Pilot-Scale Silicone Process for Low-Cost CO_2 Capture

GE Global Research

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DOE Award: DE-FE0013755

2015 NETL CO_2 Capture Technology Meeting

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Overview

Program Team

GE Global Research

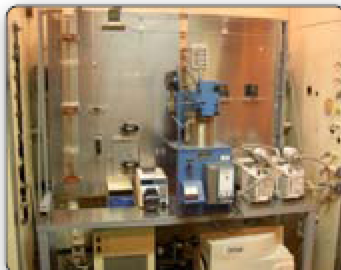
- Pilot-scale design
- Construction/Operation of Continuous System
- EH&S Assessment
- Techno-economic Assessment
- Plant Modeling

National Carbon Capture Center

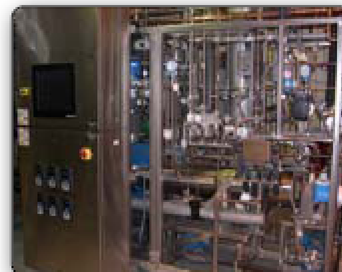
- Pilot-scale Operation
- Assessment of Data
- Integration of Components

24 Month, $5.7MM Program to Advance the Amino-Silicone Solvent Process for CO_2 Capture to Pilot Scale

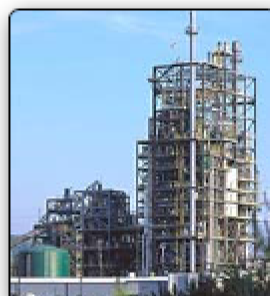
Program Objectives: Design and optimize a new process for a novel silicone CO_2 capture solvent and establish scalability and potential for commercialization of post-combustion capture of CO_2 from coal-fired power plants. A primary outcome will be a system capable of 90% capture efficiency with less than $40/tonne CO_2 capture cost.



Design & Optimize Process



Establish Scalability & Commercial Value



Pilot of Post-Combustion CO_2 Capture

Technical Approach

- Design and construct pilot-scale unit and obtain parametric data to determine key scale-up parameters
- Perform an EH&S and technical and economic assessment to determine feasibility of commercial scale operation
- Develop scale-up strategy

Outcomes

- Strategy for future scale-up
- Technical and economic feasibility determined
- Environmental assessment

Anticipated Benefits of the Proposed Technology

- 90% CO_2 Capture
- $40/tonne CO_2 capture cost

- Continuation of previous DOE/NETL funded project (DE-FE0007502)

Scope

This project is divided into two phases.

Phase I: 1/1/2014 - 12/31/2014

($1.5MM with 20% GE cost share)

- ✓ Develop preliminary process models and perform preliminary techno-economic analysis
- ✓ Perform preliminary EH&S risk assessment
- ✓ Design and construct pilot-scale aminosilicone desorber skid

Phase II: 1/1/2015 - 6/30/2016

($4.2MM with 20% GE cost share)

- Integrate skid with the NCCC pilot-scale system
- Perform pilot-scale testing (test moved from Spring 2015 to October 2015)
- Analyze data from pilot tests at 0.5 MW scale
- Perform techno-economic analysis and update cost of carbon capture
- Perform technology EH&S risk assessment
- Develop cost estimate for full-scale manufacture of solvent

Summary of Aminosilicone Advantages

- Lower volatility
  - Simplified separations
  - Less energy wasted vaporizing solvent and/or water
  - Lower airborne release rates
- Lower heat capacity
- Higher thermal stability (higher desorption T/greater capture capacity and/or pressure)
- Reduced corrosion
- Potentially decreased issues with aerosol formation

