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

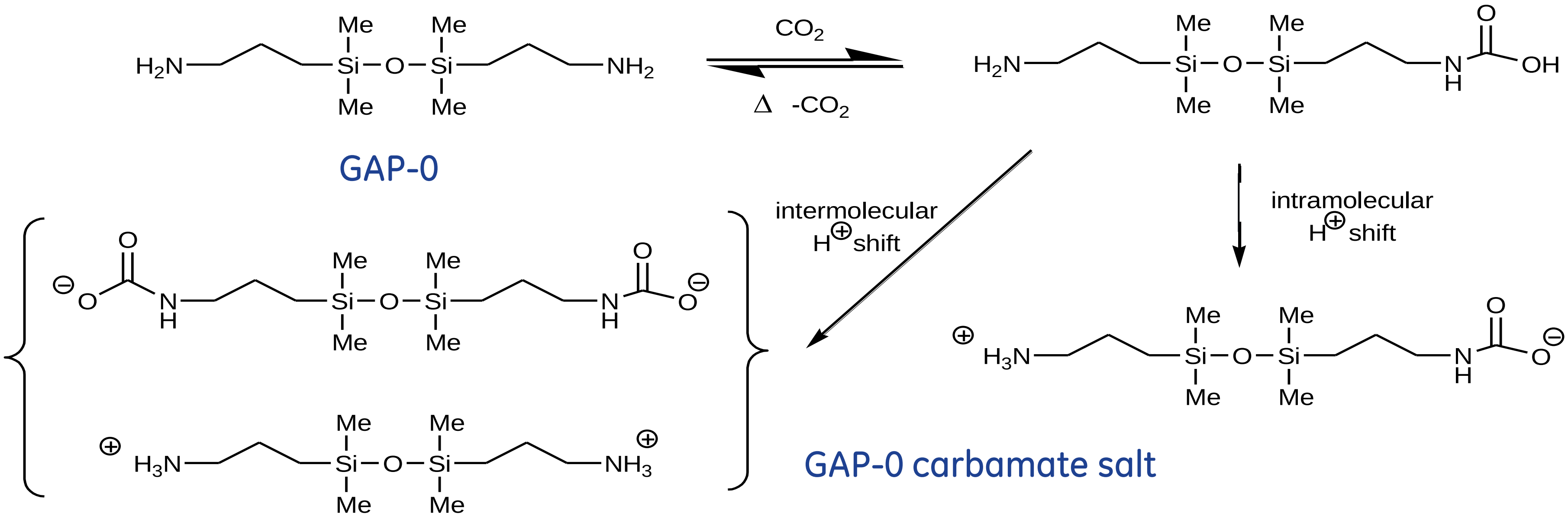
DE-FE0013687

GE Global Research

Tiffany Westendorf

2014 NETL CO_2 Capture Technology Meeting
July 30, 2014

Chemistry of GAP-0 reaction with CO_2



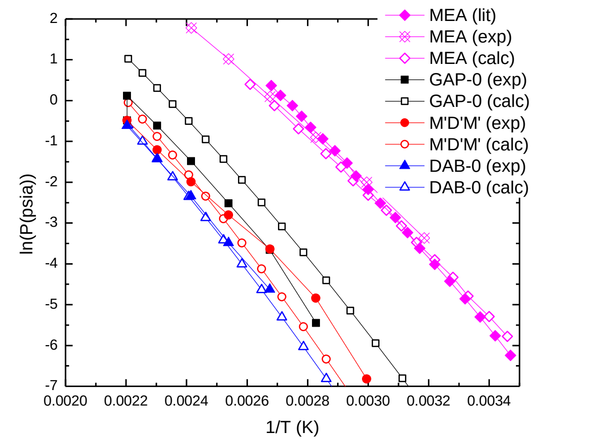
GAP-0

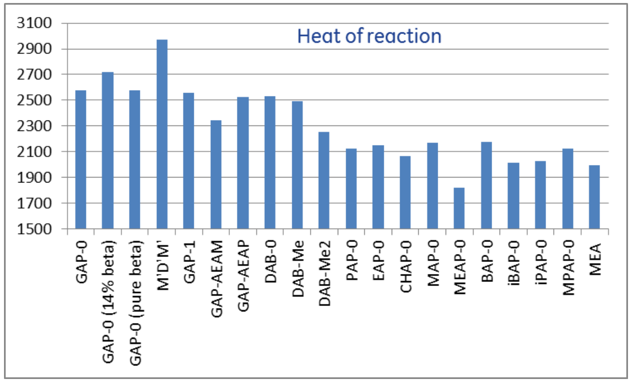
