BENCH-SCALE PROCESS FOR LOW-COST CARBON DIOXIDE (CO_2) CAPTURE USING A PHASE-CHANGING ABSORBENT

DE-FE0013687

GE Global Research

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2015 NETL CO_2 Capture Technology Meeting
June 24, 2015

BENCH-SCALE PROCESS FOR CO_2 CAPTURE USING A PHASE-CHANGING ABSORBENT

Program Team

GE Global Research Niskayuna

- Bench-Scale Design
- Construction/operation of Continuous System
- EH & S Assessment
- Techno-Economic Assessment

coperion
confidence through partnership

- Extruder Design
- Component Integration
- Heat Management

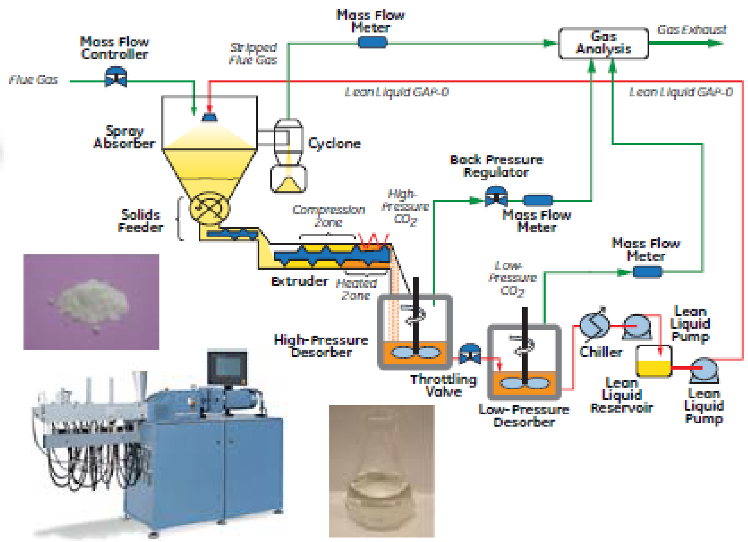
Gelest
SILAR LABORATORIES
SiVance

Solvent Manufacturers

- Aminosilicone Supply

36 Month, \$3.0MM Program to Develop a Phase-Change Process for CO_2 Capture

Program Objective: *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.*



Technical Approach

- Design and construct bench-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

\$2.4M DOE share
1/1/2014 – 12/31/2016

Program Deliverables

- 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

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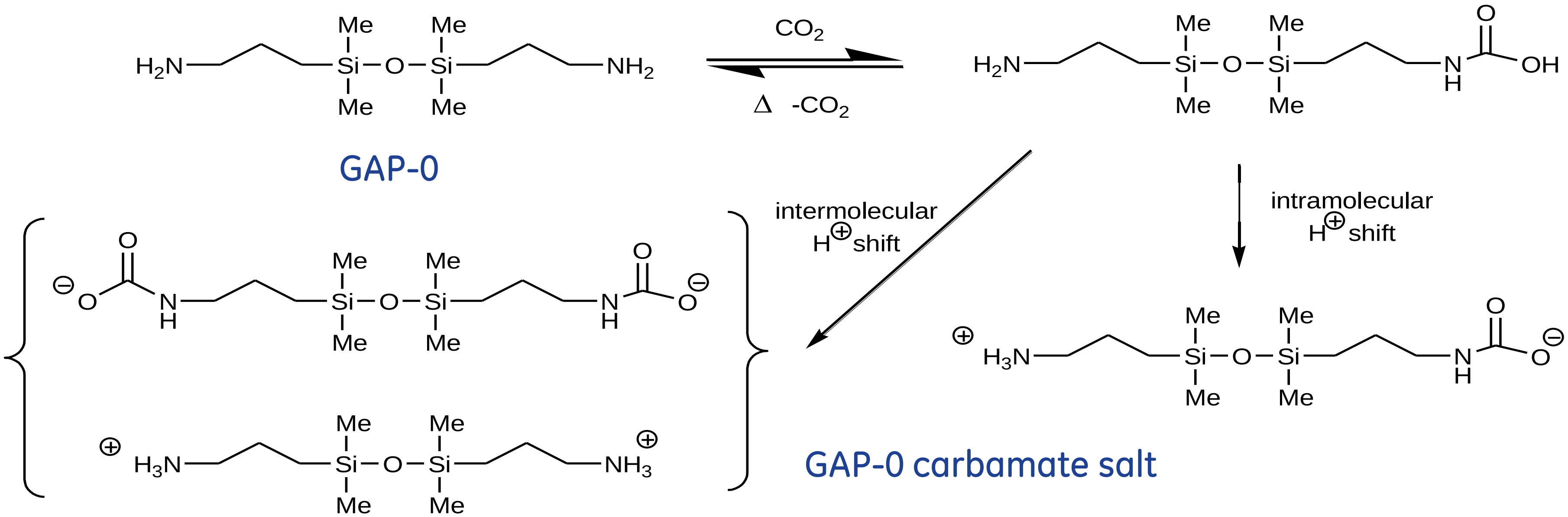
Chemistry of GAP-0 reaction with CO_2



