Results from Mini-Pilot Testing of the Mixed-salt Technology for CO₂ Capture from Post-Combustion Related Applications

Indira Jayaweera, Palitha Jayaweera, Prodig Kundu, Kaj Thomsen, Gianluca Valentì, Davide Bonalumi, and Stefano Lilla

A SRI International, 333 Ravenswood Avenue, Menlo Park, CA 94025, USA
b OLI Systems, Inc. 240 Cedar Knolls Road, Suite 301, Cedar Knolls, NJ 07927-1621, USA
c Aqueous Solutions ApS, Snoegaardsvej 149, 2860 Soeborg, Denmark
d Politecnico di Milano - Dip. di Energia Via Lambruschini, 4 20156 Milano, Italy

Long Abstract

Cost-effective capture of CO₂ emissions from coal-powered plants is of critical strategic importance to further enable the use of coal, an abundant natural resource in the U.S. without increasing greenhouse gas (GHG) emissions. SRI International (SRI) is currently developing a highly promising solvent-based CO₂ capture technology. The technology is called the Mixed-salt Technology [1] and is under the funding from the National Energy Technology Laboratory (NETL). The overall goal of the project is to test the technology at the large bench-scale level (0.25 to 1 tonne / per day CO₂ capture Mini-pilot) to demonstrate the process can capture CO₂ at high efficiency (> 90%).

Mixed-salt technology capitalizes on the advantages of both ammonia-based and potassium carbonate-based technologies with improved reaction kinetics and reduced emissions. This technology provides unique opportunities for better energy management that reduces the burden on the power plant steam cycle and is suitable for capturing CO₂ from post-combustion, pre-combustion, and other industrial gas streams. Mixed-salt technology can strip CO₂ at high pressure, reducing the CO₂ compression costs, requires no solvent chilling as in aqueous ammonia-based processes, and has a low reboiler duty for regeneration compared to conventional amine process.

The process economic analysis was conducted by Politecnico di Milano (POLIMI) based on a thermodynamic model developed by Aqueous Solutions ApS. In this analysis, a technology comparison was made using the economic results for mixed-salt process vs. the reference Case 12B proposed by NETL in the report “Cost and Performance Baseline for Fossil Energy Plants (July 6, 2015)” [2]. For this reason, the analyzed case adopts the same technical specifications as the Case 12B with exceptions made for the peculiarities introduced by the new post-combustion carbon capture technology. The methodology applied to the economic analysis strictly follows the NETL guidelines provided in the “Cost and Performance Baseline for Fossil Energy Plants” report [2]. Based on this economic evaluation, the cost of electricity (COE) presented by NETL for the Case 12B is 142.8 $/MWh vs. 127.3 $/MWh found in the POLIMI analysis for the mixed-salt process capture plant. The Mixed-salt technology shows a reduction of 10.8%. Previously, POLIMI has satisfactory reproduced the economic data for DOE Case 12 [1, 3]. Table 1 shows the cost of electricity comparisons.
Independent of the work of POLIMI and Aqueous Solutions ApS, OLI Systems has developed a rate-based model with SRI test data that was used in OLI ESP [4]. Using the updated rate-based model, OLI Systems has determined the complete mass and energy balance for a full-scale system operating with the mixed-salt CO2 capture system. The technology was modeled for the carbon dioxide recovery (CDR) facility, in which 90% percent of the CO2 from the flue gas was captured from a supercritical pulverized coal (PC) plant with a nominal net output of 550 MW (DOE Case 11) 3, 5, 6]. The other fixed parameters were regeneration of high-pressure CO2 at 99% purity and the ammonia release from the absorber to be less than 10 ppm. The Mixed-salt technology was compared with Fluor Econamine FG PlusSM technology (DOE Case 12). The Econamine FG Plus process uses a formulation of monoethanolamine (MEA) and a proprietary corrosion inhibitor to recover CO2 from the flue gas. The heat duty requirement at the reboiler stripper for the Fluor Econamine FG PlusSM technology was reported as 3,556 kJ/kg (1,530 Btu/lb) or 3.56 MJ/Kg of CO2 recovered. Table 2 summarizes the performance comparison between mixed-salt technology (basic process option) with a DOE baseline case.

Table 2. Technology combinations and results comparison.

<table>
<thead>
<tr>
<th>Performance Factors</th>
<th>Econamine FG Plus Baseline</th>
<th>SRI’s Mixed-Salt Technology</th>
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<tbody>
<tr>
<td>CO2 capture, %</td>
<td>90.2</td>
<td>90.1</td>
</tr>
<tr>
<td>CO2 purity, %</td>
<td>99.8</td>
<td>99.3</td>
</tr>
<tr>
<td>Stripper pressure, atm</td>
<td>1.0</td>
<td>12.0</td>
</tr>
<tr>
<td>Raw water recycle, m3/min (gpm)</td>
<td>1,173-1,287 (310,000-340,000)</td>
<td>341 (89,868)</td>
</tr>
<tr>
<td>Auxiliary power, KWe</td>
<td>20,600</td>
<td>3,472</td>
</tr>
<tr>
<td>Heat duty, MJ/Kg of CO2</td>
<td>3.56</td>
<td>2.0</td>
</tr>
</tbody>
</table>

CO2 capture and CO2 pipeline purity specifications were met in all the process configurations investigated in this study. SRI’s mixed-salt process can strip CO2 at high pressure, as the stripper for rich-solvent regeneration is operated at higher pressure than the Fluor Econamine FG PlusSM (Table 2). The electrical power required for compressing CO2 to delivery pressures (> 130 atm) is greatly reduced in the mixed-salt process compared to other
solvent-based technologies operating with lower-pressure regenerations. Ammonia-based technology requires absorber solvent cooling and treated gas washing to reduce ammonia emissions. The raw water consumption combines the water being used in the two water wash sections. The Fluor Econamine FG PlusSM technology requires a large water recycle in the CDR unit for cooling purposes (1,173,350-1,286,900 lpm or 310,000-340,000 gpm), which greatly exceeds the PC plant cooling water requirement (643,450-757,000 lpm or 170,000-200,000 gpm). The mixed-salt process requires a relatively smaller recycle for cooling purposes, and the overall cooling water recycled was 71% less in SRI’s mixed-salt process compared to the baseline case. As such, the auxiliary power required for SRI’s mixed-salt process CDR unit was 60% less than the baseline case. The heat duty for SRI’s mixed-salt process was calculated to be 2.0 MJ/Kg of CO₂ recovered (in the stripper reboiler). This accounts for a 44% decrease in the heat duty requirement in the SRI’s mixed-salt process compared to the baseline case.

In conclusion, SRI’s mixed-salt technology can capture CO₂ at high pressure and can meet present DOE targets of CO₂ capture and pipeline purity requirements. The study shows the technology offers much lower energy penalty than Fluor Econamine FG PlusSM technology and/or conventional MEA-based technology for post-combustion CO₂ capture. The technology can easily be scaled up with use of conventional process equipment.

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5. OLI Systems, Inc., The Environmental Simulation Program (ESP), December 1, 2015 (http://www.olisystems.com/)

Keywords: CO₂ capture; post-combustion; mixed-salt; ammonia; potassium carbonate;