GAP-0 carbamate salt

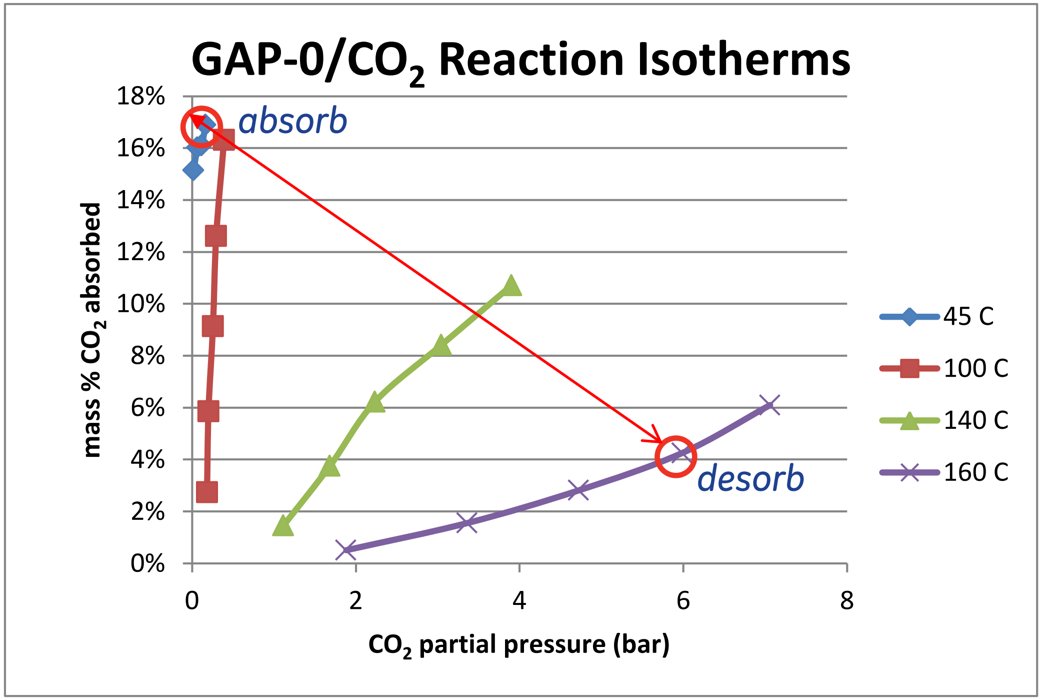
- Extensive screening of multiple solvents
- Absorbs CO_2 very rapidly in the 40-50°C range
- High CO_2 loading (>17% weight gain, >95% of theoretical value)
- Carbamate readily decarboxylates at higher temps
- Carbamate is solid → new process configuration