- Extensive screening of multiple solvents
- Absorbs CO_2 very rapidly in the 40-50°C range
- High CO_2 loading (>17% weight gain, >95% of theoretical value)
- Carbamate readily decarboxylates at higher temps
- Carbamate is solid → new process configuration

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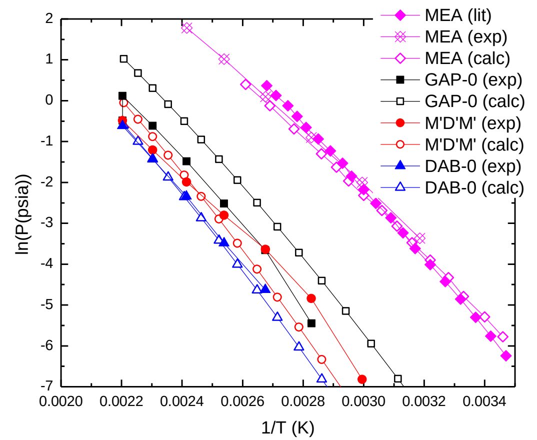
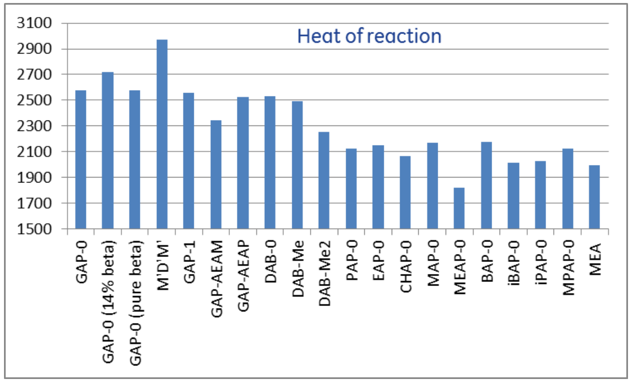
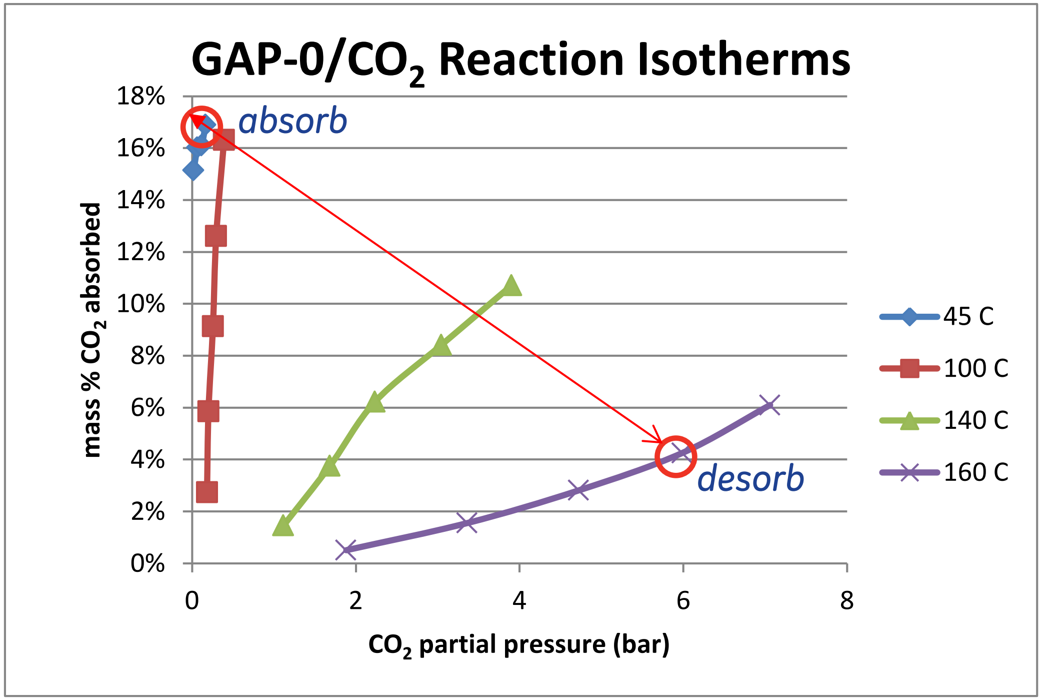
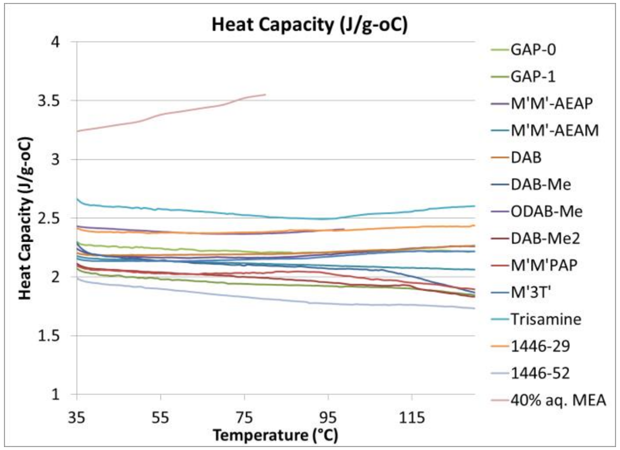
GAP-0 Properties

