Development of Mixed-Salt Technology for CO$_2$ Capture from Coal Power Plants

FE0012959

Presented By  Indira S. Jayaweera
SRI International
CA, USA

2014 NETL CO$_2$ Capture Technology Meeting
July 28-August 1, Pittsburgh PA
Project Goals

Overall Project Goal is to demonstrate that Mixed-Salt technology can capture CO₂ at a 90% efficiency and regenerate at 95% CO₂ purity at a cost of $40/tonne or less of CO₂ captured by 2025.

Budget Period 1:
• Demonstrate the absorber and regenerator processes individually with high efficiency and low NH₃ emission and reduced water use compared to the state-of-the-art ammonia-based technologies.

Budget Period 2:
• Demonstrate the high-pressure regeneration and integration of the absorber and the regenerator
• Demonstrate the complete CO₂ capture system with low cost production of CO₂ stream, optimize the system operation, and collect data to perform the detailed Techno-Economic analysis of CO₂ capture process integration to a full-scale power plant.
Project Team and Organization

NETL Project Manager: Steven Mascaro

Project Team and Technical Leaders

SRI- Indira Jayaweera; OLI Systems (OLI)- Andre Anderko; Stanford University - Adam Brant; Aqueous Systems Aps (ASAp)- Kaj Thomsen; Politecnico De Milano (POLIMI)- Gianluca Valenti; and Eli Gal
# Project Budget

<table>
<thead>
<tr>
<th></th>
<th>Budget Period 1 10/1/13 - 12/30/14</th>
<th>Budget Period 2 1/1/15 - 3/31/16</th>
<th>Total 10/1/13-3/31/16</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Project Cost</strong></td>
<td>$1,019,650</td>
<td>$1,102,092</td>
<td>$2,121,742</td>
</tr>
<tr>
<td><strong>DOE Share</strong></td>
<td>$819,534</td>
<td>$878,113</td>
<td>$1,697,647</td>
</tr>
<tr>
<td><strong>Cost-Share</strong></td>
<td>$200,116</td>
<td>$223,979</td>
<td>$424,095</td>
</tr>
</tbody>
</table>

Cost Share by SRI, OLI Systems, POLIMI, Aqueous Solutions Aps, Stanford University IHI Corporation
Mixed-Salt Technology Facts and Benefits

Technology uses potassium and ammonium salts

- Uses inexpensive, industrially available material
- Requires no feed stream polishing
- No hazardous waste generation
- Has a potential for easy permitting from many localities
- Uses known processes engineering

**NO SOLIDS**

Enhanced capture rates

High CO$_2$ loading capacity

Produces clean CO$_2$ stream at high pressure $\rightarrow$ reduced compression costs

Reduced energy consumption compared to MEA

Reduced auxiliary electricity loads

---

**Challenge:**

Reduction of ammonia evaporation at higher reaction rates

---

<table>
<thead>
<tr>
<th>Compound</th>
<th>MW (g)</th>
<th>Moles in kg of 30 wt.% solvent</th>
</tr>
</thead>
<tbody>
<tr>
<td>MDEA</td>
<td>119</td>
<td>2.5</td>
</tr>
<tr>
<td>MEA</td>
<td>61</td>
<td>4.9</td>
</tr>
<tr>
<td>NH$_3$ (20 wt.%)</td>
<td>17</td>
<td>8.8</td>
</tr>
<tr>
<td>K$_2$CO$_3$</td>
<td>138</td>
<td>2.2</td>
</tr>
<tr>
<td>Piperazine</td>
<td>86</td>
<td>3.5</td>
</tr>
</tbody>
</table>
Mixed-Salt Technology Process Conditions

- Process uses mixtures of potassium carbonate and ammonium salts
  - Dual absorber, and a selective regenerator
  - Heat of reaction 35 to 55 kJ/mol
- Absorber operation at 20° – 30°C at 1 atm with 20-30 wt.% mixture of salts
- Regenerator operation at >110°C at 20-40 atm
  - Produce high pressure CO₂

\[
\text{CO₂ Lean} \quad \begin{array}{c}
\text{K}_2\text{CO}_3-\text{NH}_3-x\text{CO}_2-\text{H}_2\text{O} \quad \leftrightarrow \quad \text{K}_2\text{CO}_3-\text{NH}_3-y\text{CO}_2-\text{H}_2\text{O}
\end{array}
\]

Where \( y > x \)

E.g., \( y = 6 \) and \( x = 3 \)
Mixed-Salt: Reduced Energy Requirement for Solvent Regeneration

Estimated regenerator heat requirement for Mixed-Salt system with 0.2 to 0.6 cyclic CO₂ loading. Comparison with neat K₂CO₃ and MEA is shown.

