Emissions Mitigation Technology for
Advanced Water-Lean Solvent Based CO₂ Capture
Processes

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DE-FE0031660
DOE Project Manager: Sai V. Gollakota

Carbon Capture, Utilization, Storage, and Oil & Gas Technologies
Integrated Review Meeting

Aug. 26th, 2019
Development History for Novel, Non-Aqueous Solvents

Technology Status

- Cumulative DOE funding > $9 MM and more than $2 MM funding from RTI industrial partners
- Solvent development work finalized
- Pilot testing completed at SINTEF, Norway and National Carbon Capture Center (NCCC)
- Pre-commercial demonstration (12 MW) planned at Technology Center Mongstad (TCM), Norway in FY20

Key Technical Advantages

- CO₂ Capture Technology with substantially reduced energy consumption
- Minimum changes to existing process to realize NAS optimal performance
- Commodity-scale production ready

Impact

- Long-term potential for large scale CO₂ capture applications
- Commercialization path via process technology licensing
- Application potential for high-efficiency acid gas separations
NAS CO₂ Capture Technology Path to Market

From lab to large scale (12 MW) demonstration through series of projects

Lab-Scale Development & Evaluation (2010-2013)
Solvent screening and Lab-scale evaluation

Large Bench-Scale System (RTI facility, 2014-2016)
Demonstration of key process features (≤ 2,000 kJ/kg CO₂) at bench scale

Pilot Testing at Tiller Plant (Norway, 2015-2018)
Demonstration of all process components at pilot scale

Pilot Testing at SSTU (NCCC, 2018)
Degradation, emission, and corrosion characterizations under real flue gas

Emissions control (Tiller, 2018+)
Effective emissions mitigation strategy for WLS at engineering-scale

Engineering-Scale Validation (2018+)
Pre-commercial Demonstration at Technology Centre Mongstad, Norway (~12 MWe)
Test in late 2020

~$2.7MM
6kW

~$3 MM
60 kW

~$0.75MM
50 kW

~$3.5MM

~$21MM
12 MW
- Similar emissions levels and species seen at SINTEF and NCCC
- Intercooling reduces emissions by almost 10x
- Largest minor emissions include hydrophobic diluent species and other degradation species
Objective:
Develop and optimize the emission control solutions to reduce the amine emission for advanced, 2nd generation solvent – WLS class

Key Metrics
- Emissions from absorber & desorber
- Solvent loss and make-up cost reduction
- Technoeconomic and EHS evaluation

Specific Challenges
- Aerosols generation and characterization
- Amine reclaiming unit and process integration
- Organic wash solvent screening

Timeframe:
BP1 10/01/18 to 03/31/20
BP2 04/01/20 to 09/03/21

Budget:
BP1 Federal $1.7MM Cost Share $0.4MM
BP2 Federal $1.2 MM Cost Share $0.4 MM

Potential emissions control technologies for WLS systems to be incorporated at the RTI’s BsGAS
<table>
<thead>
<tr>
<th>Team Member</th>
<th>Role</th>
<th>Expertise</th>
</tr>
</thead>
</table>
| Prime recipient, project management, developer of NAS technology, emissions characterization, solvent screening, ECT design and modeling, and economic analyses | | ▪ Effective project management and execution under DOE cooperative agreements  
▪ Lead developer of NAS CO₂ capture technology  
▪ Process design, modeling, and engineering capabilities  
▪ Process technology scale-up and operation from lab to large precommercial demonstration systems  
▪ Aerosol emissions characterization |
| Technical advisory and contributor to joint-emission report | | ▪ Leading industrial gas supplier  
▪ CO₂ capture plant design and pre-commercial scale demonstration  
▪ Advance front-end emission control equipment design and fabrication |
| Technical advisory and EH&S support | | ▪ World leading test facility for CO₂ capture  
▪ EH&S and quality standards |
BP1 Tasks and Project Goals

BP1 Tasks

Task 1.0: Project Management and Planning

Task 2.0: Establish emission baseline without ECT
  • Aerosol generation at BsGAS
  • Baseline measurement
  • Empirical model development

Task 3.0: Prototype ECT for WLSs evaluation at RTI’s BsGAS
  • 2nd wash column and amine recovery process
  • Evaluation of BsGAS with ECTs

