Bench-Scale Silicone Process for Low-Cost CO_2 Capture

GE Global Research

GE Energy

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GE Energy
Milliken/SiVance

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DOE Contract: DE-FE0007502

Milliken

2013 NETL CO_2 Capture Technology Meeting

July 9, 2013

Overview

Program Team

GE Global Research

- *Bench-Scale Design and Testing of Absorption/ Desorption Process*
- *Materials of Construction*

GE Energy

- *Modeling and Design of Integrated Energy Systems*
- *Economic Analysis*
- *Technical and Economic Feasibility Study*

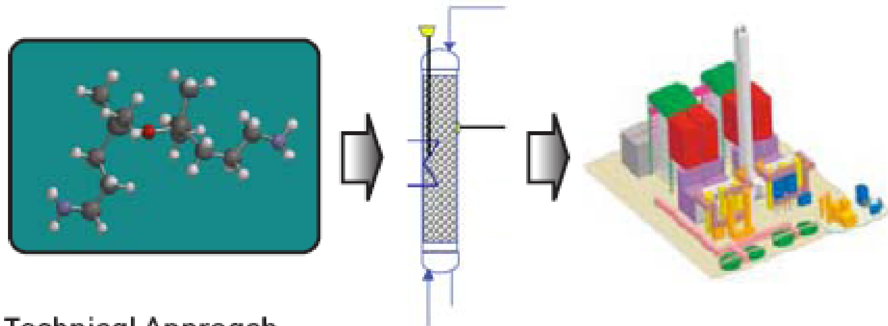
SiVance

Chemistry… for Precision Performance

- *Optimized Process for Solvent Synthesis*
- *Large Scale Manufacture of Silicone Solvent*
- *EH&S Risk Assessment*

27 Month, $3.75M Program to Develop a Silicone Process for CO_2 Capture

Program Objective: *Design and optimize a new process for 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 35% increase in the cost of energy services (COE).*



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 material manufacturing plan
- Develop scale-up strategy

Outcomes

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

Anticipated Benefits of the Proposed Technology

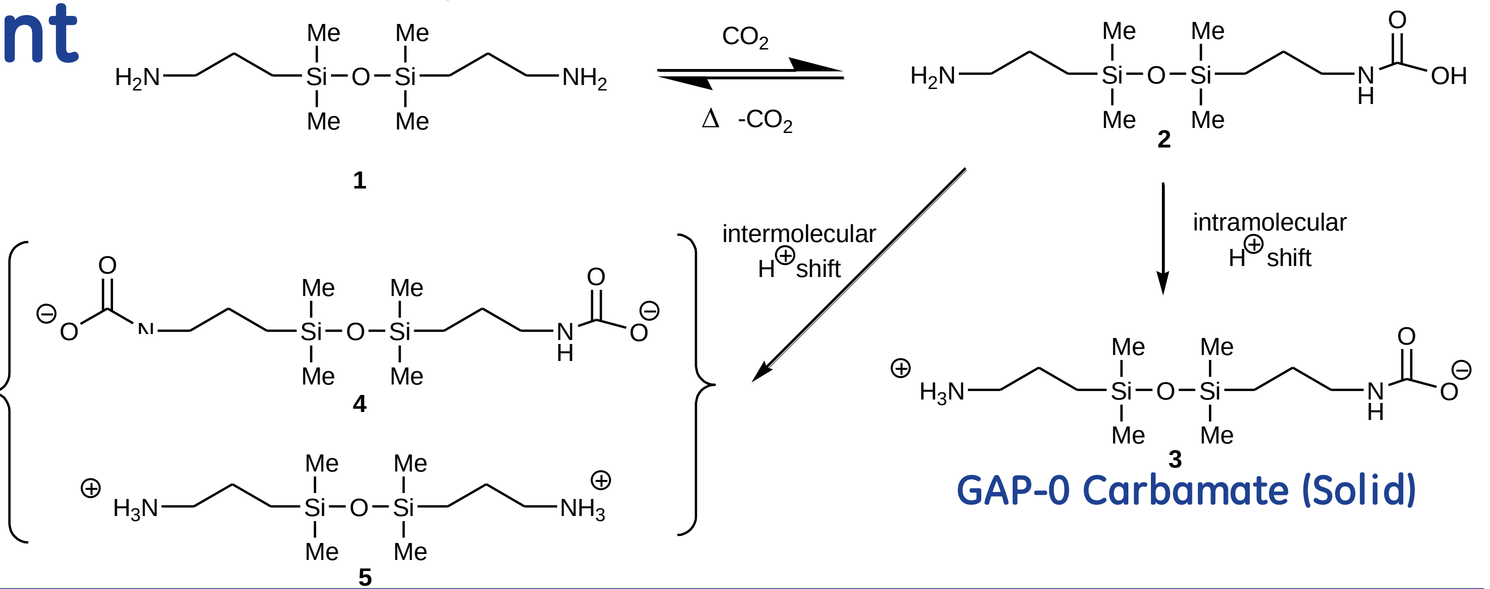
- 90% CO_2 capture with <35% COE increase