- Lower vapor pressure vs. MEA
- Higher heat of reaction vs. MEA
- Lower heat capacity vs. MEA
- >11% Dynamic CO_2 capacity @ 6 bara









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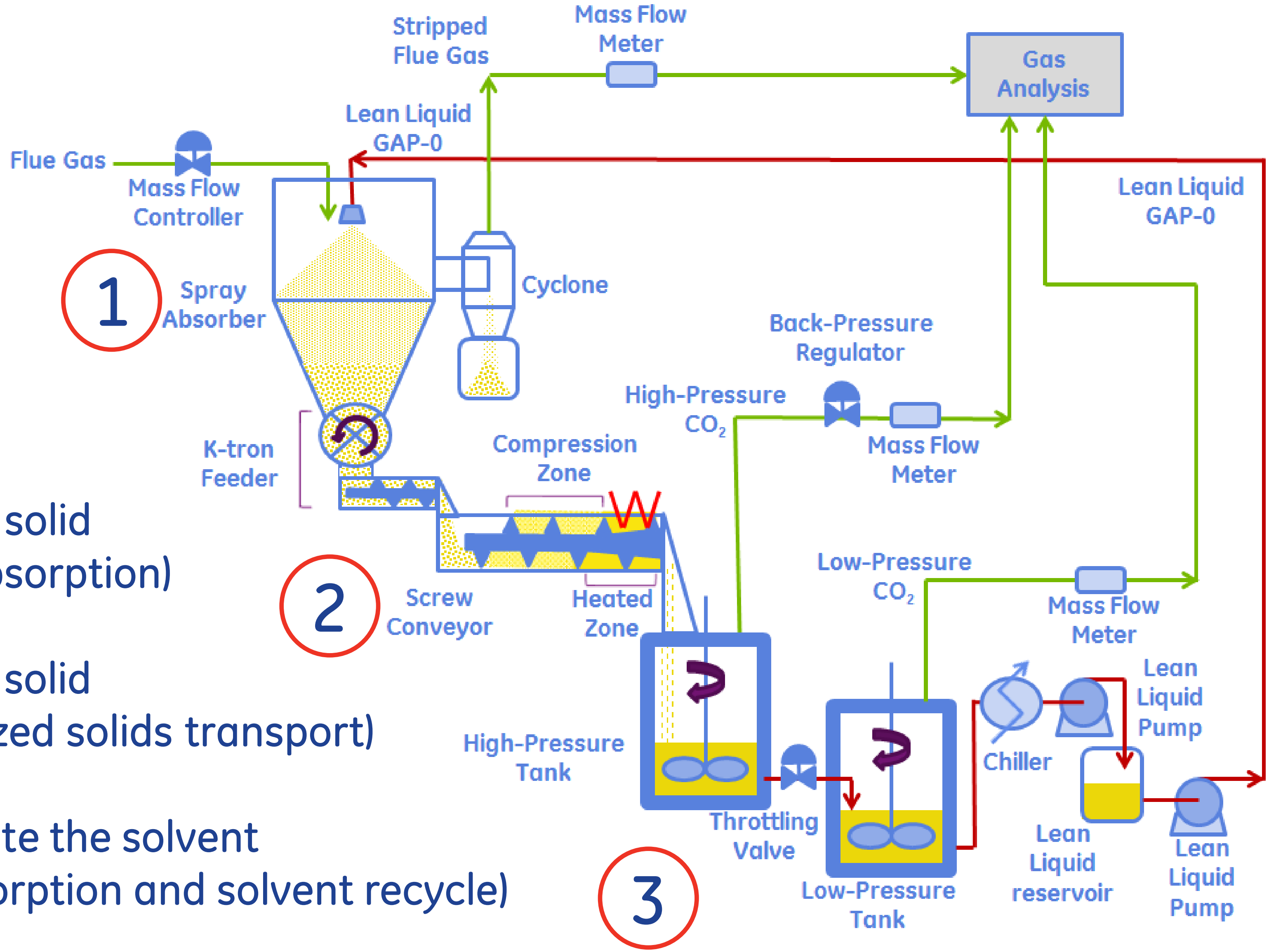
Phase-Changing CO_2 Capture Process