K₂CO₃ Data: GHGT-11; Schoon and Van Straelen (2011). TCCS-6
Mixed-Salt Data; SRI Modeling

Mixed-Salt process requires a minimal energy for water stripping.
Mixed-Salt Development Time Line

Proof of Concept (6 slph)  
2012

Small Bench-Scale Testing (50 slpm or 1.7 acfm)  
2013

Current DOE Project  
Large Bench-Scale Testing (>500 slpm)  

Results from small bench-scale testing

- **CO₂ Absorption Rate (Arbitrary Unit)**
  - Mixed-salt
  - MEA

- **Starting Absorbent Weight Percent**
  - 0.30 Loading
  - 0.35 Loading
  - 0.32 Loading
  - 0.37 Loading

- **Temperature (°C)**
  - (130°C, >20 bar)

Attainable CO₂ pressure during solvent regeneration: Mixed-salt with CO₂ loading value of 0.6 CO₂/salt

No thermal or oxidative degradation of mixed-salts in the regenerator.
## DOE Project Schedule

<table>
<thead>
<tr>
<th>Task</th>
<th>Start Date</th>
<th>End Date</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixed-Salt BP1 and BP2</td>
<td>10/1/2013</td>
<td>3/31/2016</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 2.0: Individual Absorber and Regenerator Testing in Semi-Continuous mode</td>
<td>10/1/2013</td>
<td>11/30/2014</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subtask 2.1 - Test Systems Design and Installation</td>
<td>10/1/2013</td>
<td>4/28/2014</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subtask 2.2 - Test Plans</td>
<td>2/1/2013</td>
<td>2/30/2014</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subtask 2.3 - Absorber Tests</td>
<td>4/30/2014</td>
<td>11/30/2014</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subtask 2.4 - Regenerator Tests</td>
<td>7/1/2014</td>
<td>11/3/2014</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subtask 2.5 - Bench-Scale Test Data Analysis</td>
<td>2/28/2014</td>
<td>11/30/2014</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subtask 3.2 - Preliminary Economic Analysis</td>
<td>8/1/2014</td>
<td>12/15/2014</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 4.0 - Budget Period 2 Continuation Application</td>
<td>12/1/2014</td>
<td>12/30/2014</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continuation Report Submission</td>
<td>12/30/2014</td>
<td>12/30/2014</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 5.0 - Bench-Scale Integrated System Testing</td>
<td>1/15/2015</td>
<td>3/31/2016</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subtask 5.1 - Design of the Bench-Scale Integrated Test System</td>
<td>1/15/2015</td>
<td>3/31/2015</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subtask 5.2 - Installation of the Bench-Scale Continuous, Integrated Test System</td>
<td>1/15/2015</td>
<td>3/31/2015</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subtask 5.3 - Bench-Scale Test Plans</td>
<td>1/15/2015</td>
<td>2/15/2015</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subtask 5.4 - Bench-Scale Tests and Data Analysis</td>
<td>4/1/2015</td>
<td>3/31/2016</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subtask 6.2 - Techno-Economic Analysis</td>
<td>8/1/2015</td>
<td>3/30/2016</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subtask 6.3 - Technology EH&amp;S Risk Assessment</td>
<td>9/1/2015</td>
<td>3/30/2016</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Regenerator System

20-ft

Vent line
Liquid feed
Schematic of the Absorber System
Photographs of the Completed System

Mixed-Salt System Commissioned on May 29, 2014
Data acquisition and control hardware interface

Online data monitoring

NH₃ Analyzers

CO₂ Analyzers
Absorber Data with 20 wt% Mixed-salt at 20°C: Mass Balance
Absorber Data with 20 wt% Mixed-salt at 20°C: CO₂ Capture Rate

Test Series 1: 20 wt% Mixed-Salt

CO₂ Loading

>99% Efficiency

Achieved equilibrium capture rates

Parametric Testing
Rate Based Model Development
Techno Economic Analysis
Project Status as of July 15, 3014

• Program Management Plan Updated
• Design and Installation of Absorber Completed
• Regenerator modification and Installation Completed
• Absorber Testing in progress
• Modeling:
  – VLE model update for $K_2CO_3$-NH$_3$-CO$_2$-H$_2$O completed
  – Power cycle integration for reference plant completed (good agreement with NETL model)
Project Location

SRI’s site in Menlo Park, CA (~ 65 acres)
SRI also has a test site near Livermore, CA (480 acres)
Acknowledgements

• NETL: Steven Mascaro and Lynn Brickett

• SRI Staff:
  – Palitha Jayaweera, Regina Elmore, Jianer Bao; Srinivas Bhamidi, Bill Olsen, Robert Bell, David Thibert, Paul Zuanich, Gopala Krishnan, Marcy Berding, Kelli Connolly, Karen Withington.
  – Chris Lantman, Barbara Heydorn, Rachel Stahl, Michele Lefevre, and Lauren May.

• Subcontractors and Cost Sharing Partners:
  – OLI Systems, Stanford, ASAps, POLIMI, IHI Corporation

• Consultant:
  – Eli Gal
Disclaimer

- This presentation was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.
Thank You