- Continuation of previous DOE/NETL funded project (DE-NT0005310)
- Current project has 2 phases
  - Phase 1: 10/1/2011 to 12/31/2012
  - Phase 2: 1/1/2013 to 12/31/2013

Absorbent

GAP-0 (Liquid)

GAP-0 Carbamate (Solid)



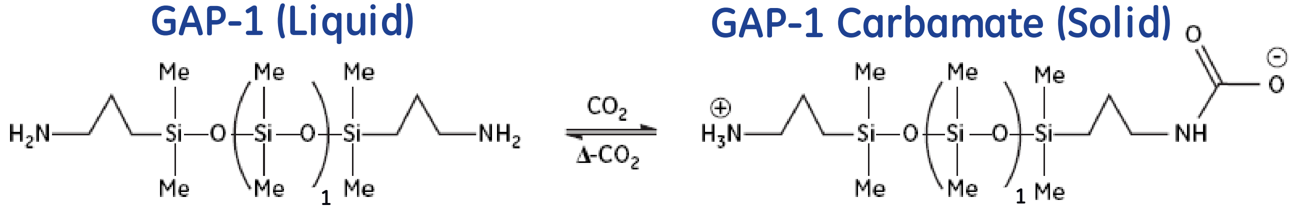
GAP-0 Carbamate (Solid)

- GAP-0 demonstrates 17.7% wt gain of CO_2 (10.2% wt gain for 30% MEA/H_2O)
- Co-solvent required to inhibit solidification (50 wt% triethylene glycol, TEG)
- Even in a 50/50 (wt/wt) mixture of GAP-0/TEG, eventually carbamate precipitates

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

GAP-1 (Liquid)

GAP-1 Carbamate (Solid)



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

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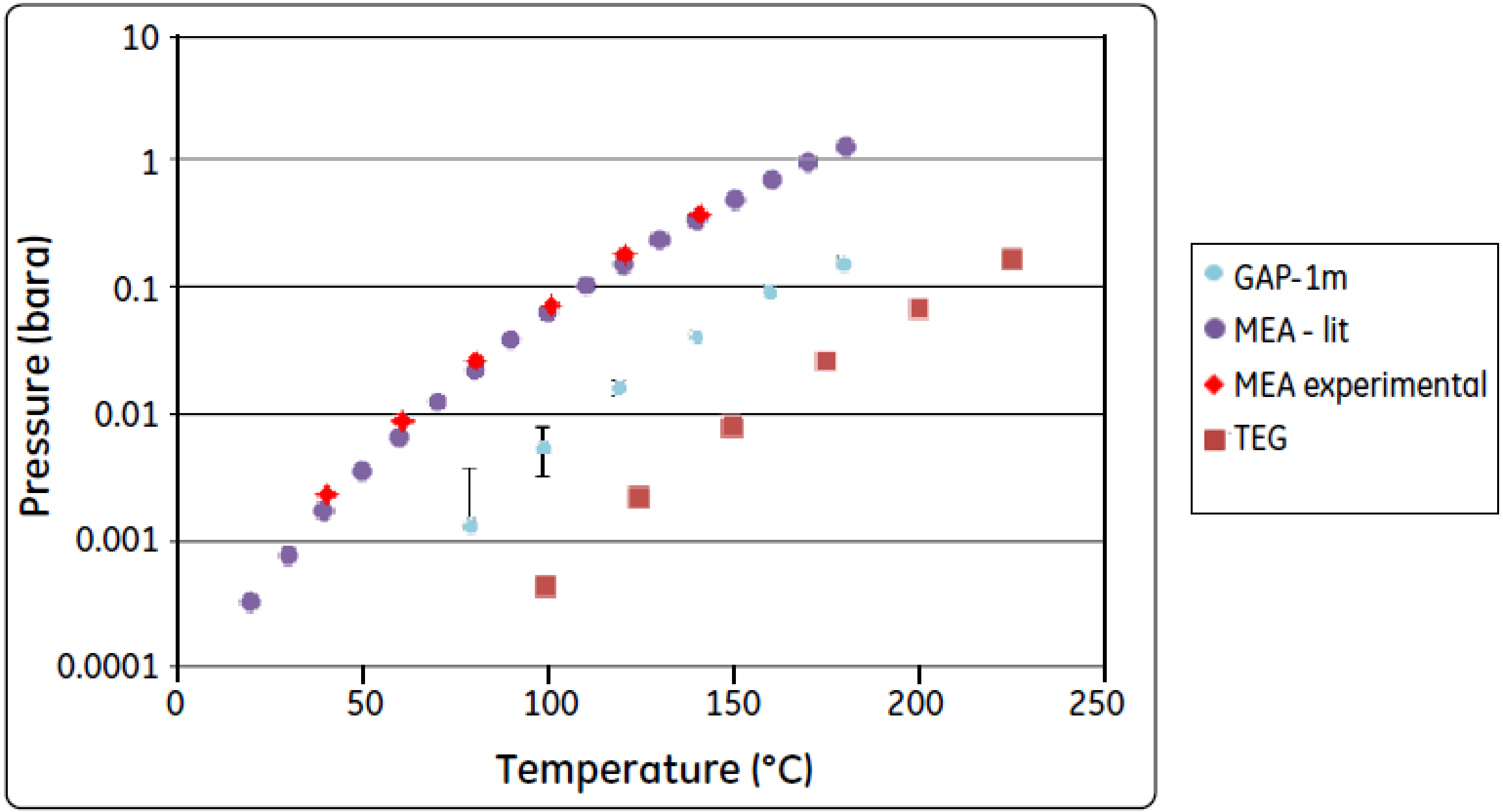
Vapor Pressure



