Field Testing of a Warm-Gas Desulfurization Process in a Pilot-scale Transport Reactor System

Gasification Technologies Conference 2006

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RTI International

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Objective:

Pilot scale demonstration of RTI/Eastman warm syngas desulfurization technology with commercial syngas

- Transport reactor system
- Regenerable RTI-3 sorbent

Technical and Economic comparison versus existing AGR technologies
Pressure: 100- 1000 psig

ZnO + H₂S → ZnS + H₂O
ZnO + COS → ZnS + CO₂
(600 -1000°F)

ZnS + 3/2O₂ → ZnO+SO₂
(1100-1400°F)

SO₂ / N₂ TO SCRUBBER OR DSRP

RAW SYNGAS

Sulfided Sorbent

Riser

Standpipe

Cyclone

ZnO + H₂S
ZnO + COS
ZnS + H₂O
ZnS + CO₂
ZnS + 3/2O₂
ZnO + SO₂
600 -1000°F
1100-1400°F

Sorbed Recycle

Raw Syngas

Regenerated Sorbent

Mixing Zone

Solids Withdrawal to Regen Loop

N₂/O₂

Clean Syngas

Raw Syngas

Sulfided Sorbent Standpipe

Riser

Mixing Zone

Regenerated Sorbent to Absorber Mixing Zone

Cyclone
Eastman Gasification Plant

RTI Desulfurization Unit / DSRP
# Summary of 2005 Syngas Runs

<table>
<thead>
<tr>
<th></th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong># of Runs</strong></td>
<td></td>
<td>33</td>
</tr>
<tr>
<td><strong>Duration, hr</strong></td>
<td>0.4</td>
<td>23.5</td>
</tr>
<tr>
<td><strong>Average Duration</strong></td>
<td></td>
<td>4.7</td>
</tr>
<tr>
<td><strong>Total Syngas hr</strong></td>
<td></td>
<td>156.4</td>
</tr>
<tr>
<td><strong>System Pressure, psig</strong></td>
<td>130</td>
<td>800</td>
</tr>
<tr>
<td><strong>Absorber Temp, °F</strong></td>
<td>740</td>
<td>975</td>
</tr>
<tr>
<td><strong>Effluent Sulfur Concentration, ppmv</strong></td>
<td>0.5</td>
<td>5</td>
</tr>
</tbody>
</table>
Sulfur Absorption/Regeneration Rates
150 psig Abs 762 °F Regen 1330 °F
Summary of EMN 2005 Pilot Plant Testing

- Sorbent can achieve:
  - >99.7% sulfur removal
  - Reduce total sulfur to 0.5 to 5 ppm
- Sorbent can be regenerated
  - Regenerator equipment design issues prevented steady state operation
- Regenerated sorbent has similar ability to absorb sulfur
- Attrition resistance increases
  - DI of fresh sorbent: 9.0
  - DI of used sorbent: 7.6
System Modifications

• Regenerator Modifications:
  – Mixing Zone
  – Standpipe

• Improve control and reliability of Regenerator:
  – Sorbent flow
  – Reactor temperature
### 2006 Results to Date

Live feeds since Sept. 5, 2006

<table>
<thead>
<tr>
<th></th>
<th>Pressure, psig</th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>300</td>
<td>450</td>
<td>600</td>
<td></td>
</tr>
<tr>
<td><strong>Inlet Concentration, S ppmv</strong></td>
<td>8,116</td>
<td>8,159</td>
<td>8,212</td>
<td></td>
</tr>
<tr>
<td><strong>Effluent Concentration, S ppmv</strong></td>
<td>6.9</td>
<td>5.7</td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td><strong>S Absorbed, lb/hr</strong></td>
<td>4.26</td>
<td>4.36</td>
<td>4.41</td>
<td></td>
</tr>
<tr>
<td><strong>S Removal, %</strong></td>
<td>99.91</td>
<td>99.93</td>
<td>99.97</td>
<td></td>
</tr>
</tbody>
</table>

*All data are averages over multiple hours of operation*
Sulfur in Clean Syngas, ppbv

H2S Removal, 99.97%

COS Removal, 99.96%
Direct Sulfur Recovery Process

\[ \text{SO}_2 + \text{H}_2 \rightarrow \frac{1}{n} \text{S}_n + \text{H}_2\text{O} \]

Pilot demonstration Oct. – Nov. 2006
Multicontaminant Control

Removal of other pollutants (NH$_3$, HCN, HCl and heavy metals like Hg, As, Cd, Se) from syngas is necessary to reduce overall cost of IGCC-based systems.

RTI & Eastman are pursuing removal of a host of contaminants other than sulfur from syngas at high-temperature, high-pressure conditions.