Project Goals

- Control and manage amine emissions
- Identify emission pathways for WLSs
- Model the amine emission
- Refine Techno-economic analysis
- Gain operational experience on WLS process with ECTs
<table>
<thead>
<tr>
<th>Key Tasks</th>
<th>Approaches/ planned Activities</th>
<th>Planned Completion Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop method to monitor and quantify emissions at the BsGAS</td>
<td>• Install SO₃ injection at BsGAS&lt;br&gt;• Particle counter and aerosols quantification equipment tie-in</td>
<td>Completed</td>
</tr>
<tr>
<td>Update BsGAS flow sheet with emission control equipment necessary to reduce amine emissions with &gt; 99% efficiency</td>
<td>• Install, commission, and evaluate ECTs at BsGAS</td>
<td>Completed</td>
</tr>
<tr>
<td>Baseline data for amine emissions using two water-lean solvents</td>
<td>• Parametric testing on 2 solvent candidates</td>
<td>08/31/19</td>
</tr>
<tr>
<td>Empirical process model for amine emissions from water-lean solvents with &lt; 10% average absolute deviation based on critical process parameters</td>
<td>• Regression on experimental results</td>
<td>03/31/20</td>
</tr>
<tr>
<td>Complete testing of emission reduction performance at BsGAS to demonstrate amine emissions reduction to &lt; 10 ppm</td>
<td>• Parametric testing</td>
<td>03/31/20</td>
</tr>
</tbody>
</table>
SO$_3$ Generator at BsGAS: installation and setup

- V$_2$O$_5$/SiO$_2$ catalyst in 3-zone heating furnace
- 99.99% SO$_2$ to SO$_3$ conversion
- SO$_3$ is mixed with steam in the abs. gas feed, producing H$_2$SO$_4$ mist (i.e., aerosols) feeding the absorber
- Concentration ranges from 0-10 ppm SO$_3$
Aerodynamic Particle Sizer (APS, 0.5-20 µm) and Scanning Mobility Particle Sizer (SMPS, 15-660 nm) were installed to characterize the aerosols from abs. inlet, outlet, and WW outlet.

Sampling probe is designed to take isokinetic samples at each location.
SO$_3$ Generator at BsGAS: Trial runs

**Particle concentration**

- Particle concentration and sizes are consistent with literature
- Aerosols grow as they travel through the process
- Large aerosols carry more mass
SO$_3$ Generator at BsGAS: Trial runs
### Parametric Testing

<table>
<thead>
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<th>Parameters</th>
<th>Units</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
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<tbody>
<tr>
<td>SO$_3$ Injection</td>
<td>ppm</td>
<td>0</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Inlet Saturation Temp</td>
<td>°C</td>
<td>20</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>L/G</td>
<td>kg/kg</td>
<td>3</td>
<td>4.5</td>
<td>6</td>
</tr>
<tr>
<td>Regenerator Temp</td>
<td>°C</td>
<td>95</td>
<td>105</td>
<td>115</td>
</tr>
<tr>
<td>Lean Return Temp</td>
<td>°C</td>
<td>30</td>
<td>40</td>
<td>50</td>
</tr>
<tr>
<td>IC Top</td>
<td>%</td>
<td>0</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>IC Middle</td>
<td>%</td>
<td>0</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>IC Lower</td>
<td>%</td>
<td>0</td>
<td>50</td>
<td>100</td>
</tr>
</tbody>
</table>

36 total runs have been scheduled, testing in progress
A top candidate was selected with working capacity of ~0.25 g-amine/g-sorbent with 1 wt% amine solution.

Kinetic parameters measured for scaling up to BsGAS system.
BsGAS modifications with ECTs

CO₂ acidification vessels

Absorber

Regenerator

Rich Solvent

Preheater

CO₂-lean Solvent Pump

CO₂-rich Solvent Pump

Interstage Coolers

Trim Cooler

Wash Section 1

2nd wash column

CO₂ product

CO₂ acidification vessels

Adv. demister

Particulate filters

Amine Filters

Reboiler

Steam

Condensate

Particulate filters

Flue gas

Cross over Heat Exchanger

Heat Exchanger

To Wash Section 1

Treated Flue Gas

Flue gas

Amine

 Filters

Particulate filters

300-600 ppm

20-50 ppm

< 1 ppm
Accomplishments

• Installed SO$_3$ Generator to generate aerosol with size distribution matches that of the actual coal-fired power plant
• Incorporated APS/SMPS for aerosol characterization and at BsGAS
• Completed detail design for the particulate filters, advanced demister, additional wash column, CO$_2$ acidification vessels, amine recovery beds.

Path forward

• Complete parametric testing at BsGAS: late Sep
• BsGAS modification: Oct-Nov 2019
• Evaluate the ECTs added to the BsGAS: Jan –Mar 2020
• Empirical model development: Oct-Mar 2020
Acknowledgments

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• DOE Project Manager: Sai Gollakota

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• TCM: Project support