Lower absorbent vapor pressure simplifies CO_2 desorption process

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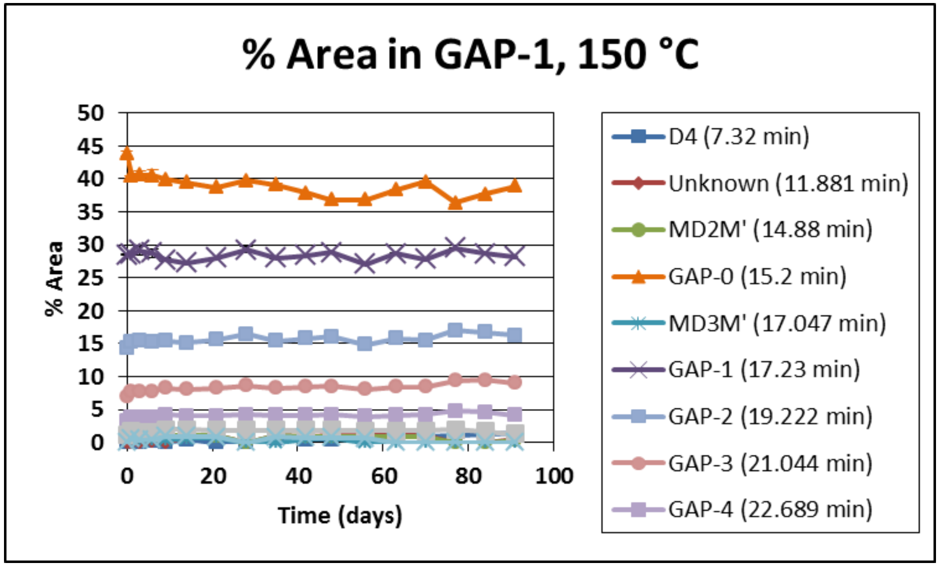
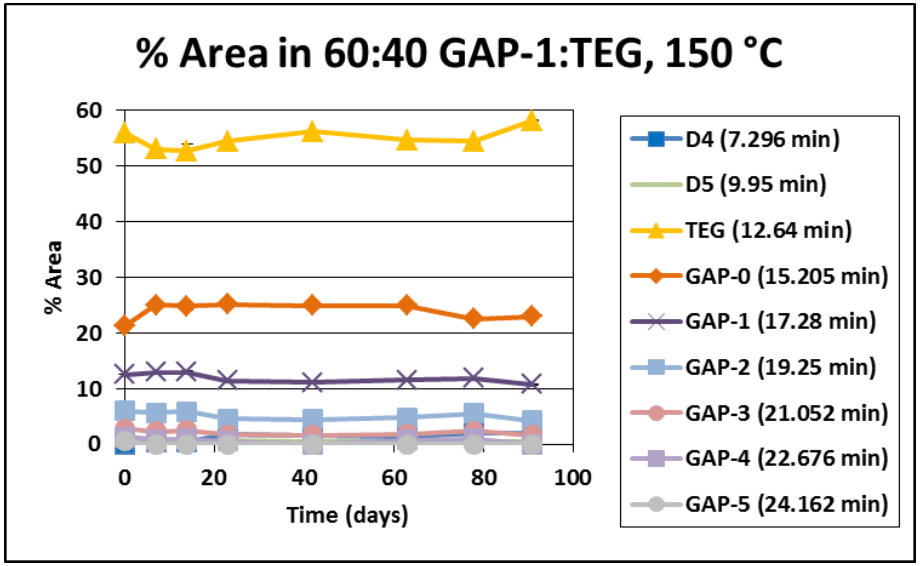
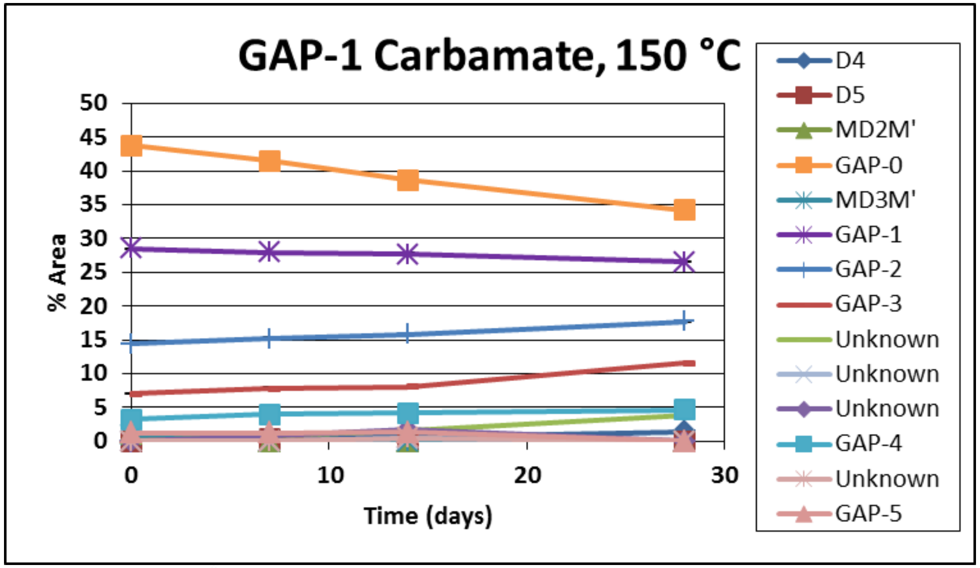
Thermal Stability Measured by GC