- Coal-derived Syngas exposure scheduled for Dec-06 thru Jan-07

Ammonia and trace metal test skid
System Studies

• Establishment of performance criteria
• Process design
• Technical and economic analysis
  – Capital cost
  – Operating cost
  – System efficiency
• Initial Nexant Process Cases
  – Base case: GE Gasification with Selexol
  – Case 1: GE Gasification with Warm Gas Desulfurization
## CAPEX Comparison ($ million)
(Net 260 MWe)

<table>
<thead>
<tr>
<th></th>
<th>MDEA</th>
<th>Rectisol</th>
<th>Warm Gas Cleanup with DSRP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasification + solid/water handling</td>
<td>67.6</td>
<td>67.6</td>
<td>67.6</td>
</tr>
<tr>
<td>Low Temperature Gas Cooling</td>
<td>12.3</td>
<td>12.3</td>
<td>0</td>
</tr>
<tr>
<td>Sulfur Removal and Recovery</td>
<td>48.2</td>
<td>77.3</td>
<td>43.1</td>
</tr>
<tr>
<td>Balance of Plant (not including COS hydrolysis)</td>
<td>246.1</td>
<td>260.6</td>
<td>234.5</td>
</tr>
<tr>
<td><strong>Total Cost ($ million)</strong></td>
<td>374.2</td>
<td>417.8</td>
<td>345.2</td>
</tr>
<tr>
<td><strong>COS Hydrolysis needed</strong></td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Sulfur Removal down to ppmv</strong></td>
<td>50-100</td>
<td>&lt;1</td>
<td>&lt;5</td>
</tr>
<tr>
<td><strong>Potential Savings with warm gas cleanup</strong></td>
<td>Total ($MM)</td>
<td>(29.0)</td>
<td>(72.6)</td>
</tr>
<tr>
<td></td>
<td>$/KW</td>
<td>$114</td>
<td>$279</td>
</tr>
</tbody>
</table>

Source: RTI/ChevronTexaco Report to DOE
Thermal Efficiency Improvement

Case | Thermal Efficiency Change
---|---
Waste Heat Boiler | 1.7↑
Quench | 2.7↑

Assumptions:
- Nominal power output: 300MWe
- Coal input: 2607 MMBtu/hr
- Sulfur: 4.2 wt%
- Carbon conversion: 98%
- Gasification pressure: 600 psig
- CT pressure: 365 psig
- MDEA temperature: 100°F
- Warm gas cleanup: 700°F
# Comparison of Desulfurization Processes

<table>
<thead>
<tr>
<th></th>
<th>Selexol</th>
<th>RTI/Eastman</th>
<th>Rectisol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (°C)</td>
<td>&lt; 20</td>
<td>Syngas dew point to radiant cooler</td>
<td>-40</td>
</tr>
<tr>
<td>Sulfur removal (ppmv)</td>
<td>&lt;10</td>
<td>&lt;5</td>
<td>0.1</td>
</tr>
<tr>
<td>COS hydrolysis required?</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Capital cost ($/kW)</td>
<td>160</td>
<td>&lt; 100</td>
<td>200</td>
</tr>
<tr>
<td>Operating Costs (¢/kWh)</td>
<td>&lt; 0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal efficiency</td>
<td>Base</td>
<td>↑1.7 – 2.7</td>
<td>&lt; Base</td>
</tr>
<tr>
<td>Commercially available</td>
<td>Now</td>
<td>2008</td>
<td>Now</td>
</tr>
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</table>
## HTDS Scale-Up Factors

<table>
<thead>
<tr>
<th></th>
<th>EMN Pilot Plant</th>
<th>Prototype</th>
<th>Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size (MWe)</td>
<td>0.3</td>
<td>50</td>
<td>600</td>
</tr>
<tr>
<td>Gas Flow (SCFH) (Thousands)</td>
<td>17</td>
<td>2,000</td>
<td>38,000</td>
</tr>
<tr>
<td>Footprint (ft²)</td>
<td>260</td>
<td>1050</td>
<td>3000</td>
</tr>
<tr>
<td>Absorber</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixing Zone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Riser</td>
<td>15'H × 2.5”ID</td>
<td>80’H × 19”ID</td>
<td>80’H × 5.5’ID</td>
</tr>
<tr>
<td></td>
<td>40’H × 1.5”ID</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regenerator</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixing Zone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Riser</td>
<td>10’H × 1”ID</td>
<td>10’H × 14”ID</td>
<td>80’H × 3.75’ID</td>
</tr>
<tr>
<td></td>
<td>20’H × 0.75”ID</td>
<td>70’H × 12”ID</td>
<td></td>
</tr>
<tr>
<td>Sorbent Regeneration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circulation Rate (lb/h)</td>
<td>500</td>
<td>62,000</td>
<td>1,000,000</td>
</tr>
</tbody>
</table>
Conclusions

• Warm Gas Cleanup with RTI-3 Sorbent can:
  – Remove >99.9% of sulfur from syngas.
  – Achieve effluent concentrations of < 5 ppmv total sulfur.
  – Be regenerated multiple cycles, >450 operating hours and counting!
  – Offer significant capital and operating cost savings versus competing technologies.
  – Enable significant efficiency improvements, resulting in as much as 5-7% savings on feedstock (e.g., coal) and oxygen costs to produce the same electric power.
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QUESTIONS