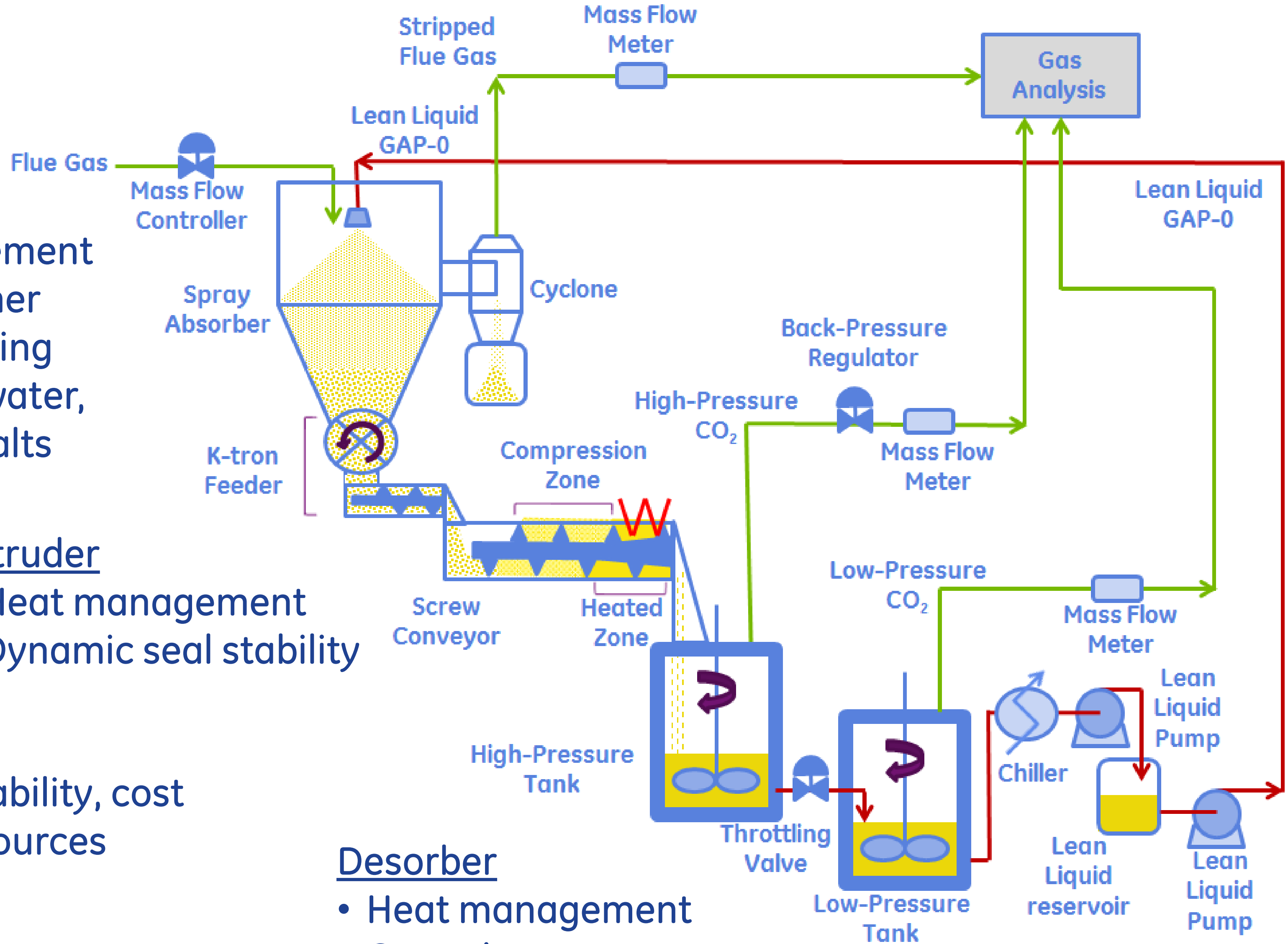


1 Make the solid
(Spray absorption)

2 Move the solid
(Pressurized solids transport)

3 Regenerate the solvent
(CO_2 desorption and solvent recycle)

Risk Assessment



Absorber

- Heat management
- GAP-0 β-isomer
- Atomizer fouling
- Presence of water, heat stable salts

Extruder

- Heat management
- Dynamic seal stability

Project

- Solvent availability, cost
- Expertise resources

Desorber

- Heat management
- Corrosion

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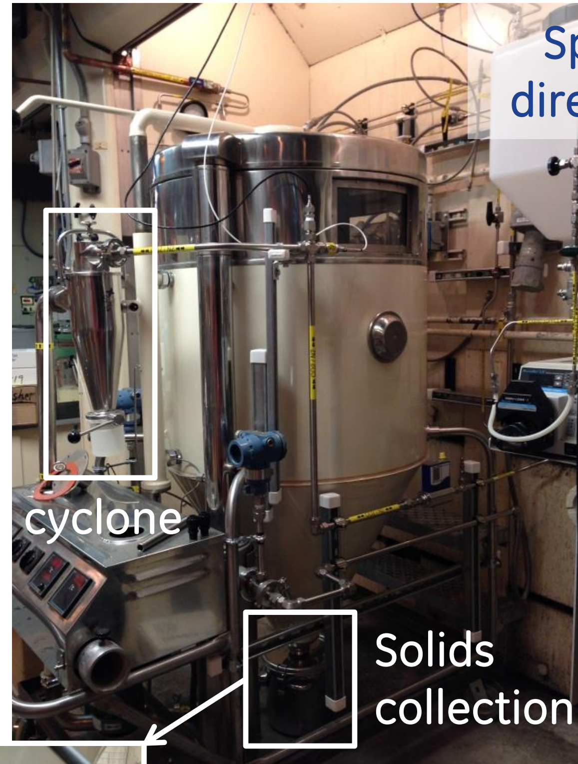
Project Structure

- Budget Period 1: Design and Build [2014]
  - Spray absorber, extruder, desorber
  - Preliminary Technical and Economic Assessment
  - Go/No-go: 90% CO_2 Capture, <$50/tonne CO_2
- Budget Period 2: Unit Operations Testing [2015]
  - Optimize individual unit operations separately
  - Solvent manufacturability study and EH&S risk assessment
  - Update Technical and Economic Assessment
  - Go/No-go: 90% CO_2 Capture, <$45/tonne CO_2
- Budget Period 3: Continuous System Operation [2016]
  - Integrate unit ops into continuous system, generate engineering data for scale-up
  - Final Technical and Economic Assessment
  - Goal: 90% CO_2 Capture, <$40/tonne CO_2

