Commercialization of MECS’ SolvR™ Regenerative SO₂ Technology

Presented by: Steve Puricelli
MECS, Inc
USA
Agenda

- Review of the SolvR™ System
- Evaluation and Selection of SO₂ Reduction Technologies
- SolvR™ Key Advantages
- SolvR™ Performance
- Southern States Startup Issues
- Design Improvements
- SolvR™ Opportunities
Safety Contact
SO₂ Toxicity

Odor threshold: 0.5 ppm

OSHA Permissible Exposure Limit (PEL) = 5 ppm (weighted, 8 hr avg)

Slight irritation to eyes and throat = 10 ppm

Coughing and eye irritation = 20 ppm

Strong irritation = 30 ppm

NIOSH Immediately Dangerous to Life and Health (IDLH) = 100 ppm

Death in a few minutes = 600 to 800 ppm
Édouard-Léon Scott de Martinville

Invented and patented in 1857 the earliest known sound recording device, the phonautograph

Hoped to create a form of stenography that could record the whole of a conversation without any omissions

Failed to invent a playback mechanism

Phonograph invented by Edison in 1877 revolutionized recording

Phonautograph recordings were deciphered and played back in 2008

Born: 25 April 1817

Died: 26 April 1879 (aged 62)
SolvR™ Technology

What is SolvR™?

• A regenerative SO₂ recovery system

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SolvR™ Process

Absorber

DynaWave™ Hydrator

Lean/Rich Heat Exchanger

Stripping Column

DuPont Sustainable Solutions

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Why is SolvR™ Different?

- Environmentally friendly, high capacity solvent
  - Readily available precursors
  - Used in food processing
  - Capable of high removal efficiencies
  - Generates minimal byproduct

- Lower CAPEX
  - Utilizes FRP and Low alloy materials
  - Smaller plot space

- Lower OPEX
  - Reduced energy usage
    - Regeneration done at atmospheric pressure
    - Uses low pressure steam
    - Energy recovery system further reduces steam usage
  - Minimal solvent losses
    - Robust and stable solvent
Typical Plant Layout

Absorber

Solvent Tank

SO₂ Recovery Column

Rectifier Column
Evaluation and Selection of SO2 Reduction Technologies
## Comparison of SO2 Abatement Technologies

<table>
<thead>
<tr>
<th></th>
<th>Double Abs</th>
<th>Caustic scrub</th>
<th>Peroxide scrub</th>
<th>NaHSO$_3$</th>
<th>SolvR™ Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Equipment</strong></td>
<td>• HIP</td>
<td>• Absorber</td>
<td>• Absorber</td>
<td>• Absorber</td>
<td>• Absorber</td>
</tr>
<tr>
<td></td>
<td>• CIP</td>
<td>• Oxidizing air</td>
<td>• Tail gas scrub</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Converter</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• FAT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• PumpTank</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Cooler</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Booster fan</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Effluent</strong></td>
<td>None</td>
<td>20 wt% Na$_2$SO$_4$</td>
<td>40% H$_2$SO$_4$</td>
<td>40 wt% NaHSO$_3$</td>
<td>SO$_2$ + Na$_2$SO$_4$</td>
</tr>
<tr>
<td><strong>Raw Materials</strong></td>
<td>None</td>
<td>NaOH @ $450/ton</td>
<td>H$_2$O$_2$ @ $600/ton$</td>
<td>NaOH @ $450/ton$</td>
<td>Solvent + NaOH LP steam</td>
</tr>
<tr>
<td><strong>ΔP</strong></td>
<td>80 InWC (20 kPa)</td>
<td>6-8 InWC (1.5-2 kPa)</td>
<td>6 + 4 InWC (1.5 + 1 kPa)</td>
<td>8-10 InWC (2-2.5 kPa)</td>
<td>6 + 2 InWC (1.5+0.5 kPa)</td>
</tr>
<tr>
<td><strong>Attainable Emissions</strong></td>
<td>100 ppm</td>
<td>5 ppm</td>
<td>100 ppm</td>
<td>100 ppm</td>
<td>20 ppm</td>
</tr>
<tr>
<td><strong>Reactions</strong></td>
<td>SO$_2$ + 1/2 O$_2$ -&gt; SO$_2$</td>
<td>SO$_2$ + 2 NaOH -&gt; Na$_2$SO$_3$ + H$_2$O</td>
<td>SO$_2$ + H$_2$O$_2$ -&gt; H$_2$SO$_4$</td>
<td>SO$_2$ + NaOH -&gt; NaHSO$_3$</td>
<td>Na$_2$R + SO$_2$ &lt;-&gt; Na$_2$SO$_3$ + R</td>
</tr>
</tbody>
</table>
## Capital, Operation and Maintenance