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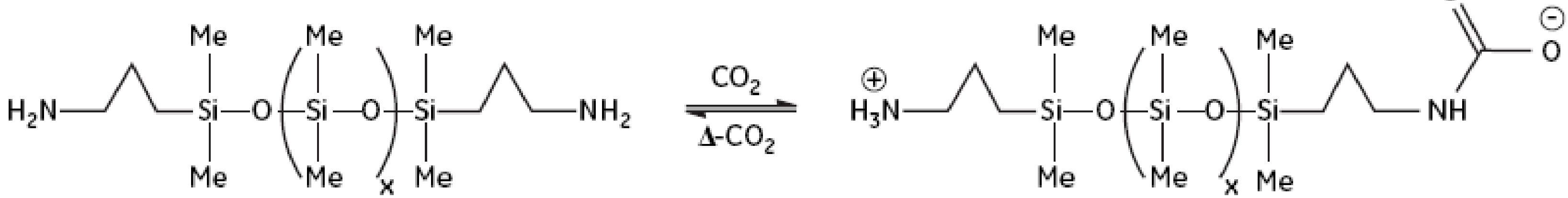
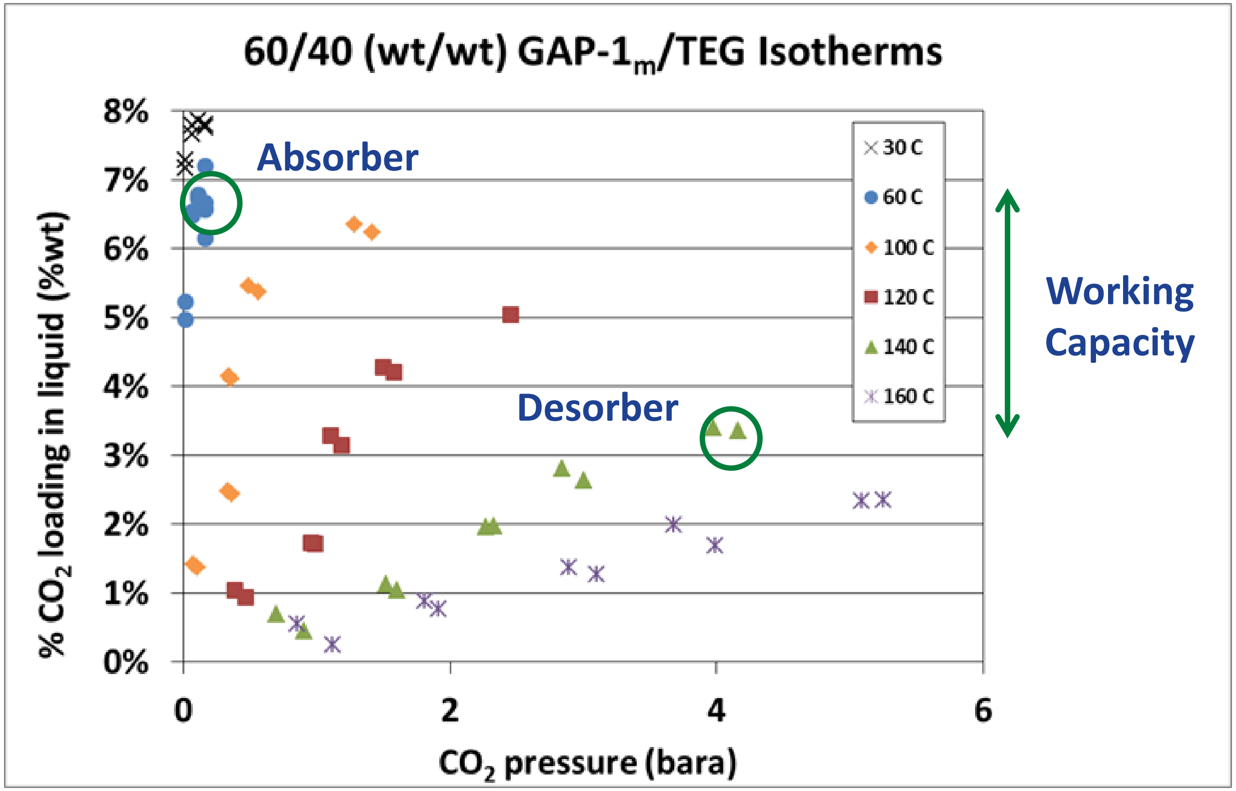
Aminosilicone Absorbent

