Advanced Hydrogen and CO₂ Capture Technology for Sour Syngas

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Air Products PLC
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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 H\textsubscript{2} Production and CO\textsubscript{2} Capture

- "Conventional" Route
  - Bulk AGR
  - Polishing PSA
  - CO\textsubscript{2} and H\textsubscript{2}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
Air Products' "Sour PSA" Technology for $H_2$ Production and $CO_2$ Capture

- Improved route
- Single step purification
- Based on existing PSA technology
- Designed to meet $H_2$ purity
  - High Purity $H_2$
  - 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
- $CO_2$ and $H_2S$ rejected in tailgas
Tailgas Disposition and Integration

Sour PSA

H₂

GTCC

H₂S

CO₂

Air

N₂

HRSG

Exhaust

Combustor

O₂

SOₓ

NOₓ

Q

CPU

HNO₃

H₂SO₄

Vent

CO₂
Sour PSA Technology Development

- Passive Adsorbent Testing (EERC)
- Build Mobile PSA
- Coal Testing (EERC)
- Alternative Flowsheet Development
- Petcoke Testing (EERC)

- Screening by H$_2$S exposure tests
- Preliminary characterization
- Selection for additional testing
Sour PSA Technology Development

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- Build Mobile PSA
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- Alternative Flowsheet Development
- Petcoke Testing (EERC)

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

Supporting text:

- Supported by Alberta Innovates Energy and Environment Solutions

Image descriptions:
- Passive Adsorbent Testing (EERC) setup.
- Build Mobile PSA equipment.
- Coal Testing (EERC) facility.
- Alternative Flowsheet Development
- Petcoke Testing (EERC) station.
H₂S Capacity Stabilizes

- **Fresh adsorbent**
- **Bed A 1st load**
- **Bed A 2nd load**
- **Bed B 1st load**
- **Bed B 2nd load**

The graph shows the H₂S capacity (mmole/g) over the number of cycles. The capacity stabilizes at approximately 1 mmole/g after several cycles for both beds A and B.
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 H₂S laden stream
  - Stability map established
  - Performance mapping underway
Reactive purification technology
- High pressure NOx catalyzed oxidation of SO₂ to H₂SO₄ acid
- Further purification to remove water and inerts
- Flowsheets for storage or EOR grade CO₂ 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>
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</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 MMSCFD</td>
<td>305</td>
<td>299</td>
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<tr>
<td>Power Produced</td>
<td>MWₙₑᵗ</td>
<td>279</td>
<td>273</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$</td>
<td>106</td>
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<tr>
<td>Operating Savings</td>
<td>Millions USD$/yr</td>
<td>24</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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Summary and Conclusions

- Air Products is developing a proprietary low-cost CO₂ capture option for pre-combustion systems
  - Applicable to H₂ and power production

- The technology consists of:
  - H₂ PSA adapted to handle sour syngas
  - Low-BTU oxyfuel burner
  - SOₓ, NOₓ, 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 CO₂ capture
  - Feasible to achieve ~100 % CO₂ capture rate
Scale-Up Pathway

H₂S/CO₂ → PSA → H₂ Product
Sour Syngas [H₂S+CO₂] → CO₂
O₂ → [Q]

Design of pilot plant

Lab scale Gasifier / PSA
Adsorbent life tests

EERC
Grand Forks, ND

AERI
Calgary, Canada

Grand Forks, ND

Pilot

EERC

AERI

Alberta Innovates Energy and Environment Solutions

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