<table>
<thead>
<tr>
<th></th>
<th>Double Absorption Retrofit</th>
<th>Caustic Scrubber</th>
<th>Hydrogen Peroxide Scrubber</th>
<th>SolvR™ Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative Capital Installed Costs</td>
<td>100</td>
<td>25</td>
<td>40</td>
<td>75</td>
</tr>
<tr>
<td>Relative Operating Expenses</td>
<td>0.2</td>
<td>0.7</td>
<td>1</td>
<td>0.1*</td>
</tr>
<tr>
<td>Relative Maintenance Expenses (As a percentage of capital)</td>
<td>3</td>
<td>0.2</td>
<td>0.4</td>
<td>0.4</td>
</tr>
</tbody>
</table>

* Excludes steam cost
## Net Present Value
### Taking Acid Production Recovered into Account

<table>
<thead>
<tr>
<th>Relative Net Present Value</th>
<th>Dual Absorption Retrofit</th>
<th>Caustic Scrubber</th>
<th>Hydrogen Peroxide Scrubber</th>
<th>SolvR Scrubber</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(78)</td>
<td>(100)</td>
<td>(62)</td>
<td>(50)</td>
</tr>
</tbody>
</table>

- Using dual absorption, hydrogen peroxide scrubbing and SolvR scrubbing, the sulfur molecule (SO\textsubscript{2}) is converted/recovered and used to make product acid.

- When using caustic scrubbing, the sulfur molecule leaves with the effluent.
Other Considerations
SO2 capability, Reagent and Effluent Stream

<table>
<thead>
<tr>
<th></th>
<th>Double Abs</th>
<th>Caustic Scrubber</th>
<th>Peroxide Scrubber</th>
<th>SolvR Scrubber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outlet SO₂ (ppm)</td>
<td>100</td>
<td>5</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Reagent</td>
<td>n/a</td>
<td>NaOH</td>
<td>H₂O₂</td>
<td>NaOH (pH control)</td>
</tr>
<tr>
<td>New Effluent Stream</td>
<td>None</td>
<td>Yes</td>
<td>Maybe</td>
<td>Small</td>
</tr>
</tbody>
</table>

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SolvR™ Key Advantages

• Lowest overall cost of ownership
• Recovers SO₂ as product acid
• Capable of low SO₂ emissions
• No byproducts to market
• Uses waste energy
• Robust process
• Small footprint
• Modular design
SolvR™ Performance
At
Southern States Chemicals

- SO$_2$ emissions
- Steam consumption
- Sulfate generation and solvent losses
Actual vs. Capability

- Stack emissions controlled at 700 ppm
  - Performance limited by solvent flow over absorber
  - SO2 in lean solvent measured at 30 - 70 ppm
- Predicted stack emissions with higher absorber solvent flow
  - <10 ppm
Steam Consumption
(Based on a fixed flow of steam to the stripper)

• Estimated steam flow = 500 lb/hr

• SO$_2$ processed = 1,200 ppm -> 700 ppm
  • Lb steam / Lb SO$_2$ recovered = 9

• Extrapolated to <10 ppm conditions
  • Lb steam / Lb SO$_2$ recovered = 3.5
Sulfate Generation

Sodium Sulfate Production, Actual IC Data

- P1 - Absorber Base/Stripper Feed
- P2 - Stripper Base Make
- P3 - Absorber Feed
- P1 Total Solids, wt%
- P2 Total Solids, wt%
- P3 Total Solids, wt%