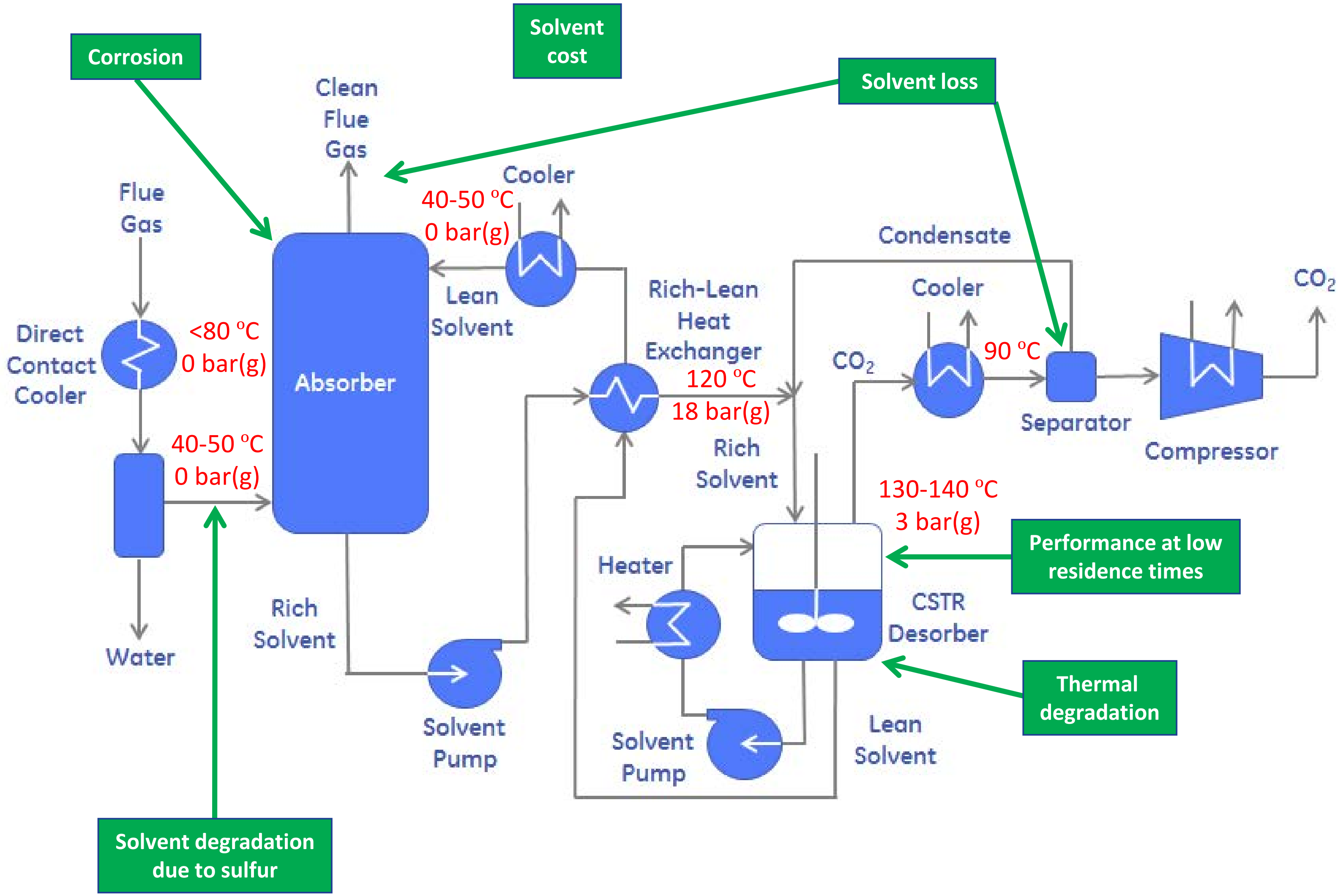


GAP-1$_m$ Absorbent Composition
- 40% GAP-0
- 33% GAP-1
- 19% GAP-2
- 8% GAP-3

Carbamate does not precipitate in a 60/40 (wt/wt) GAP-1$_m$/TEG mixture



Technical Risks



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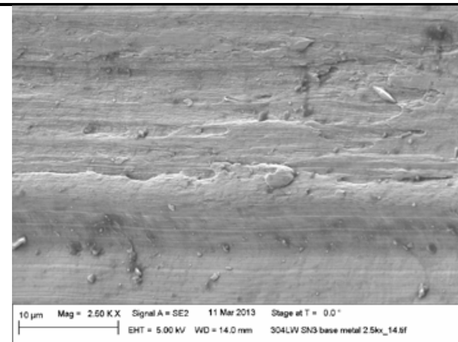
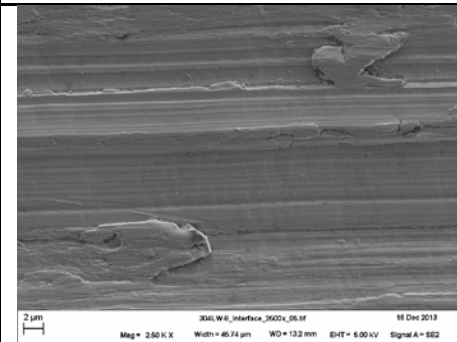
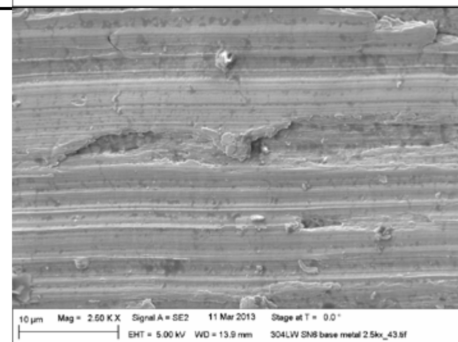
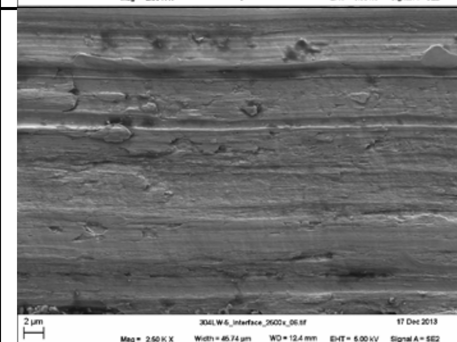
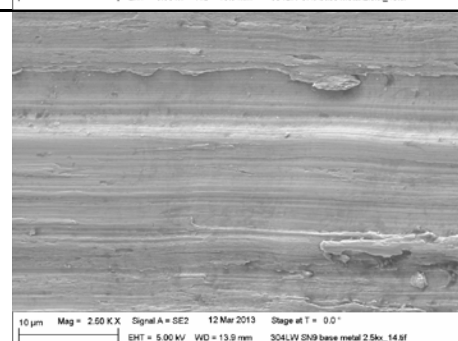
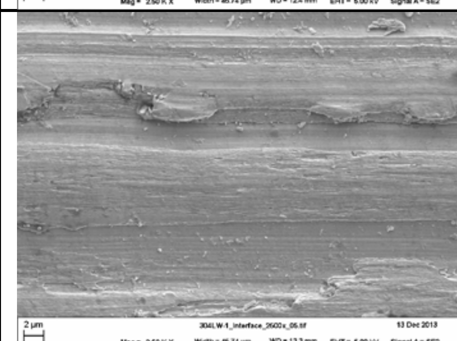
Corrosion Studies (Stainless Steel)