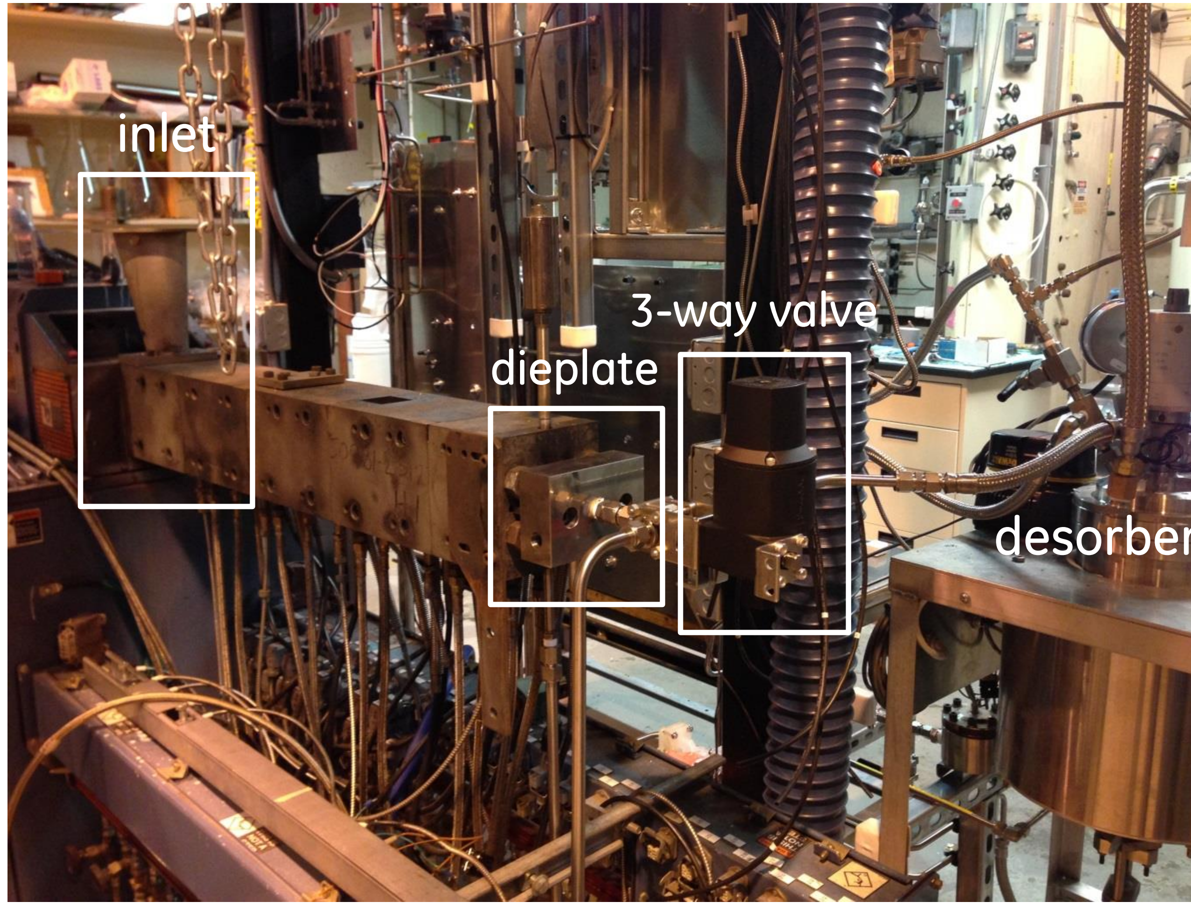
Design and Build – Absorber

Gas supply system



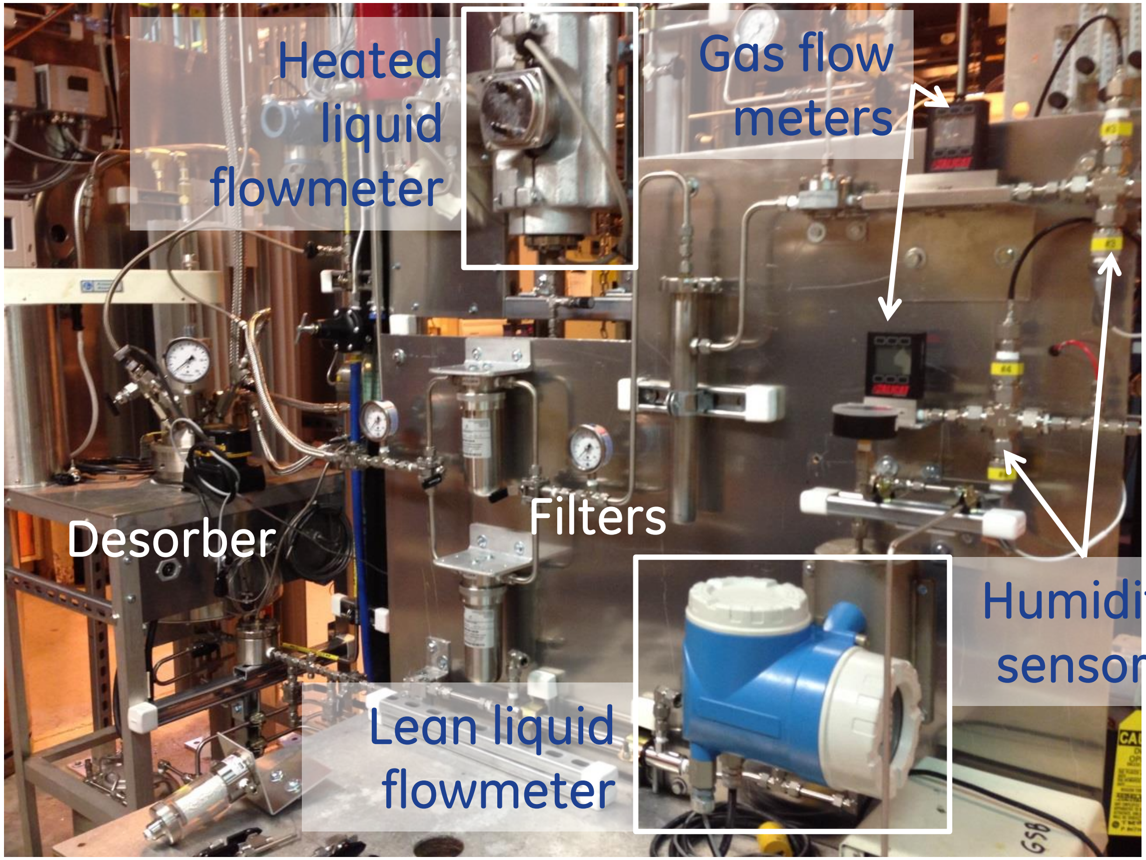
Spray absorber and liquid supply system

Design and Build – Extruder



K-Tron solids feeder and 25mm extruder, connected to desorber inlet

Design and Build – Desorber



Pressurized and atmospheric pressure desorbers

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Bench Scale Experiment Plan

	Absorber (2Q 2015)	Extruder (3Q 2015)	Desorber (4Q 2015)
Vary	• Gas inlet composition • Gas flow rate • Liquid flow rate • CO_2 : GAP-0 mole ratio • Atomizer type and settings	• Solids flow rate • Screw RPM • Screw design • Barrel T profile • Outlet pressure	• Feed rate • Temperature • Pressure • Agitation rate • Residence time
Measure	• % CO_2 capture • % GAP-0 conversion • Gas outlet T • Solids yield	• Maximum delivery pressure	• % GAP-0 conversion • CO_2 flow rate
Optimize	High % GAP-0 conversion (high quality solids)	High delivery pressure (stable solids seal)	• High CO_2 desorbed at pressure • Complete solvent regeneration for recycle

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Absorber experiments to date

Solids production: 16-100% CO_2, 50-200mL/min GAP-0, 100-200slm simulated flue gas