Na2SO4 (wt %)

Total Solids, wt%

Time (hrs)

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Sulfate Generation

- Prior to chimney tray failure
  - 0.5% of throughput was converted to Na$_2$SO$_4$
    - (Na$_2$-R + SO$_4$ -> Na$_2$SO$_4$ + R)

- After rerouting of SO2 laden saturator stream to stripping tower
  - 50% increase in Na$_2$SO$_4$ production

- Minimal stack losses due to extremely low volatility
Solvent Performance

- Controlling sulfate concentration in the solvent is important

- Some accumulation of chlorides and metal ions in solvent occurred, but no affect on performance
SolvR™ Startup Issues

- Chimney Tray Leakage
- Solvent in Steam Lines
- Stack Opacity
  - Mist Generation
  - $\text{SO}_3$ Slip
Chimney Tray Leak

Solvent mixed with quench water

- Dilution water contaminated
- Reduced steam consumption to achieve neutral water balance
Chimney Tray Leak

Possible Causes:
- Peripheral seal leak
- Damaged riser
- Overflow

Temporary Solution
- Discontinued use as dilution water
- Used live steam only to replace evaporation losses
- Controlled level by routing saturator effluent to the solvent tank
Solvent in Stripping Steam Line

Return flow from the reboiler was entering the LP steam inlet nozzle.

Corrected by use of a gas injection nozzle
Stack Opacity After Initial Operation

Possible Causes:
• Mist
• SO$_3$ slip

Plant #2 with SolvR
Stack After Adjusting Absorbing Tower Parameters
Design Improvements
Eliminate the SO$_2$ Blower

Operating the stripper under pressure can eliminate the SO2 blower
Eliminate Stages in the Rectification Column

Interim operation showed that water saturated with SO2 did not have a significant impact on stripper performance.
Practical Application of SolvR™
SolvR™ Generates New Opportunities

- Innovating our core technologies
- Improving adjacent technologies

New Low Capital Sulfuric Acid Process

SolvR™ Technology

SolvR™ after Claus

Debottlenecking of existing Sulfuric Acid Plants

Hybrid Plants

New High Energy Recovery Acid Process Maxene™

Low Capital Sulfuric Acid Plants

Gas Plants

Refineries

High Energy Recovery Sulfuric Acid Plants
SolvR™ Sulfuric Acid Debottlenecking

- Advantages
  - Low capital investment
  - Low SO$_2$ emissions

- Disadvantages
  - Lower specific steam production
12.2%
1,500 ppm
Hybrid Sulfuric Acid Plants (High Energy Recovery)
Hybrid Sulfuric Acid Flow Scheme
## Relative Overall Order of Magnitude Savings

### 2,400 MTPD

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>Conventional</th>
<th>SolvR + HRS</th>
<th>NPV Δ Conventional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall TIC</td>
<td>1.0</td>
<td>1.2</td>
<td>1.1</td>
<td>($8 MM)</td>
</tr>
<tr>
<td>Parasitic power (MW)</td>
<td>4.3</td>
<td>4.3</td>
<td>3.5</td>
<td>$3.5 MM</td>
</tr>
<tr>
<td>Power generation (MW)</td>
<td>33</td>
<td>39</td>
<td>42</td>
<td>$38 MM</td>
</tr>
<tr>
<td>SolvR steam (MW)</td>
<td></td>
<td>(1.6)</td>
<td></td>
<td>($7 MM)</td>
</tr>
<tr>
<td>Total NPV</td>
<td></td>
<td></td>
<td></td>
<td>$26.5 MM</td>
</tr>
</tbody>
</table>

### Notes:
1. Discount rate = 9% for 30 years
2. Electricity = $0.05/kWH
3. LP steam = $8/MT
4. SolvR steam = 16 T/hr at 5 T/T
Claus + SolvR™
Advantages of SolvR in Claus Tail Gas Applications

- No reactor required
- No reducing gas generator required
Future Claus Configuration Using SolvR™

**FIG. 1**
Southern States Chemicals
SolvR™ Unit

Phonautograph

Original Edison Tin Foil Phonograph
Questions?