Location / Metal Type	Conditions	Unexposed samples	Exposed samples
Lean Storage / 304L	~380 hours at ~34 °C and ~6138 hours at ~25 °C		
Absorber Sump/ 304L	~389 hours at ~52 °C and ~6138 hours at ~25 °C		
Desorber / 304L	~388hours at ~145 °C and ~6138 hours at ~25 °C		

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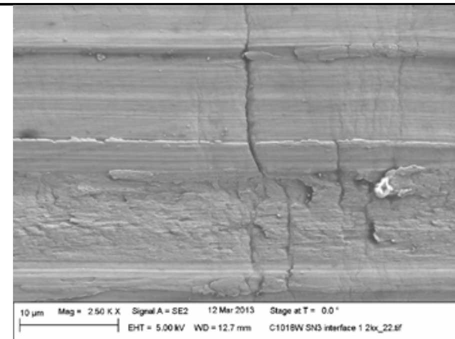
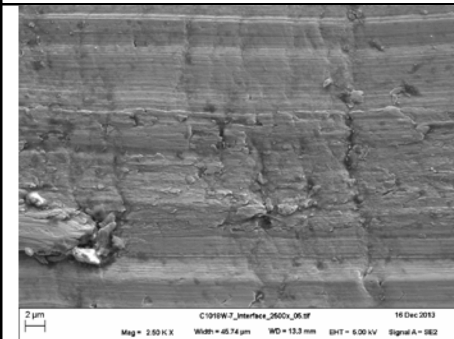
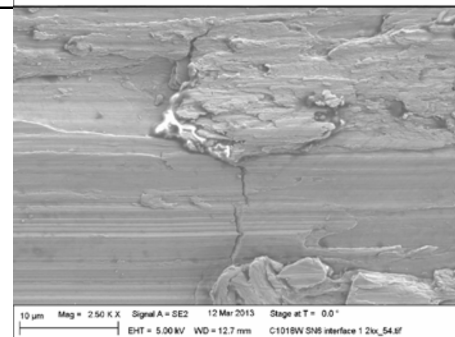
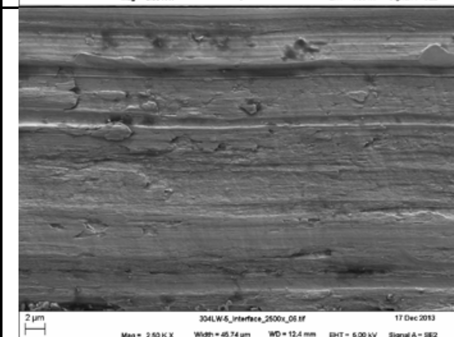
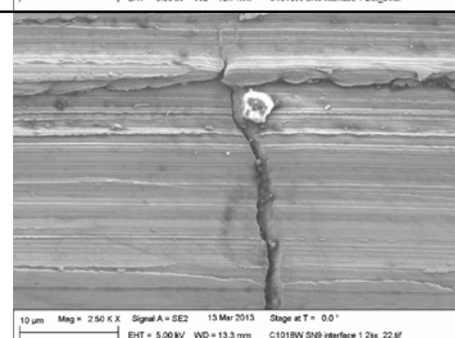
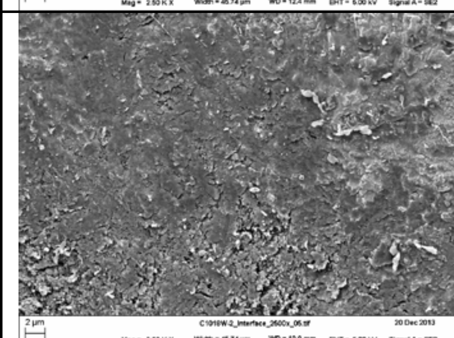
Corrosion Studies (Carbon Steel)

