Sorbent-based Oxygen Production for Energy Systems

Project DE-FE0024075
U. S. Department of Energy
National Energy Technology Laboratory

Dr. Arun Bose
Ms. Harolynne Blackwell

Prime Contractor:
Western Research Institute
Partners (Sub-contracts):
Arizona State University
New Mexico State University
Cosponsor:
LP Amina

2015 Gasification Systems and Coal & Coal-Biomass to Liquids Workshop
Lakeview Conference Center, Morgantown, WV
August 10-11, 2015
Introductions:

Dr. Jerry (Y. S.) Lin-ASU, Regents’ Professor
- internationally recognized pioneer in inorganic membranes
- known for his work with adsorbents that can selectively separate various gases and liquids
- serving as an adviser to 70 graduate and post-doctoral students

Dr. Shuguang Deng-NMSU, Bob Davis Professor
- Research Lead with BOC to work with adsorbents for separations of gases and liquids
- Inducted in the NMSU’s chapter of the National Academy of Inventors
- Transitioning to ASU as a tenured faculty

Dr. Matt Targett-LP Amina, Vice President R&D
- Founding Member of US-China Clean Energy Center
- Head of Innovation, Asia Pacific for Bayer Technology Services
- LP Amina is pursuing power generation as a chemicals coproduction platform…
Background

Sorbent-based Oxygen Production Process (ABO$_{3-x}$)

- Adsorb O$_2$ from air in a solid sorbent
- Use of vacuum, CO$_2$-rich flue gas and/or steam as sweep gas allows optimization of the O$_2$ concentration for various advanced energy systems.
- High-temperature process driven by partial pressure of oxygen
Sorbent-based Oxygen Production Process (ABO$_{3-x}$)

Between 2005 and 2008, under two separate Cooperative Agreements, a two-bed, 60-pph unit was developed by BOC/Linde and tested at WRI. The unit was integrated with an existing 250,000 Btu/h Combustion Test Facility to demonstrate oxy-fuel combustion concepts.

Conclusions:
- Improve oxygen uptake capacity
- Lower operating temperature from 850° C to about 600° C
- Improve desorption kinetics
Integration with IGCC

Air Separation

Coal Processing

Gasification + Syngas Clean Up

Water/Gas Shift

Shifted Syngas

Shifted Syngas Clean Up/Processing

Gas Turbine

CO₂ Compression

CO₂

N₂

Steam

Process Coal

O₂

Ash/Slag

Waste Stream

Clean Syngas

Hot Tail Gas

Electric Power to Grid

HRSG To Steam Turbines
Integration with IGCC
Integration with Oxy-Combustion

Air-Blown

Oxy-combustion with Conventional ASU
Integration with Oxy-Combustion
New Materials

- Improve oxygen uptake capacity
- Lower operating temperature
- Improve desorption kinetics

<table>
<thead>
<tr>
<th>Sorbent</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Linde/BOC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation temperature (°C)</td>
<td>400-700</td>
<td>500-700</td>
<td>700-800</td>
<td>850</td>
</tr>
<tr>
<td>Oxygen sorption capacity (g/g)</td>
<td>400--0.0154</td>
<td>500--0.0176</td>
<td>600--0.0093</td>
<td>0.008</td>
</tr>
<tr>
<td></td>
<td>500--0.0109</td>
<td>600--0.0144</td>
<td>700--0.0086</td>
<td></td>
</tr>
<tr>
<td></td>
<td>600--0.0102</td>
<td>700--0.0118</td>
<td>800--0.0134</td>
<td></td>
</tr>
<tr>
<td></td>
<td>700--0.0074</td>
<td>900--0.0131</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxygen desorption rate (1/2)</td>
<td>0.5-2x10^{-2}</td>
<td>0.2-1x10^{-2}</td>
<td>0.5-3x10^{-2}</td>
<td>1-4x10^{-4}</td>
</tr>
</tbody>
</table>
### Capital and Power Requirements for O₂ Delivery Rate of 400,000 Nm³/hour*

<table>
<thead>
<tr>
<th></th>
<th>Cryogenic</th>
<th>Linde/BOC CAR Process</th>
<th>New Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>O₂ capacity (Nm³/hour)</td>
<td>400,000</td>
<td>400,000</td>
<td>400,000</td>
</tr>
<tr>
<td>Total sorbent loading (ton)</td>
<td>N/A</td>
<td>637</td>
<td>255</td>
</tr>
<tr>
<td>Purge Gas</td>
<td>N/A</td>
<td>CO₂</td>
<td>CO₂</td>
</tr>
<tr>
<td>Adsorber temperature (°C)</td>
<td>N/A</td>
<td>800</td>
<td>600</td>
</tr>
<tr>
<td>Oxygen recovery (%)</td>
<td>N/A</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>Specific O₂ production system cost ($/ton O₂/day)</td>
<td>25,000</td>
<td>14,000</td>
<td>9,800</td>
</tr>
<tr>
<td>Specific power requirement (kWh/ton O₂)</td>
<td>223</td>
<td>115</td>
<td>90</td>
</tr>
</tbody>
</table>

* Based on early work performed by Alstom
Preliminary Results

600 degC
49.8 g Sorbent

Sorption

Desorption
Preliminary Results
DE-FE0024075:

- Deals with the development of a high-temperature sorbent-based oxygen production technology
- Is developing more efficient and stable, higher sorption capacity, newer class of materials operating at lower temperatures
- If successful sorbent-based oxygen production process represents a major advancement in air separation technology
- New ceramic sorbent materials have a higher $O_2$ adsorption capacity, >200 °C lower operating temperatures, and up to two orders of magnitude faster desorption rates than those used in earlier development efforts
- The performance advancements afforded by the new materials can lead to substantial savings in capital investment and operational costs
Questions/Comments?