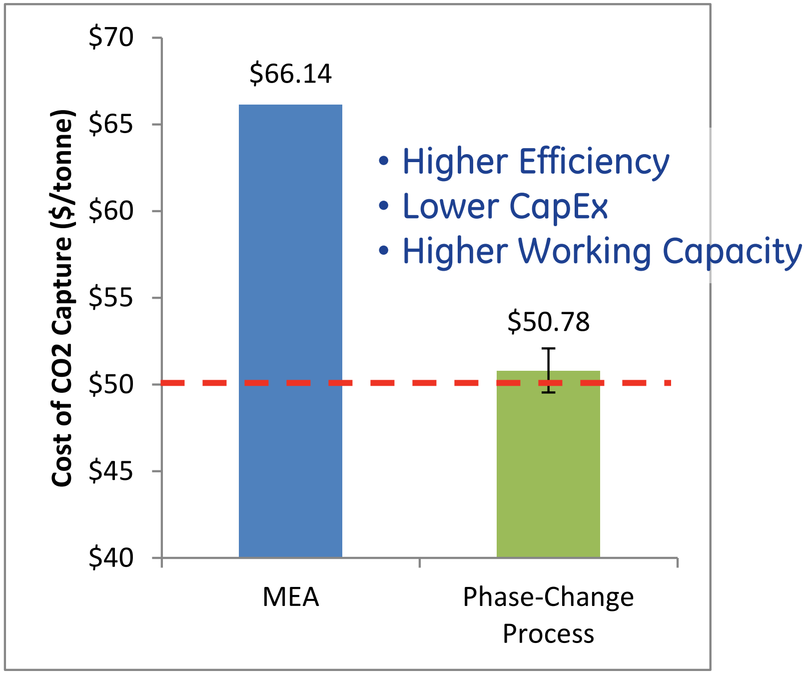
90-97% GAP-0 conversion

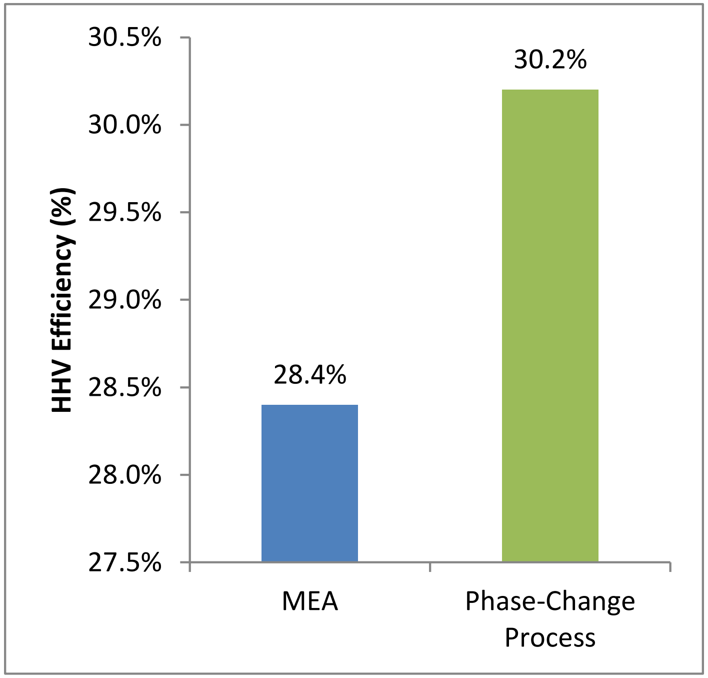
Solids can accumulate around the hopper outlet

Limited atomizer fouling in 20min sprays

Next: Continue with <16% CO_2, establish operating window that yields solids

Preliminary Process and Cost Modeling





Phase-changing aminosilicone process offers substantially higher efficiency, lower cost vs. MEA

BP1 Milestones and Success Criteria

Budget Period	Task	Milestone Title/Description	Planned Completion Date	Actual Completion Date	Verification Method
1	1	Updated Project Management Plan	1/31/2014	1/31/2014	Project Management Plan file
1	1	Kickoff Meeting	12/31/2013	11/20/2013	Presentation file
1	2.1-2.2	Preliminary process and cost modeling complete	3/31/2015	3/31/2015	Preliminary Process and Cost Modeling Report
1	3.1	Absorber Built and Operational	12/31/2014	12/31/2014	Research Performance Progress Report file
1	3.2	Extruder Built and Operational	3/31/2015	3/31/2015	Research Performance Progress Report file
1	3.3	Desorber Built and Operational	12/31/2014	12/31/2014	Research Performance Progress Report file
1	3.4	Integrated system design complete	3/31/2015	3/31/2015	Bench-Scale System Design Topical report

BP1 Success Criteria

- ✓ Unit operations are built and operational
- ✓ 90% CO_2 Capture, <$50/tonne CO_2

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BP2 Milestones and Success Criteria

Budget Period	Task	Milestone Title/Description	Planned Completion Date	Actual Completion Date	Verification Method
2	4.2	Absorber Parameters Established	3/31/2016		Unit Operations Testing Topical report
2	4.2	Extruder Parameters Established	3/31/2016		Unit Operations Testing Topical report
2	4.2	Desorber Parameters Established	12/31/2015		Unit Operations Testing Topical report
2	4.5	Continuous System Assembled	3/31/2016		Research Performance Progress Report file
2	5.1	Technology EH&S Risk Assessment	3/31/2016		EH&S Risk Assessment Topical report
2	5.2	Preliminary cost study completed	3/31/2016		Preliminary Cost Study report

BP2 Success Criteria

- >90% GAP-0 conversion in absorber, reactor T < 90°C
- <5% solids lost from absorber solids collection
- >90% of carbamate conversion dictated by isotherms at T, P in pressurized desorber
- >95% of carbamate conversion in atmospheric desorber (polisher)
- 90% CO_2 Capture, <$45/tonne CO_2

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Thank You

- NETL
  - Lynn Brickett, David Lang
- GE GRC Project Team
  - Mike Bowman, Joel Caraher, Wei Chen, Rachel Farnum, Mark Giammattei, Terri Grocela-Rocha, Robert Perry, Surinder Singh, Norberto Silvi, Irina Spiry, Paul Wilson, Benjamin Wood
- Coperion
  - Paul Andersen, Eberhard Dieterich

Acknowledgement. The information, data, or work presented herein was funded in part by the Advanced Research Projects Agency – Energy (ARPA-E), U.S. Department of Energy, under Award Number DE-AR0000084 and DOE- NETL under Award Number DE-NT0005310.