Location / Metal Type	Conditions	Unexposed samples (interface images)	Exposed samples (interface images)
Lean Storage / C1018	~380 hours at ~34 °C and ~6138 hours at ~25 °C		
Absorber Sump / C1018	~389 hours at ~52 °C and ~6138 hours at ~25 °C		
Desorber / C1018	~388hours at ~145 °C and ~6138 hours at ~25 °C		

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Corrosion Studies

- Significant corrosion only seen with carbon steel under desorber conditions
- Carbon steel should be fine for other process components

Sample	Corrosion rate (µm/yr)
C1018 – lean storage	1.27
C1018 - absorber	0.47
C1018 - desorber	2188
304L – lean storage	0.31
304L – absorber	0.53
304L – desorber	-0.50

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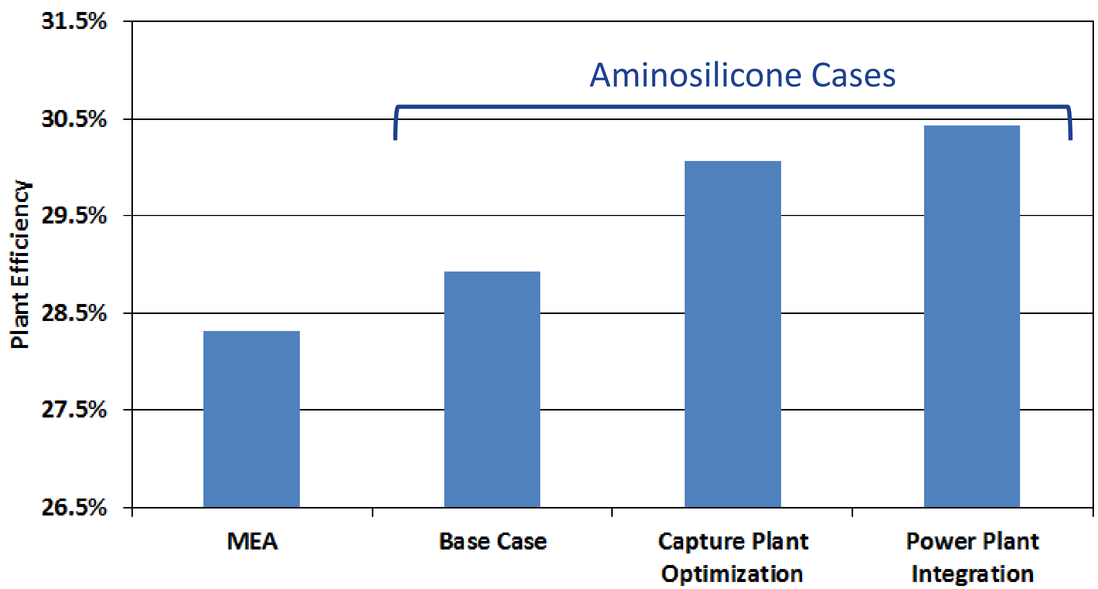