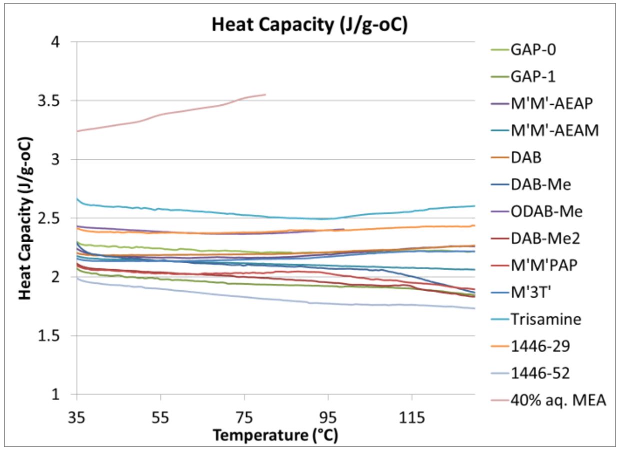
GAP-0 Properties

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





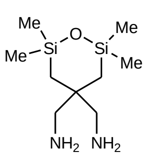




imagination at work

Effect of Water on Carbamate Salt

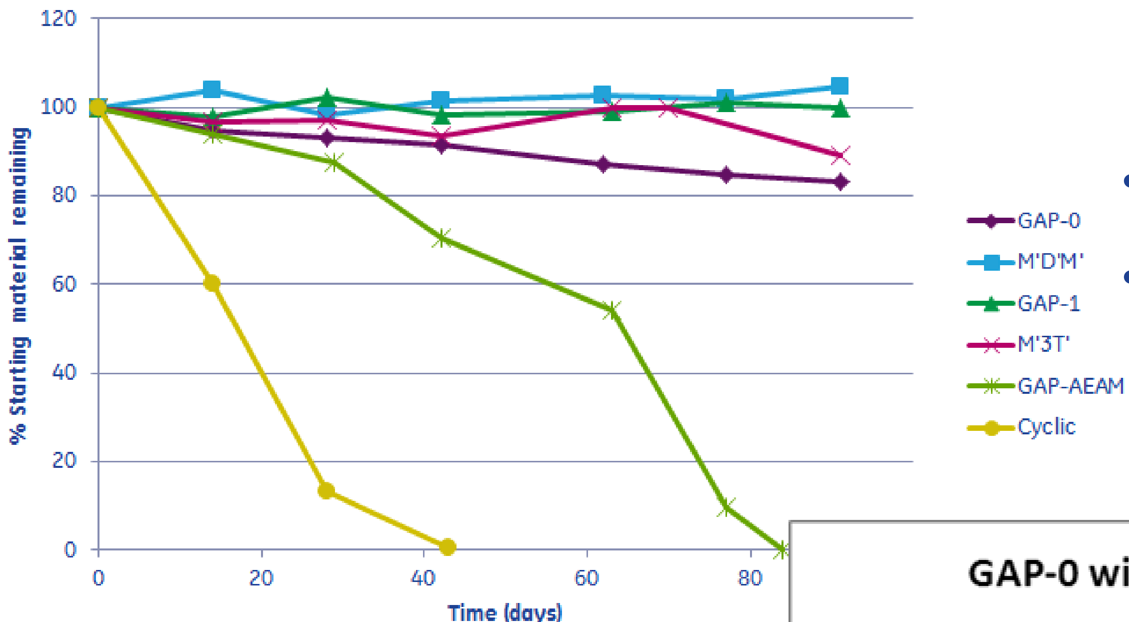
Impact of dry vs wet CO_2

Solvent	Dry % Wt Gain (% of Theoretical)	Dry Salt Form	Wet % Wt Gain (% of Theoretical)	Wet Salt Form
GAP-0	17.3 (98)	Powder	18.4 (104)	Powder
GAP-1	13.1 (96)	Powder	14.1 (103)	Sticky Wax
M'D'M'	17.8 (99)	Powder	16.6 (92)	Glass
M'_3T'	18.8 (103)	Powder	17.4 (96)	Sticky Gum
	17.3 (92)	Powder	20.7 (109)	Powder

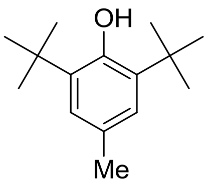
- Pure compounds GAP-0 & cyclic diamine looked best
- Oligomer-based salts softened with H_2O & became sticky

imagination at work

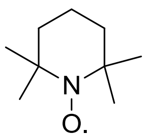
Thermal Stability



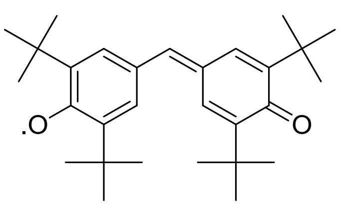
- Good stability of GAP-0
- Improvement w/ stabilizers