- Thermal stability of GAP materials is high
- Carbamate materials have lower thermal stability
  - GAP-0 converts to higher MW GAP materials
  - Have discovered additives that greatly improve thermal stability

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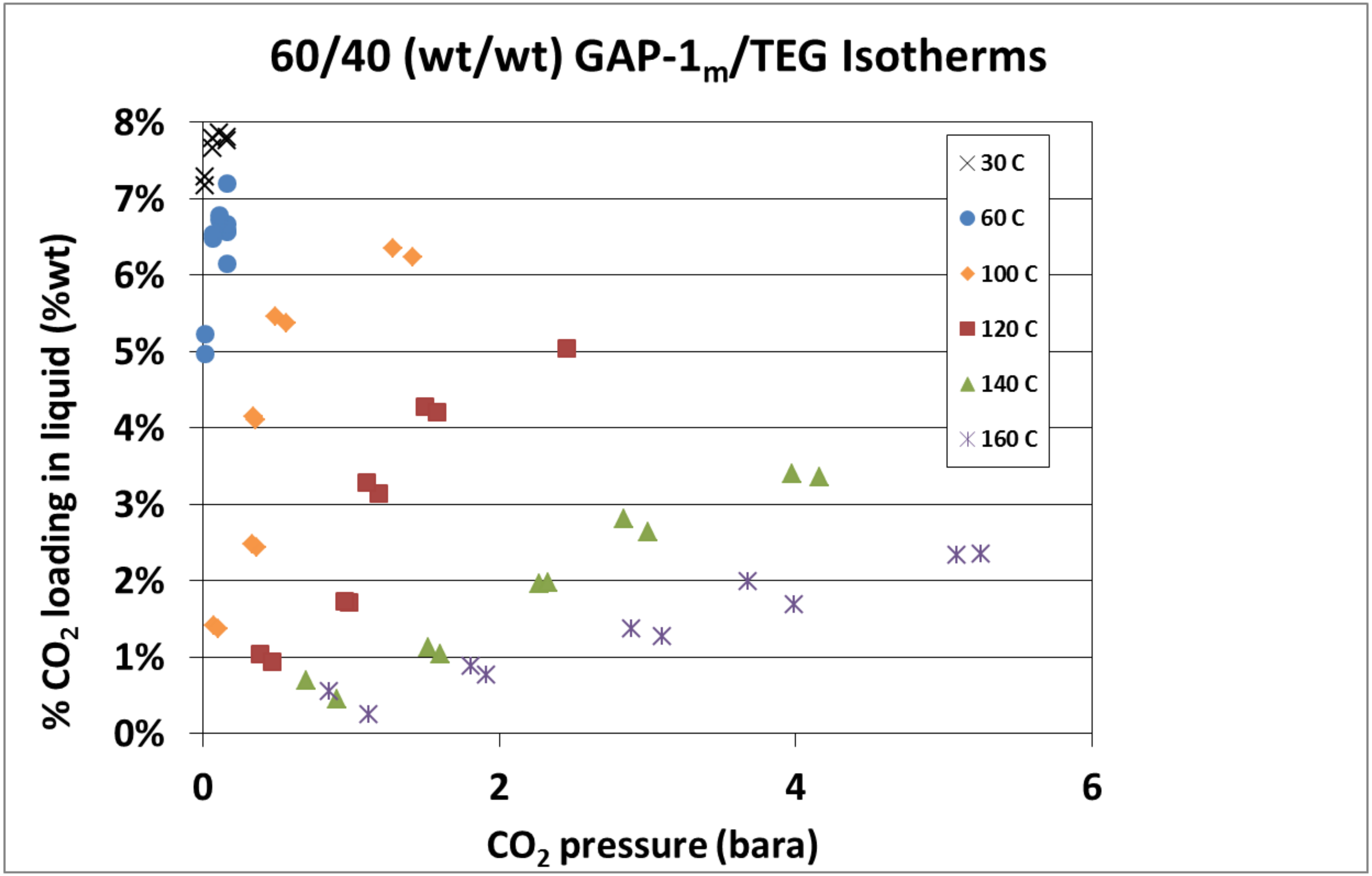
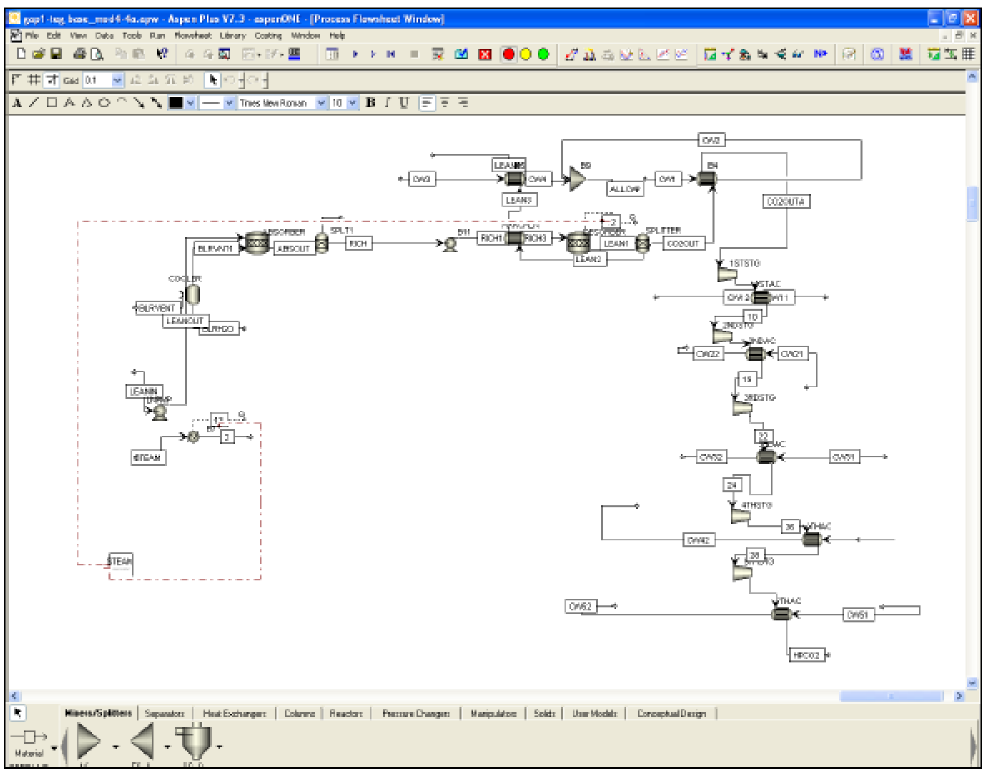
Isotherms