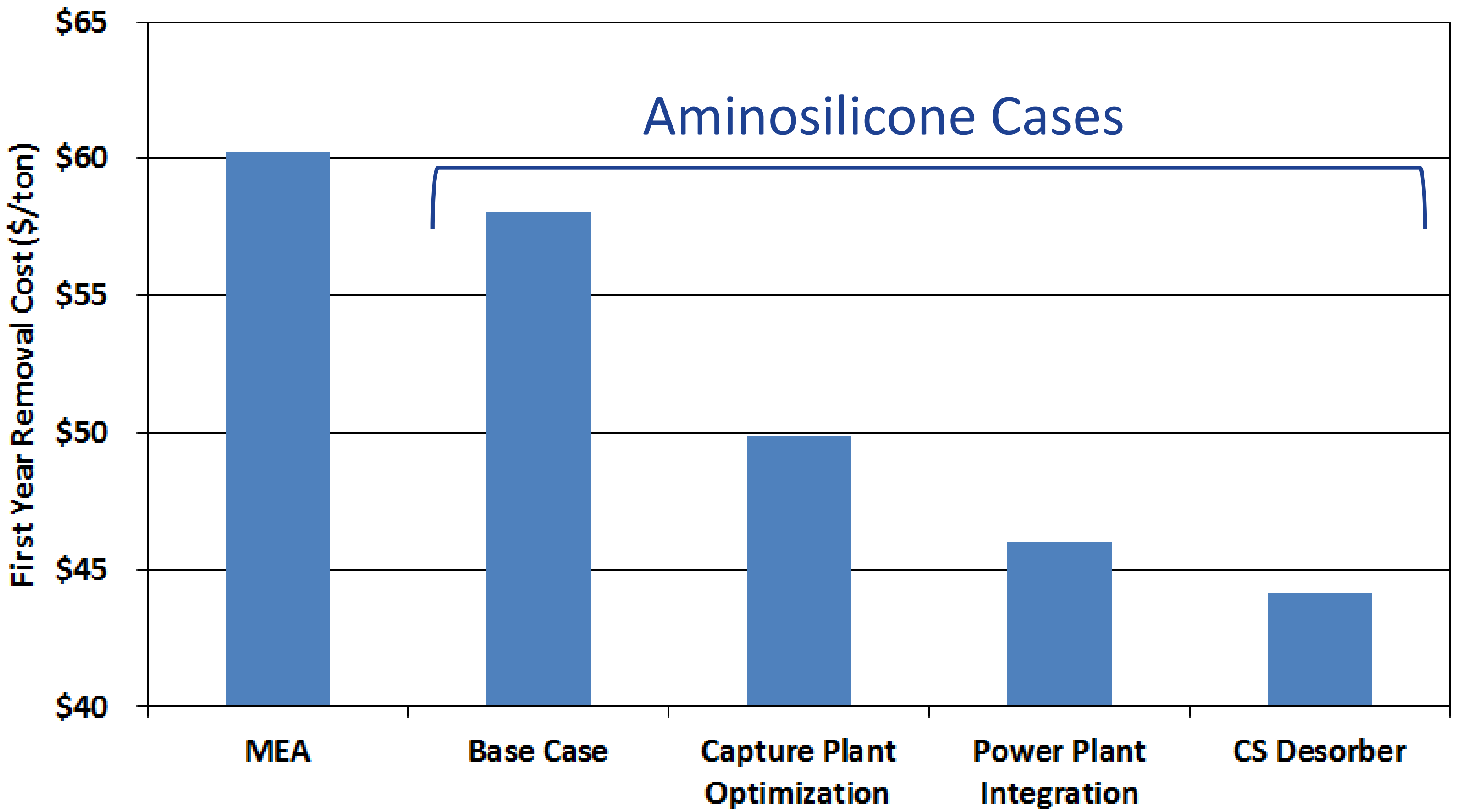
Process Modeling

- Data from the bench-scale system were used to tune bench-scale carbon-capture model in ASPEN Plus
  - Model scaled up to pilot- and 550 MW commercial-scale
- Process modeling of the coal-fired power plant was performed in Thermoflow by GE Power and Water
  - Model without carbon capture was tuned to match Case 11 from Bituminous Baseline Study
- Power plant model and carbon capture model were integrated



- Base Case – Desorber at 140 °C and 4 bar(a)
- Capture Plant Optimization - Optimization of desorber T, absorber column intercoolers, packing type, etc.
- Power Plant Integration – Cooling water integration and waste heat recovery

