Air Separation Unit (ASU) and CO$_2$ Processing Unit (CPU) for Oxy-Coal Power Plant

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APP OFWG capacity building course
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Outline

- Economic analysis for CO$_2$ capture
- ASU (Air Separation Unit)
- CPU (CO$_2$ Processing Unit)
- Jamestown demonstration project
- Summary
Oxy-Coal Power Plant

Excess $O_2$ in combustion

Air Leak

FGR (Flue gas recirculation)

$O_2$ purity

CO$_2$ Purification & Compression

Inerts

CO$_2$ Purity Specification

Industrial Gas Technologies

$O_2$, $N_2$
## Economic Analysis Assumptions

**January 2007 Study**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Assumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Power Plant Capital cost</td>
<td>$1600/kW net</td>
</tr>
<tr>
<td>Net Output (base and oxy-coal)</td>
<td>600 MW</td>
</tr>
<tr>
<td>Base Plant Efficiency</td>
<td>39% HHV</td>
</tr>
<tr>
<td>Operating rate</td>
<td>90%</td>
</tr>
<tr>
<td>Coal</td>
<td>Illinois #6</td>
</tr>
<tr>
<td>Coal Cost</td>
<td>$1.5/MMBtu (HHV)</td>
</tr>
<tr>
<td>Air Leak</td>
<td>3% of wet flue gas</td>
</tr>
<tr>
<td>$O_2$ Purity</td>
<td>95%</td>
</tr>
<tr>
<td>$CO_2$ Purity</td>
<td>99.9%</td>
</tr>
<tr>
<td>$CO_2$ Pressure</td>
<td>1500 psia</td>
</tr>
<tr>
<td>FGD, SCR</td>
<td>Included</td>
</tr>
<tr>
<td>$CO_2$ Pipeline &amp; Injection</td>
<td>Included</td>
</tr>
</tbody>
</table>
Power Breakdown

![Power Breakdown Chart]

- **Misc**
- **CPU**
- **ASU**
- **Aux**
- **Net**
Effect of O₂ Purity

- CO₂ cost, $/ton
- CO₂ Recovery
- $/ton captured
- $/ton avoided

O₂ Purity, %

- 90.0%
- 95.0%
- 97.5%
- 99.5%

- 75%
- 80%
- 85%
- 90%
- 95%
- 100%
Extent of CO₂ Purification

\[ \text{CO₂ Purity, \%} \]

\[ \text{CO₂ cost, \$/ton} \]

\[ \text{$/ton captured} \]

\[ \text{$/ton avoided} \]

\[ \text{CO₂ Recovery} \]
Impact of Air Leak

- CO₂ cost, $/ton
- CO₂ Recovery
- $/ton avoided
- $/ton captured

Air Leak, %

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

0 20 40 60 80 100

PRAXAIR
ASU – Oxy-Coal ASU Technology Improvements

- Technology areas include process, heat transfer, distillation, turbomachinery, prepurification and advanced controls

- Power reduction
  - Increase thermal integration in distillation system
  - Larger efficient compressors
  - Reduce $\Delta P$s
  - Reduce $\Delta T$s

- Capital cost reduction
  - Advanced equipment design
  - Scale up to 5000 tpd single train

- Heat integration
  - Heat of compression
ASU - Advancing Distillation Process

Double Column Cycle
- LP COLUMN
- N₂
- O₂
- Air

Side Column Cycle
- HP COLUMN
- 10 - 12% Less kW
- N₂
- O₂
- Air

“Oxycoal Cycle”
- HP COLUMN
- N₂
- O₂
- Air

Less kW
- 7 - 10% Less kW

CPU – Praxair CO$_2$ Plants Globally

- 73 Locations World Wide
  - Asia – China, India, Korea, Thailand
  - Europe – Italy, Spain
  - North America – US, Canada, Mexico
  - South America – Brazil, Argentina, Bolivia, Chile, Colombia, Peru, Venezuela

- 85 Operating Units
  - Individual Plant Capacity Range: 30-600TPD

- 14,700 TPD LCO$_2$ Capacity

- Variety of sources
  - Ethanol, NG processing, ammonia, hydrogen, combustion
### CPU – Oxycoal Flue Gas Example

<table>
<thead>
<tr>
<th>Flue Gas Composition</th>
<th>mol% unless noted</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>58.7%</td>
</tr>
<tr>
<td>N₂</td>
<td>5%</td>
</tr>
<tr>
<td>Ar</td>
<td>2.4%</td>
</tr>
<tr>
<td>O₂</td>
<td>3.9%</td>
</tr>
<tr>
<td>H₂O</td>
<td>29.8%</td>
</tr>
<tr>
<td>HCl</td>
<td>~370 ppm</td>
</tr>
<tr>
<td>HF</td>
<td>~70 ppm</td>
</tr>
<tr>
<td>NOx</td>
<td>~280 ppm</td>
</tr>
<tr>
<td>SOx</td>
<td>~280 ppm</td>
</tr>
<tr>
<td>Hg</td>
<td>~10 μg/m³</td>
</tr>
<tr>
<td>CO</td>
<td>~280 ppm</td>
</tr>
<tr>
<td>Particulate Matter</td>
<td>~14 mg/m³</td>
</tr>
</tbody>
</table>
**CPU – Target for High Purity CO$_2$**

<table>
<thead>
<tr>
<th>Component</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO$_2$</td>
<td>&gt;99.8%</td>
</tr>
<tr>
<td>H$_2$O</td>
<td>&lt;10 ppmv</td>
</tr>
<tr>
<td>O$_2$</td>
<td>&lt;50 ppmv</td>
</tr>
<tr>
<td>CO</td>
<td>&lt;50 ppmv</td>
</tr>
<tr>
<td>SOx</td>
<td>&lt;500 ppmv</td>
</tr>
<tr>
<td>NOx</td>
<td>&lt;300 ppmv</td>
</tr>
<tr>
<td>Hg</td>
<td>&lt;1 ppbv</td>
</tr>
</tbody>
</table>
CPU Developments

- US DOE supported 3-yr (2009 – 2011) $5.4 MM program
  - High CO₂ recovery (>95%)
  - SOx/NOx/Hg removal
- Fate of trace impurities
- Heat integration
Jamestown Demonstration Project

50 MWe Oxy-Coal CFB Power Plant with CO₂ Capture and Storage
Jamestown Demonstration Project

- 50 MW (gross) oxy-CFB combined heat and power
- $6MM authorized by NY state for engineering studies
- $0.8MM received from NYSERDA for geology evaluation
- Proposal to DOE in Jan 2009 for financial support
- Regulatory support from NY state
- Permits and approvals expected to take 16 – 24 months
- Target start date 2013

Directly Scalable to 500+ MW
Emissions Comparison

*Using Patented Praxair technology.*
Summary

- Optimum O$_2$ purity range defined
- Air leak in boiler must be minimized
- Advanced ASU and CPU technologies under development
- Potential for reducing power for ASU by 10 – 20%
- DOE award for pursuing CPU technology development
- 50 MWe CCS demonstration project planned