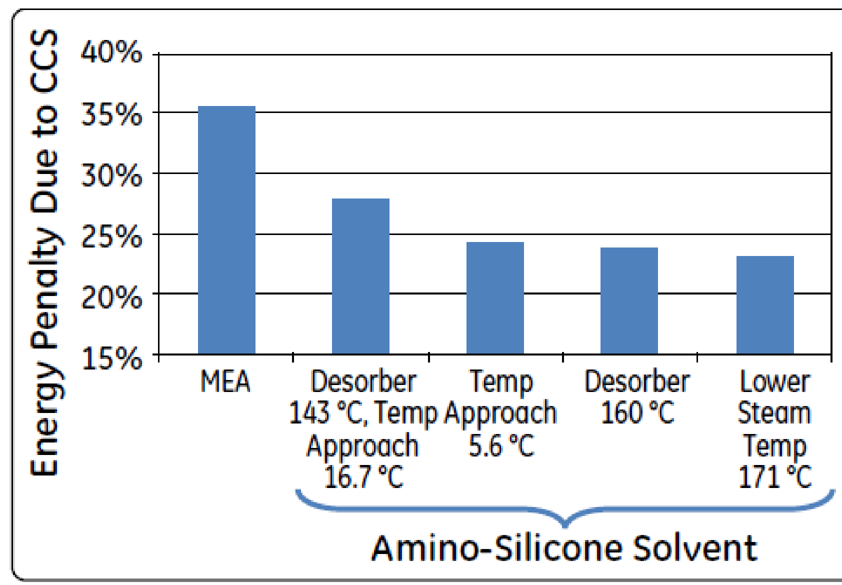


• The maximum possible working CO_2 capacity can be determined

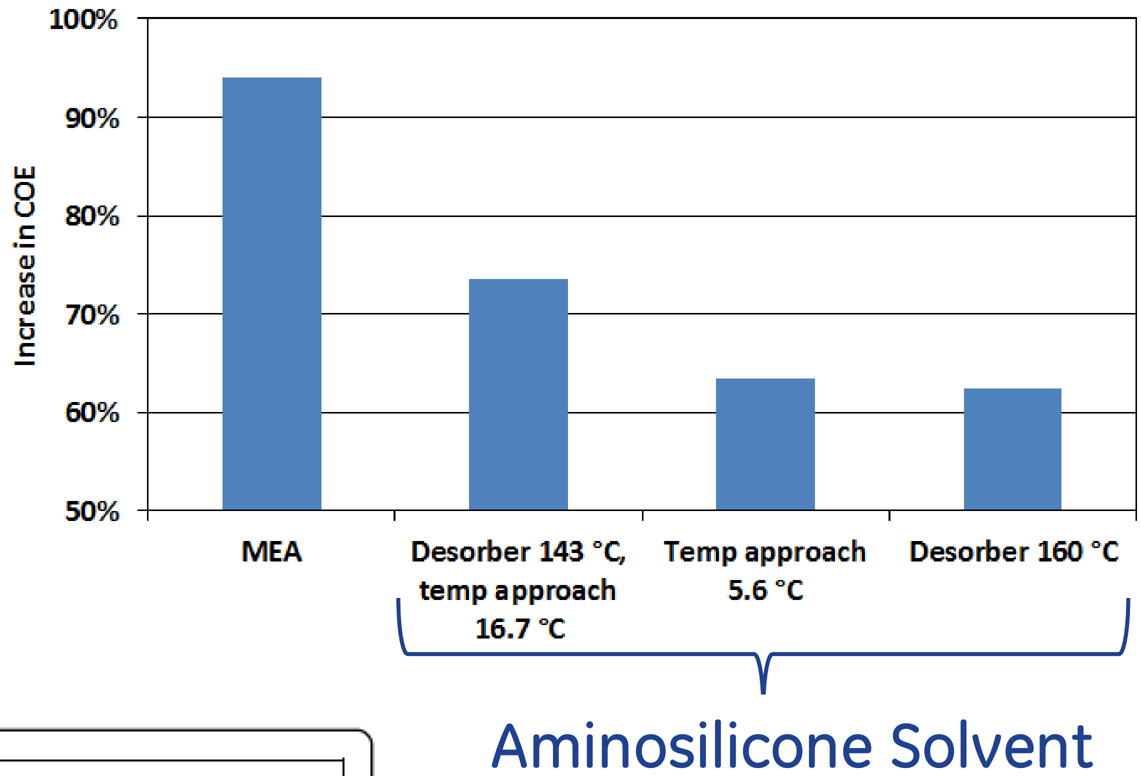
Energy Penalty

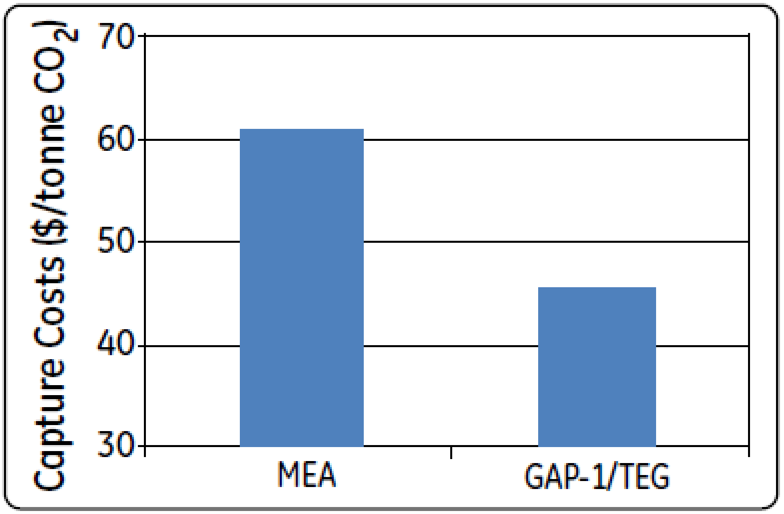
- ASPEN Plus model built for CO_2 separation unit using MEA or GAP-1/TEG
- GE coal-fired power plant model used to model effects on power plant
- Assumptions and methodologies specified in cooperative agreement used
- GAP-1/TEG energy penalty for the overall system ~23% vs. ~35% for MEA