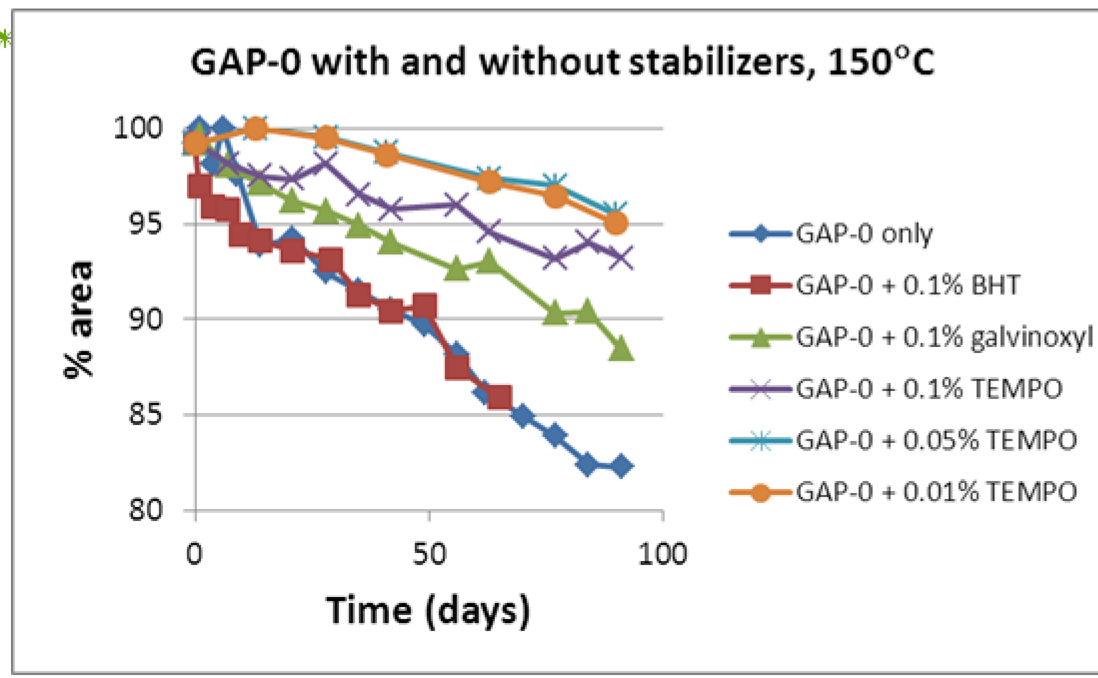
BHT



TEMPO

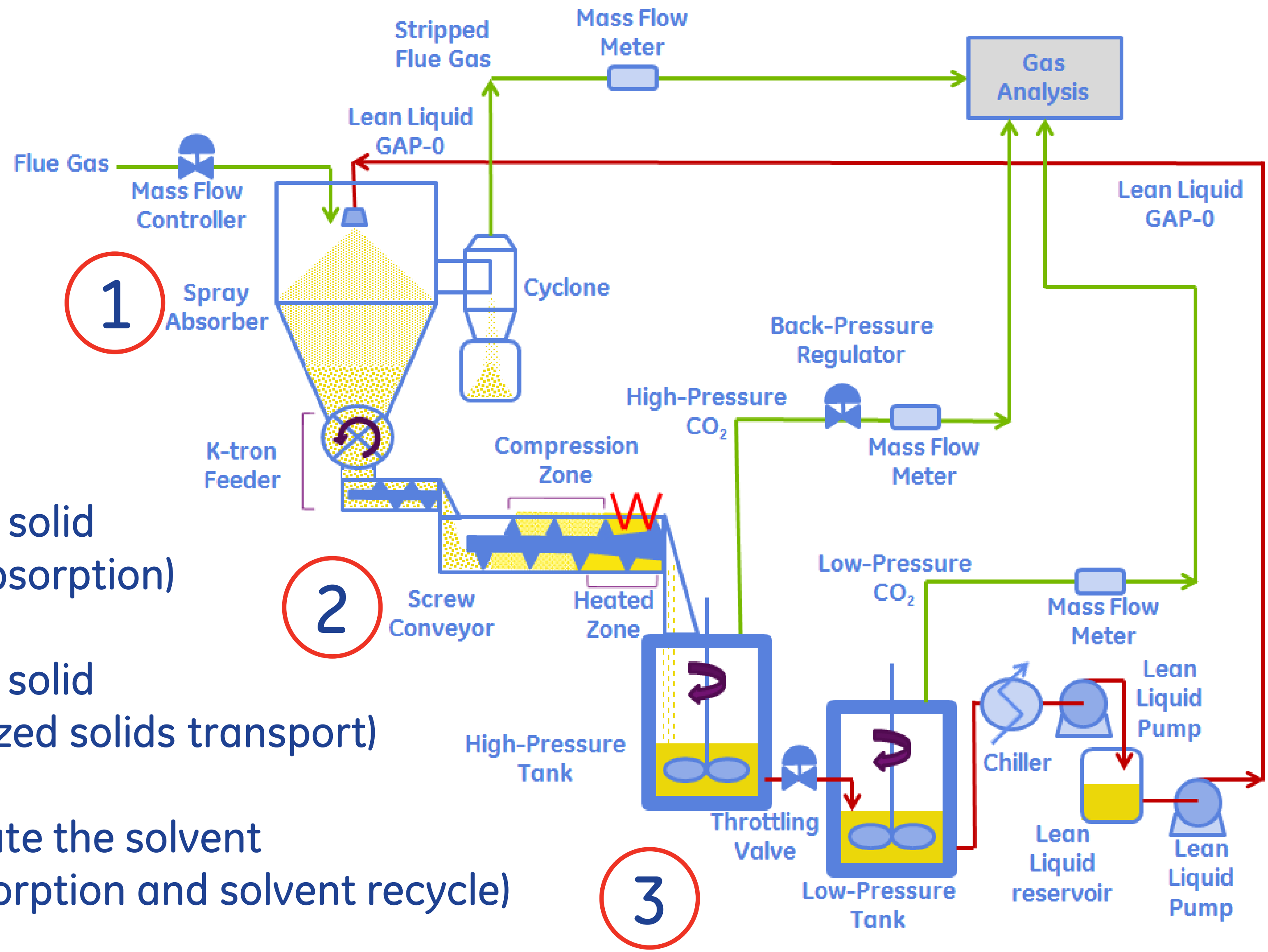


Galvinoxyl



imagination at work

Continuous System



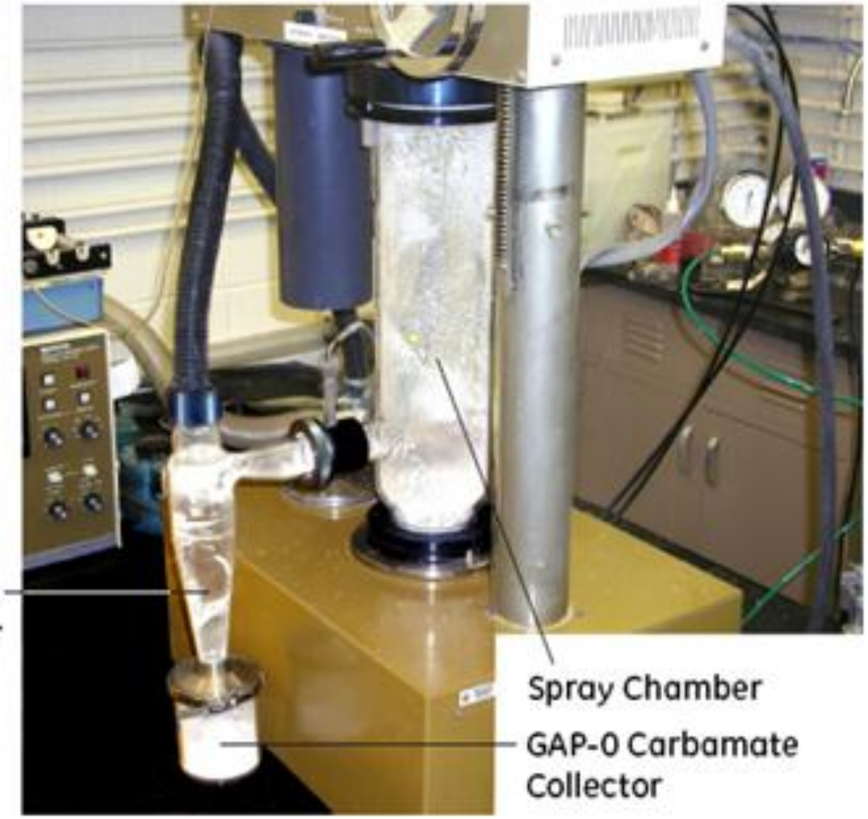
1 Make the solid
(Spray absorption)

2 Move the solid
(Pressurized solids transport)

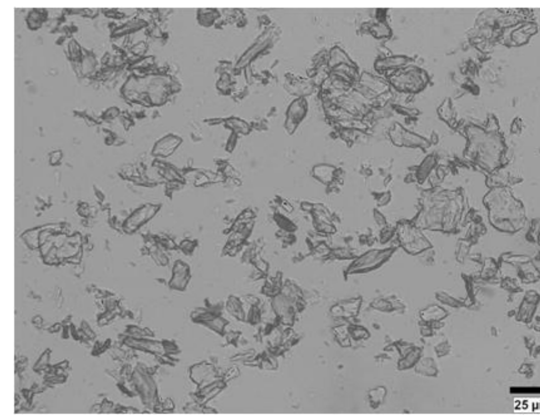
3 Regenerate the solvent
(CO_2 desorption and solvent recycle)

