Advanced Hydrogen and CO₂ Capture Technology for Sour Syngas

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Air Products provides technology to capture CO₂ from fossil-fuel-based processes

**Hydrogen** production from natural gas with CO₂ capture
- For power generation, vehicle fuels, refinery applications

**Oxyfuel** technology for pulverized coal boilers
- Amenable to both new-build supercritical power plants and retrofitting the large installed base of existing coal-fired assets

**CO₂ capture from gasification**
- Integrated CO₂ capture and acid gas removal

**Advanced separation** technology
- CO₂ technology using membranes, adsorption, absorption and cryogenic systems
Simplified Gasification Flowsheet for $\text{H}_2$ Production and $\text{CO}_2$ Capture

- **“Conventional” Route**
  - Bulk AGR
  - Polishing PSA
  - $\text{CO}_2$ and $\text{H}_2\text{S}$ separated
  - Tailgas philosophy

- **Acid Gas Removal**
  - Physical solvents
  - Multi-column, multi-flash process
  - Heat integration
  - Minimizing cooling load
  - Manage impurities

From Gasifier → Water Gas Shift → Cooling (-40 to 32 °F) → AGR → Claus Plant

$\text{H}_2$ → PSA → $\text{CO}_2$ → Vent → Sulfur

$\text{H}_2\text{S}$ → CO$_2$
Air Products' "Sour PSA" Technology for H\textsubscript{2} Production and CO\textsubscript{2} Capture

- Improved route
- Single step purification
- Based on existing PSA technology
- Designed to meet H\textsubscript{2} purity
  - High Purity H\textsubscript{2}
  - Lower purity for power
  - Sulfur slip of < 3 ppmv, can design for ppb applications
- Reduced capital and operating cost
- Reduced cooling duty, no chilling or refrigeration
- CO\textsubscript{2} and H\textsubscript{2}S rejected in tailgas
Tailgas Disposition and Integration

Sour PSA

H₂S, CO₂

GTCC

H₂, N₂

HRSG

Air, Exhaust

Combustor

O₂, SOₓ, NOₓ

CPU

H₂SO₄, HNO₃

Vent, CO₂
Sour PSA Technology Development

- Screening by H₂S exposure tests
- Preliminary characterization
- Selection for additional testing
Sour PSA Technology Development

- Flexible arrangement: PSA or TSA
- Proof of concept on actual syngas
- Adjust operational parameters
- Advanced characterization
- Enabled rapid model development
- Multiple feedstocks
H$_2$S Capacity Stabilizes

![Graph showing H$_2$S Capacity over Number Cycles for different loads and fresh adsorbent.]

- **Bed A 1st load**
- **Bed B 1st load**
- **Bed A 2nd load**
- **Bed B 2nd load**
Sour Combustor Development

- **Design Basis**
  - Oxy-Tailgas burner
  - Leverage off oxy-fuel combustion expertise
  - Single or multiple burners
  - Housed in a fired heater or package boiler

- **Status**
  - Designed and tested prototype burners
  - Conducted tests with $\text{H}_2\text{S}$ laden stream
  - Stability map established
  - Performance mapping underway
**CO$_2$ Purification Unit**

- Reactive purification technology
  - High pressure NOx catalyzed oxidation of SO$_2$ to H$_2$SO$_4$ acid
  - Further purification to remove water and inerts
  - Flowsheets for storage or EOR grade CO$_2$ applications

- Originally developed for oxycoal power boiler applications
  - Currently in the pilot phase of development

- Extended for sour combustion flue gas
## Techno-Economic Benefits

<table>
<thead>
<tr>
<th>Case</th>
<th>Units</th>
<th>High Purity H₂</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Base</td>
<td>Sour PSA</td>
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<tr>
<td>Petcoke Input</td>
<td>MT/d</td>
<td>4,000</td>
<td>4,000</td>
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<tr>
<td>H₂ Produced</td>
<td>kNm³/hr</td>
<td>305</td>
<td>299</td>
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<tr>
<td></td>
<td>MMSCFDD</td>
<td>279</td>
<td>273</td>
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<tr>
<td>Power Produced</td>
<td>MW&lt;sub&gt;net&lt;/sub&gt;</td>
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<td></td>
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<tr>
<td>% CO₂ Captured</td>
<td></td>
<td>~95%</td>
<td>&gt;99%</td>
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<tr>
<td>Capital Savings</td>
<td>Millions USD$</td>
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<tr>
<td>Operating Savings</td>
<td>Millions USD$/yr</td>
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<tr>
<td>Reduction in CO₂ Capture Cost</td>
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<td>25.2%</td>
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</tbody>
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Air Products is developing a proprietary low-cost CO$_2$ capture option for pre-combustion systems
- Applicable to H$_2$ and power production

The technology consists of:
- H$_2$ PSA adapted to handle sour syngas
- Low-BTU oxyfuel burner
- SO$_x$, NO$_x$, and inert removal system developed by Air Products for oxyfuel coal combustion

Potential advantages over the state of the art:
- Lower capital and operating costs
  - 25 % reduction in the cost of CO$_2$ capture
- Feasible to achieve ~100 % CO$_2$ capture rate
Scale-Up Pathway

Lab scale Gasifier / PSA

Design of pilot plant

Grand Forks, ND

EERC

Calgary, Canada

AERI

Pilot

Adsorbent life tests

H<sub>2</sub>S/CO<sub>2</sub> PSA

H<sub>2</sub> Product

H<sub>2</sub>S+CO<sub>2</sub>

Q

O<sub>2</sub>

CO<sub>2</sub>
Thank you
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