Increase in COE and Capture Costs

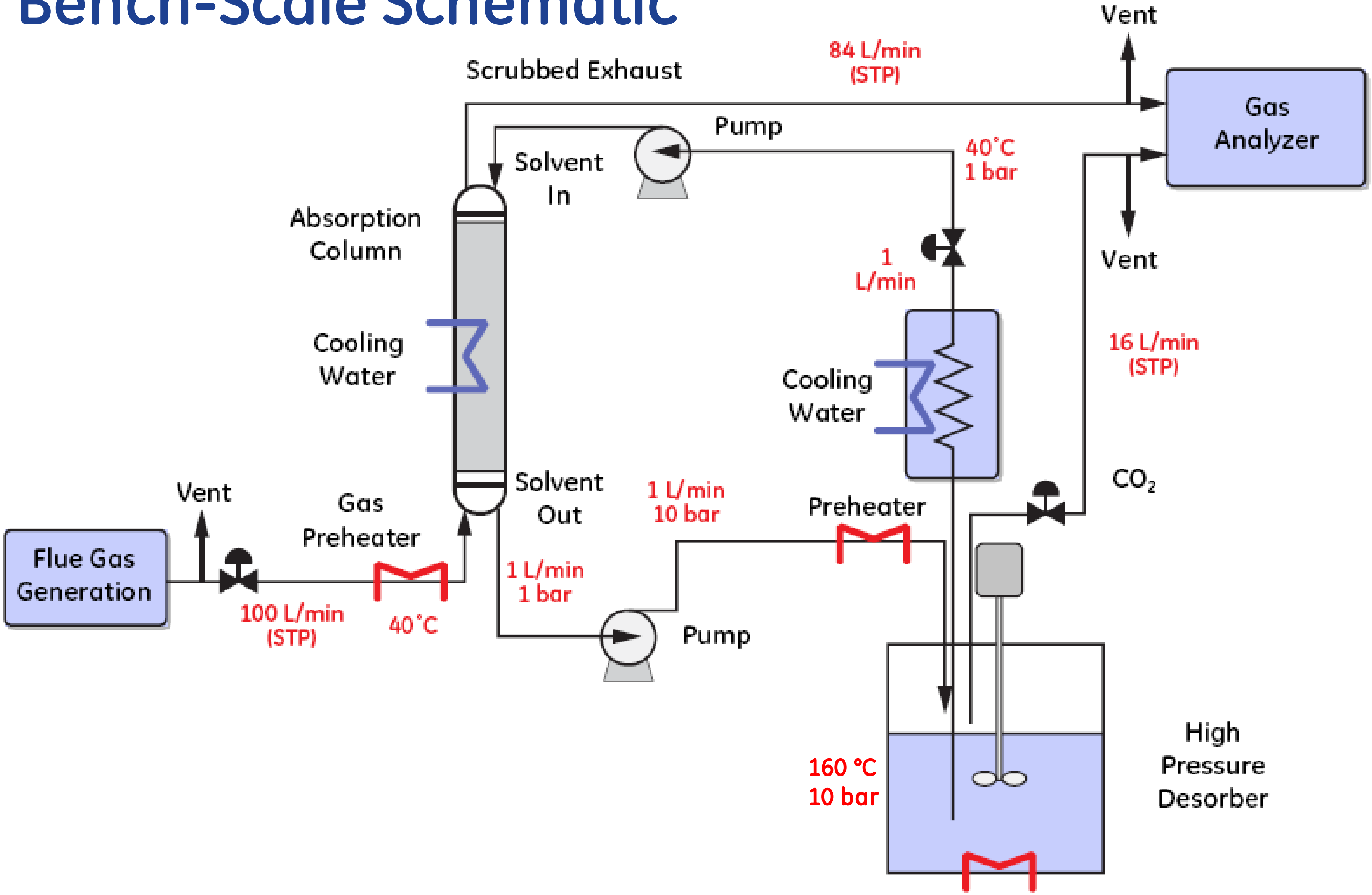




- GAP-1/TEG is capable of reduced capture costs relative to aqueous MEA

DOE Grant DE-FE0007502
July 9, 2013

Bench-Scale Schematic



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Bench-Scale CO_2-Capture System

- Entire process is automated
- Gasoline generator produces exhaust gas as a proxy for flue gas
- Various gases (e.g. extra CO_2, SO_2, NO_x, can be dosed in through gas manifold