imagination at work

Solid Formation and Isolation



GE GRC Spray Reactor

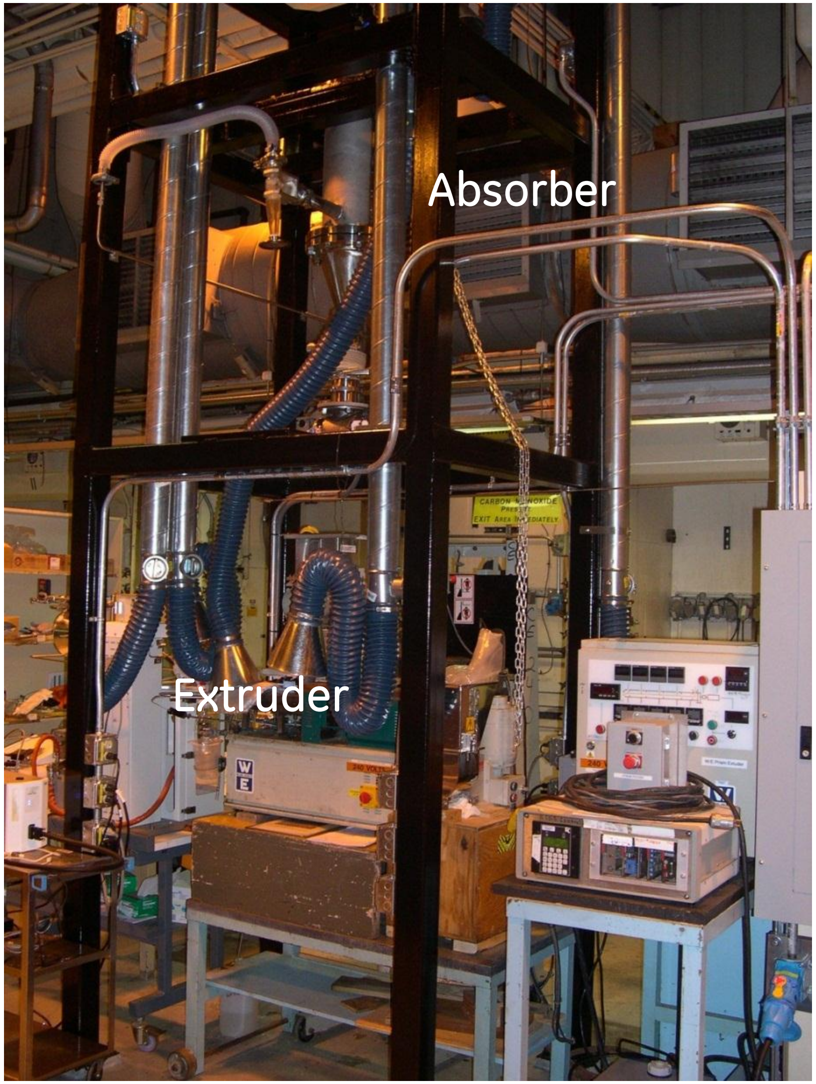


- Spray reactor with co-current CO_2 flow
- Nearly instantaneous solid formation
- 50-400 g sample size

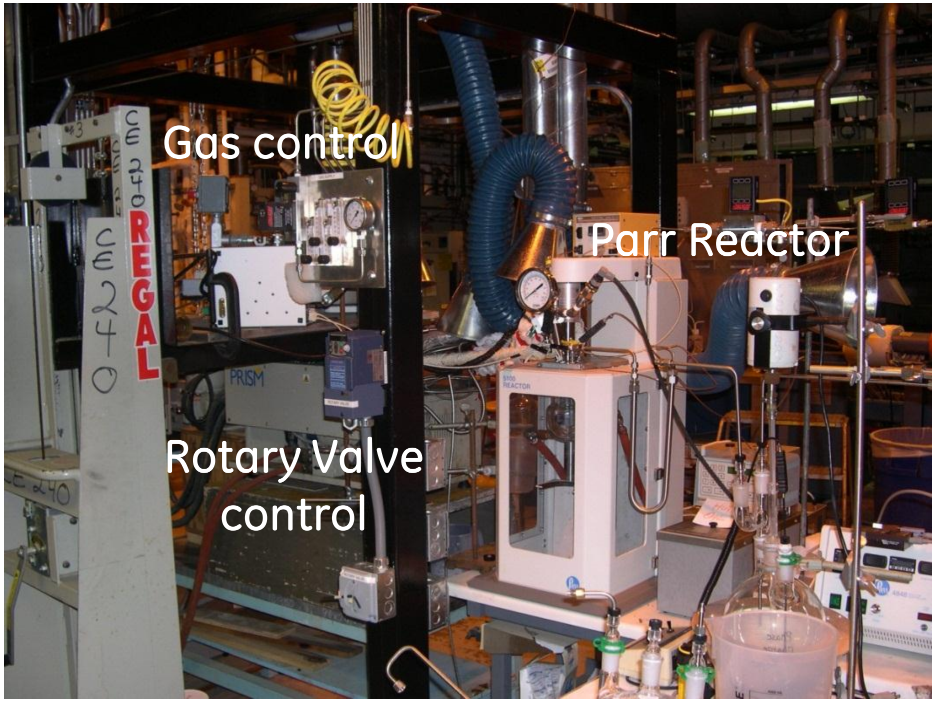
- Mean particles < 50μm
- Highly crystalline

imagination at work

Phase-Change Continuous System



- System built for ARPA-e project
- 2 months of data gathering
- Demonstrated continuous operation of key process steps



imagination at work

Phase-Changing Aminosilicone CO_2 Capture

Advantages

- Non-aqueous, pure solvent
- Superior properties to MEA:
  - Lower heat capacity
  - Low corrosivity
  - Higher thermal stability
  - Higher vapor pressure
- Supports pressurized CO_2 desorption
- Intensified mass transfer, smaller footprint

