 2)}}}$$

**CO$_2$ product (from stripper) based:**

$$100 \times \frac{CO_2^{\text{produced from stripper}}}{CO_2^{\text{after pretreatment (toABS column 2)}}}$$

**Liquid analysis based:**

$$100 \times \frac{CO_2^{\text{in rich solvent from ABS column 2}} - CO_2^{\text{in lean solvent enter ABS column 1}}}{CO_2^{\text{after pretreatment (toABS column 2)}}}$$
### Typical flue gas conditions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>INLET</th>
<th>TO ABS COLUMN 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEMPERATURE</td>
<td>150 – 170</td>
<td>35 – 45</td>
</tr>
<tr>
<td>$H_2O$ (%v-wet)</td>
<td>20 – 22</td>
<td>6 – 9</td>
</tr>
<tr>
<td>$CO_2$ (%v-wet)</td>
<td>10 – 11</td>
<td>11 – 12</td>
</tr>
<tr>
<td>$O_2$ (%v-wet)</td>
<td>4 – 5</td>
<td>5 – 6</td>
</tr>
<tr>
<td>$SO_2$ (ppmv-wet)</td>
<td>149 – 152</td>
<td>4 – 5</td>
</tr>
<tr>
<td>$NO_X$ (ppm-wet)</td>
<td>184 – 186</td>
<td>194 – 195</td>
</tr>
</tbody>
</table>
CO$_2$ balance

Flue gas = 125 m$^3$/h, solvent flow = 0.34 m$^3$/h
Effect of L/G changes on CO₂ recovery

Liquid analysis  CO₂ product based  treated flue gas based

CO₂ recovery (%) vs. L/G (L/Nm³)
Effect of L/G changes on CO$_2$ recovery

CO$_2$ recovery (%) vs. L/G (L/Nm$^3$)

Graph showing the relationship between L/G (L/Nm$^3$) and CO$_2$ recovery (%).
Effect of L/G changes on heat duty

Reboiler heat duty (MJ/kg CO₂)

L/G (L/Nm³)

(69%)

(60%)

(72%)

(75%)

(81%)

(83%)

(83%)

(84%)

(90%)

(89%)
Comparison of CO₂ absorbed between ABS columns 1 and 2

Co₂ recovered (kg/h)

ABS column 1  ABS column 2  Total

L/G (L/Nm³)

Flue Gas pre-treatment  Absorber 2  Absorber 1

National Research
FLAGSHIPS  CSIRO
Simulation based on WinSim Design II for Windows
Temperature profiles in ABS 1

ABS 1: captured 15.4 kg CO$_2$/h

Gas rate = 150 m$^3$/h
Solvent rate = 0.34 m$^3$/h
Temperature profiles in ABS 2

ABS 2: captured 4.3 kg CO$_2$/h

Gas rate = 150 m$^3$/h
Solvent rate = 0.34 m$^3$/h
### CO₂ recovery between WinSim simulation and Pilot plant experiment

<table>
<thead>
<tr>
<th>L/G (L/Nm³)</th>
<th>Simulation</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ABS 1</td>
<td>ABS 2</td>
<td>ABS 1</td>
<td>ABS 2</td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td>11.8</td>
<td>8.2</td>
<td>11.2</td>
<td>3.6</td>
<td></td>
</tr>
<tr>
<td>2.4</td>
<td>12.6</td>
<td>7.5</td>
<td>13.5</td>
<td>3.2</td>
<td></td>
</tr>
<tr>
<td>2.7</td>
<td>13.1</td>
<td>10.3</td>
<td>15.4</td>
<td>4.3</td>
<td></td>
</tr>
</tbody>
</table>
Temperature profiles in Stripper

Gas rate = 150 m³/h
Solvent rate = 0.34 m³/h

Temperature (°C)
Relative distance from the bottom (m)
<table>
<thead>
<tr>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIMS</td>
</tr>
<tr>
<td>INTRODUCTION</td>
</tr>
<tr>
<td>PCC DEVELOPING BY CSIRO IN AUSTRALIA</td>
</tr>
<tr>
<td>EXPERIMENTAL PROGRAM</td>
</tr>
<tr>
<td>RESULTS</td>
</tr>
<tr>
<td>FUTURE WORKS</td>
</tr>
</tbody>
</table>
Future Works

Campaign 04 & 05
• Similar to campaigns 1-2 and 3, but using blended solvent

Campaign 06 & 07
• $\text{CO}_2$ concentration profile in Absorbers
• Trials with developmental solvent from semi-commercial scale
• Contaminants in treated flue gas emissions and product degradation
Conclusion

- Pilot plant trials run successfully and CO$_2$ balance is satisfactory
- A minimum reboiler heat duty versus L/G ratio is observed
- Increasing L/G ratio improve CO$_2$ recovery
- Simulation and experiment show similar trend in temperature profiles of the stripper
- Simulation gives higher CO$_2$ recovery than that of pilot plant
Acknowledgements

Energy Technology Innovation Strategy (ETIS)

Paul Feron (CSIRO PCC Stream Manager), Aaron Cottrell (Head of pilot plant operations) and Moetaz Attalla (Head of solvent development)

Loy Yang Pilot Plant: Erik Meuleman (Project Manager), James Jansen (Plant Engineer), Mick Osborn (Assistant Plant Engineer) and Pauline Pearson (Experimental Chemist)

Leigh Wardhaugh, Scott Morgan, Andrew Allport, James McGregor, Rob Rowland, Terence Chow, Ashleigh Cousins and Doug Palfreyman