First Year Removal Cost of CO_2



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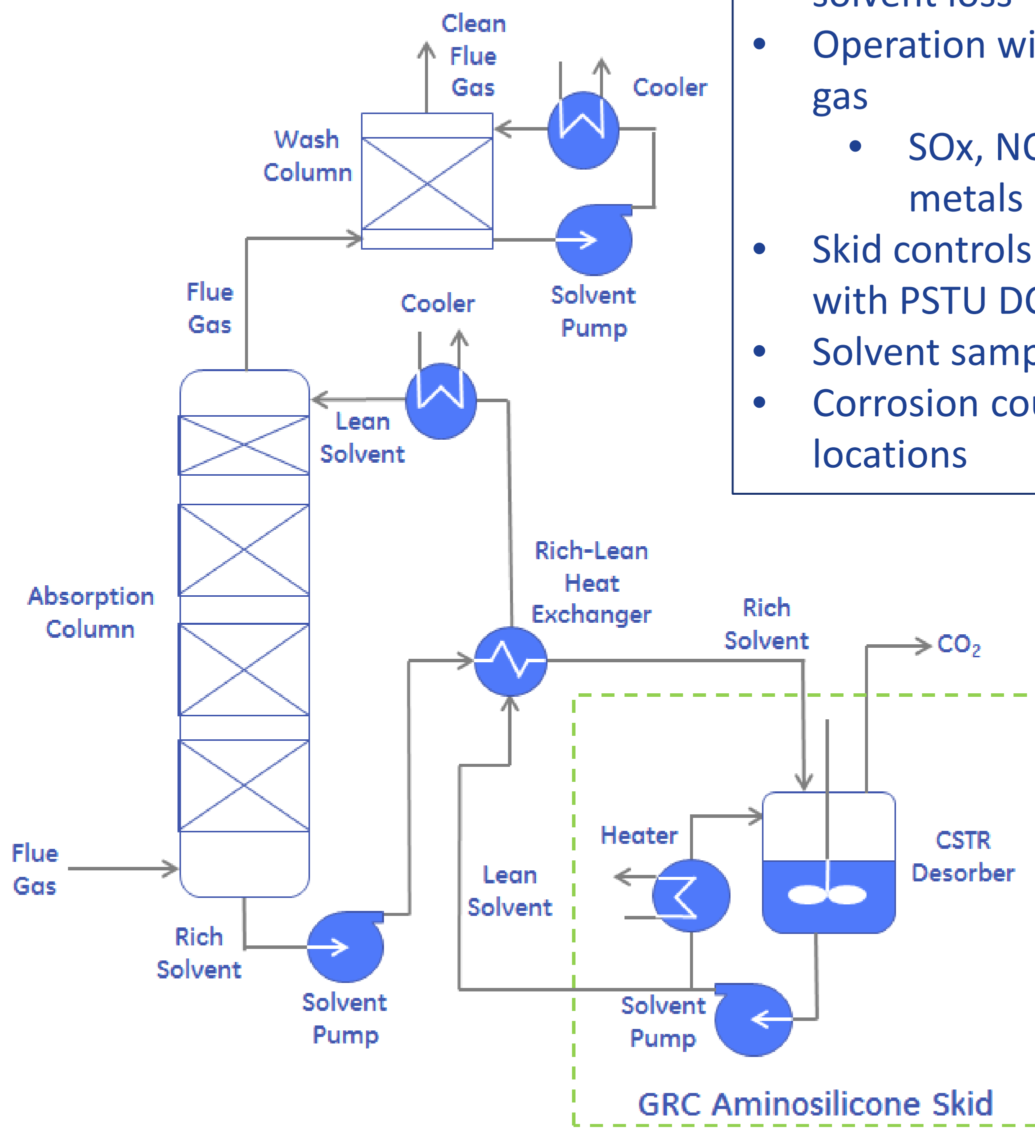
Pilot-Scale Process

- Ability to measure solvent loss
- Operation with real flue gas
    - SOx, NOx, heavy metals
- Skid controls integrated with PSTU DCS
- Solvent sampling points
- Corrosion coupon testing locations

The NCCC PSTU



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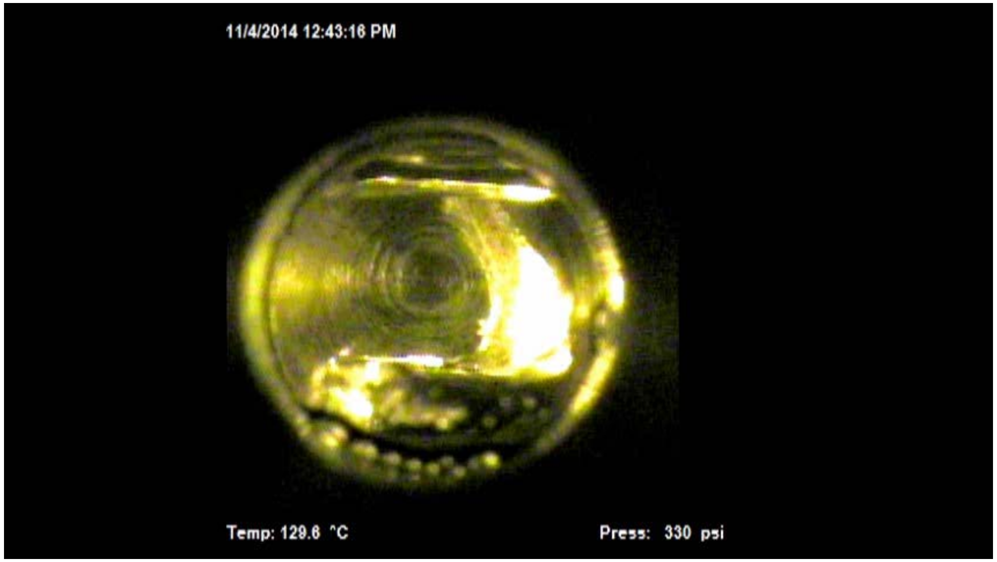
Aminosilicone desorber skid will be integrated with PSTU at the NCCC