Challenges

- Solvent cost, availability
- Pressurized solids handling
- Management of reaction heat in absorber
- Chemical deactivation of solvent
- Scaleup of extruder

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

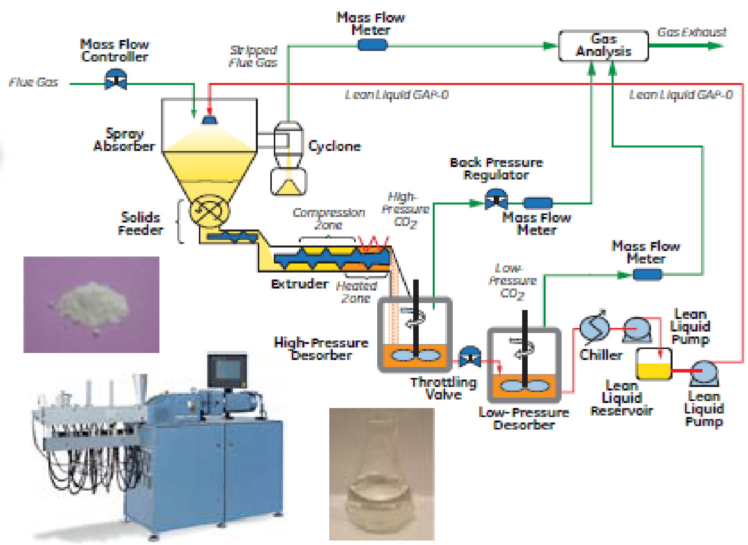
Gelest · SILAR LABORATORIES · SiVance

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

imagination at work

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 scaleup
  - Final Technical and Economic Assessment
  - Goal: 90% CO_2 Capture, <$40/tonne CO_2

Budget Period 1

- Design and construction of bench-scale unit
  - Spray reactor
    - efficient spray formation and contact with simulated flue gas
    - low fouling nozzle
    - disengagement of particles from gas stream
    - operation at 200 mL/min solvent flow rate
    - 120 slm gas flow rate
    - solids transfer device (rotary valve)
  - Extruder
    - system to handle 20-150 lb/hr solid
    - maintain dynamic seal
    - design elements to optimize seal
    - consult with Coperion as needed

COPERION

Budget Period 1

- Design and construction of bench-scale unit
  - Desorber
    - 2 vessels in series
    - elevated pressure to maintain extruder backpressure
    - atmospheric vessel for polishing
  - Integrated system
    - work closely with Facilities for installation
    - process controls/instrumentation
    - automated controls where possible
    - data logging capability
- Preliminary Technical & Economic Assessment
  - Leverage model developed in ARPA-e project
  - Estimate cost of CO_2 capture

Success Criteria

- Budget Period 1: Design and Build [2014]
  - Unit operations are built and operational
  - 90% CO_2 Capture, <$50/tonne CO_2
- Budget Period 2: Unit Operations Testing [2015]
  - >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
  - 90% CO_2 Capture, <$45/tonne CO_2
- Budget Period 3: Continuous System Operation [2016]
  - <0.3%/day thermal degradation of solvent
  - >20% improvement in energy penalty vs. MEA
  - 90% CO_2 Capture, <$40/tonne CO_2

