Synthesis Gas Purification in Gasification to Ammonia/Urea Plants

GASIFICATION TECHNOLOGIES CONFERENCE

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Conversion of low valued refinery residue and coke to syngas using gasification is proven and viable for ammonia production

Case studies were conducted to evaluate today’s syngas purification technologies for ammonia and urea production

Compare the process differences between Selexol + PSA to Rectisol + N2 Wash process. Compare their capital and operating costs

The process configuration was adopted in the Coffeyville Resources Ammonia Fertilizer Complex. Operating data of the gas purification unit are reviewed
## Gas Purification Technologies

<table>
<thead>
<tr>
<th>Technology 1</th>
<th>Technology 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rectisol</strong></td>
<td><strong>Selexol</strong></td>
</tr>
<tr>
<td>Methanol solvent operates at very low temperatures. Methanol solvent is H$_2$S selective.</td>
<td>DMPEG solvent operates at mildly refrigerated or ambient temperatures. Selexol is H$_2$S selective</td>
</tr>
<tr>
<td><strong>N$_2$ Wash</strong></td>
<td><strong>PSA</strong></td>
</tr>
<tr>
<td>Fractionation process operates at cryogenic temperatures</td>
<td>Adsorption process operates at ambient temperatures</td>
</tr>
</tbody>
</table>
Case Studies

- Case 1 - Selexol/ PSA
- Case 2 - Selexol/PSA + CO₂ production
- Case 3 - Rectisol/N₂ Wash
- Case 4 - Rectisol/N₂ Wash + CO₂ production
<table>
<thead>
<tr>
<th>Selexol/ PSA</th>
<th>Rectisol/ N₂ Wash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partially remove CO₂</td>
<td>Removes all CO₂</td>
</tr>
<tr>
<td>0° to 40°F (CS Material)</td>
<td>-80°F (SS Material)</td>
</tr>
<tr>
<td>Regen by Steam</td>
<td>Regen by N₂ stripping</td>
</tr>
<tr>
<td>Syngas contains ppm levels of inerts</td>
<td>Very pure syngas product</td>
</tr>
<tr>
<td>CO₂ product at high pressure</td>
<td>CO₂ product at low pressure</td>
</tr>
</tbody>
</table>

**FLUOR®**
## Capital Cost Comparison

<table>
<thead>
<tr>
<th>Cost ($1,000)</th>
<th>No CO₂ Production</th>
<th>With CO₂ Production</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Case 1</td>
<td>Case 3</td>
</tr>
<tr>
<td>Selexol/PSA</td>
<td>Selexol/PSA</td>
<td>Rectisol/N2 Wash</td>
</tr>
<tr>
<td>Selexol Unit</td>
<td>22,862</td>
<td>N / A</td>
</tr>
<tr>
<td>PSA Unit</td>
<td>34,342</td>
<td>N / A</td>
</tr>
<tr>
<td>Rectisol/N2 Wash Units</td>
<td>N / A</td>
<td>100,800</td>
</tr>
<tr>
<td>Balance of Plant (BOP*)</td>
<td>430,080</td>
<td>412,020</td>
</tr>
<tr>
<td>Incremental Capital Costs</td>
<td>Base</td>
<td>43,596</td>
</tr>
<tr>
<td>Incremental BOP Costs</td>
<td>Base</td>
<td>(18,060)</td>
</tr>
<tr>
<td>Incremental Overall Plant Capital Costs</td>
<td>Base</td>
<td>25,536</td>
</tr>
</tbody>
</table>

*BOP Cost exclude ammonia synthesis
## Operating Cost Comparison

<table>
<thead>
<tr>
<th>Cost ($1,000)</th>
<th>No CO₂ Production</th>
<th>With CO₂ Production</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Case 1</td>
<td>Case 3</td>
</tr>
<tr>
<td>Selexol/PSA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rectisol/N₂</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wash</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Gas Purification &amp; BOP</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixed Operating Costs</td>
<td>19,430</td>
<td>19,900</td>
</tr>
<tr>
<td>Utility &amp; Feed &amp; Chemicals</td>
<td>52,980</td>
<td>54,360</td>
</tr>
<tr>
<td>Total Annual Oper. Cost</td>
<td>72,410</td>
<td>74,260</td>
</tr>
<tr>
<td><strong>Incremental Oper. Cost:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixed Operating Costs</td>
<td>Base</td>
<td>470</td>
</tr>
<tr>
<td>Utility &amp; Feed &amp; Chemicals</td>
<td>Base</td>
<td>1,380</td>
</tr>
<tr>
<td>Annual Operating Cost</td>
<td>Base</td>
<td>1,850</td>
</tr>
</tbody>
</table>
Selexol + PSA syngas is more economical than Rectisol + N$_2$ Wash in syngas purification, both in capital and operating costs

Same conclusions apply to different gasification technologies, plant capacities and types of feedstocks

The Selexol + PSA design were applied in the syngas purification process of Coffeyville Resources Coffeyville, Gasification Ammonia Complex for ammonia and urea production
Coffeyville Resources
Coffeyville, Kansas, USA
Gasification Ammonia Complex
Feedstock: 45 MT/H petroleum coke

Commercial Operation: July 2000

**Process Licensors**

Gasification: ChevronTexaco

Gas Purification Block:
- Acid Gas Removal: Selexol
- \( \text{H}_2 \) Purification: Polybed PSA

Sulfur: Black & Veatch Pritchard

Air Separation: BOC

Ammonia / UAN: Ammonia Casale / Weatherly
Coffeyville Block Flow Diagram

Air

Air Separation Unit

N₂

Ammonia Synthesis

High Purity Hydrogen

Polybed PSA

Raw H₂

Tail Gas

Quench Gasification

Petroleum Coke

O₂

Syngas Scrubbing

CO₂ Purification

Raw CO₂

CO₂ Vent

UAN Plant

Purified CO₂

Selexol 2-stage

Acid Gas

UOP Technologies

CO₂ Vent

UAN Product

NH₃ Product

UOP Technologies

Claus Unit

2-stage

Claus Plant

Petroleum Coke

Acid Gas

CO₂ Vent

O₂
Coffeyville Resources Gasification Ammonia / UAN Complex
Coffeyville Operations Summary

Operated since July 2000
- Convert pet coke to urea and ammonia using UOP Gas Purification Block
  • SELEXOL + PSA

SELEXOL Products
>90 MM SCFD of raw H₂
< 1 ppm H₂S
< 1 ppm COS
>10.6 MM SCFD of CO₂
>93% of CO₂ Removed
Acid Gas >44 mole % H₂S

PSA Product
H₂ Purity >99.3%
< 5 ppm CO
CO₂ below Det. Limits
Coffeyville Operations Summary

Operated since July 2000

- Highly Reliable
  - No Solvent-Related Issues
    - No reclaiming
    - Minimal Solvent Losses

- Meets All Product Specifications
  - H₂ Purity to PSA
  - CO₂ Purity for Urea Production
  - H₂S in Acid Gas
Conclusions

- Due to high natural gas prices, production of fertilizer products from refinery residue and coal is economically attractive.

- Coffeyville Resources has proven that UOP SELEXOL plus POLYBED PSA processes are viable for fertilizer production.

- Fluor and UOP have proven Gas Purification Portfolio for:
  - Separation of H₂S and CO₂
  - Separation of CO₂ and H₂
  - Purification of H₂
Any Questions?