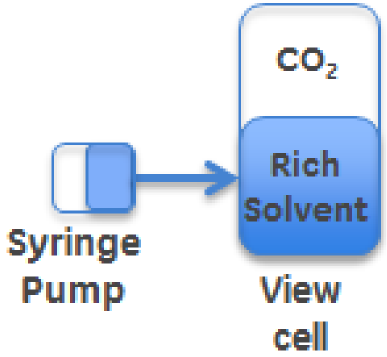
Pilot-Scale Skid Design and Fabrication

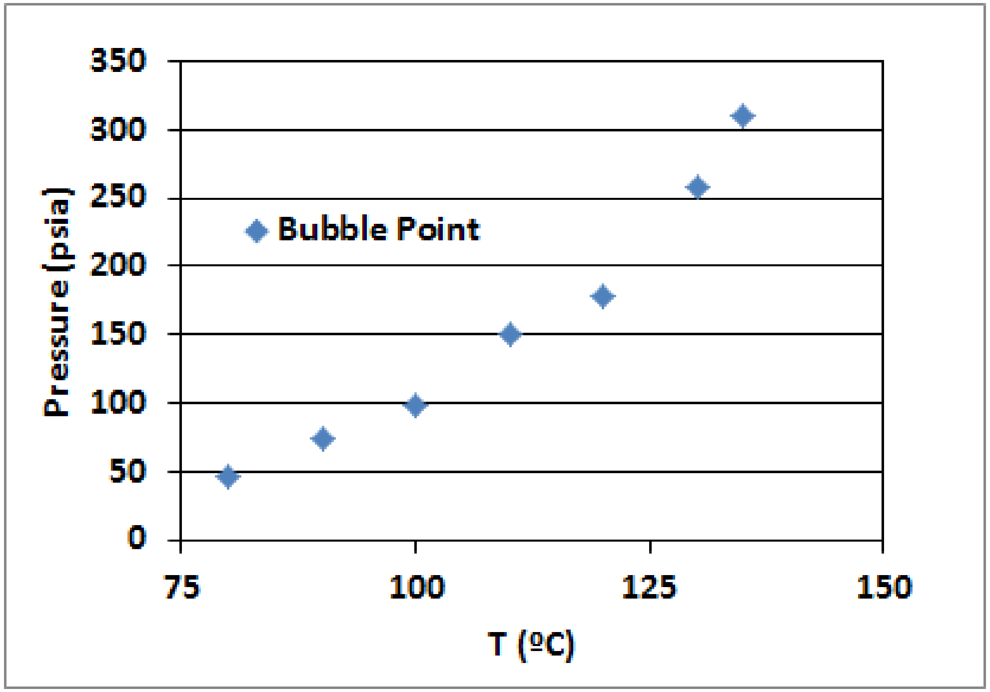
- ✓ Detailed Engineering Package complete
- ✓ Skid construction is complete
- ✓ Solvent delivered to NCCC
- Working with the NCCC to complete
  - ✓ Detailed HAZOP (completed 12/4/14)
  - Integration of skid with PSTU

Pilot-Scale Skid

Bubble Point Measurements







Bubble Point Measurements

- Heated pressure cell with syringe pump and window
- Set temperature and adjusted pressure until boiling occurred
- Bubble point data is critical to determining acceptable operating conditions for the rich/lean heat exchanger (120 °C and 275 psig)
    - Bubble formation can damage equipment and reduce heat transfer

Future Work

- 2015-2016
    - Integrate skid with PSTU at the NCCC
    - Perform tests (~2 months)
    - Use data to update process models
    - Update Techno-Economic Analysis and EH&S Risk Assessment
- Beyond
    - Determine next scale for testing
    - Look for partners
        - Test site
        - Solvent manufactures
            - Need to grow solvent supply

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Thanks

- Andrew O'Palko (program manager)
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- GE Power and Water
- The National Carbon Capture Center

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