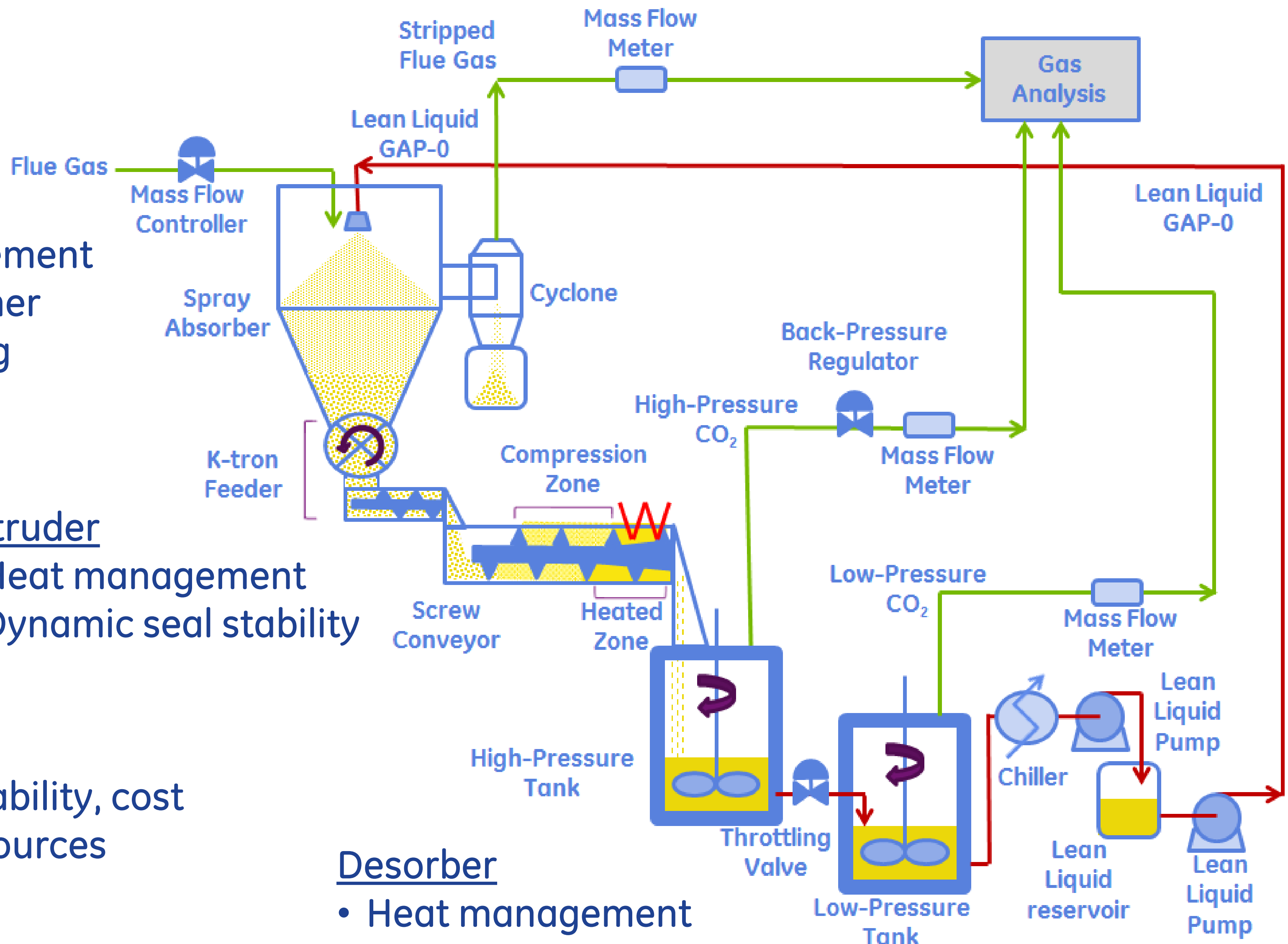
Risk Assessment

Absorber
- Heat management
- GAP-0 β-isomer
- Nozzle fouling

Extruder
- Heat management
- Dynamic seal stability

Project
- Solvent availability, cost
- Expertise resources

Desorber
- Heat management
- Corrosion



imagination at work

Status / Next Steps

Status

- Design and build
  - Conceptual design and initial P&IDs
  - Secured key process equipment
  - New equipment orders in progress
  - Kickoff with Facilities for installation
  - Negotiated lower price for solvent
- Process and economic modeling
  - Prioritized task plan for process modeling established
  - Synergies with pilot scale solvent project – power plant modeling/integration

Next Steps

- Design and build
  - Complete equipment installation
  - Equipment commissioning
  - Experimental plan for unit ops testing / BP2
- Process and economic modeling

imagination at work

Phase-Changing Aminosilicone: Beyond 2016

Flexible, unique capture process may be advantageous in diverse applications:

- Remote settings
- Process transients (startup, excursions/upset)
- Variable load

Thank You

- NETL
  - David Lang
- GE GRC Project Team
  - Mike Bowman, Wei Chen, Rachel Farnum, Mark Giammattei, Terri Grocela-Rocha, Robert Perry, Surinder Singh, 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.