- Absorption column has a modular design, so that total height can be varied
  - Can have packing height up to 9 ft
  - Intalox Ultra T random packing
- Desorber is 15 liter, high-pressure, jacketed CSTR
  - Has recycle loop for added heat and mass transfer
- Gas composition measured by CAI CO_2 analyzer and MKS mass spec
- Liquid CO_2 loading measured by IR

Picture from factory acceptance test

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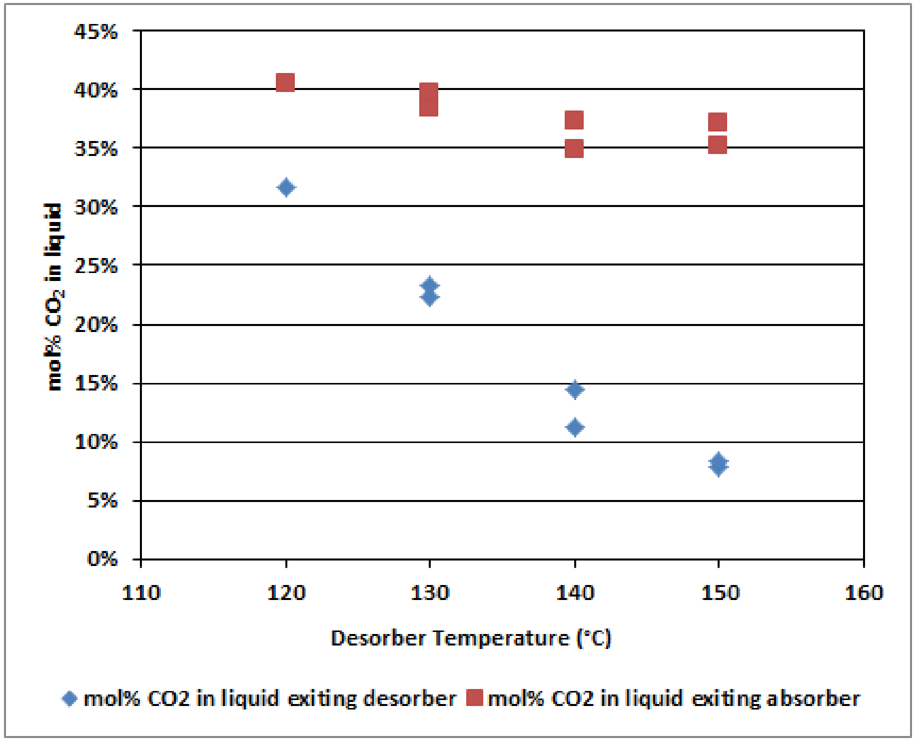
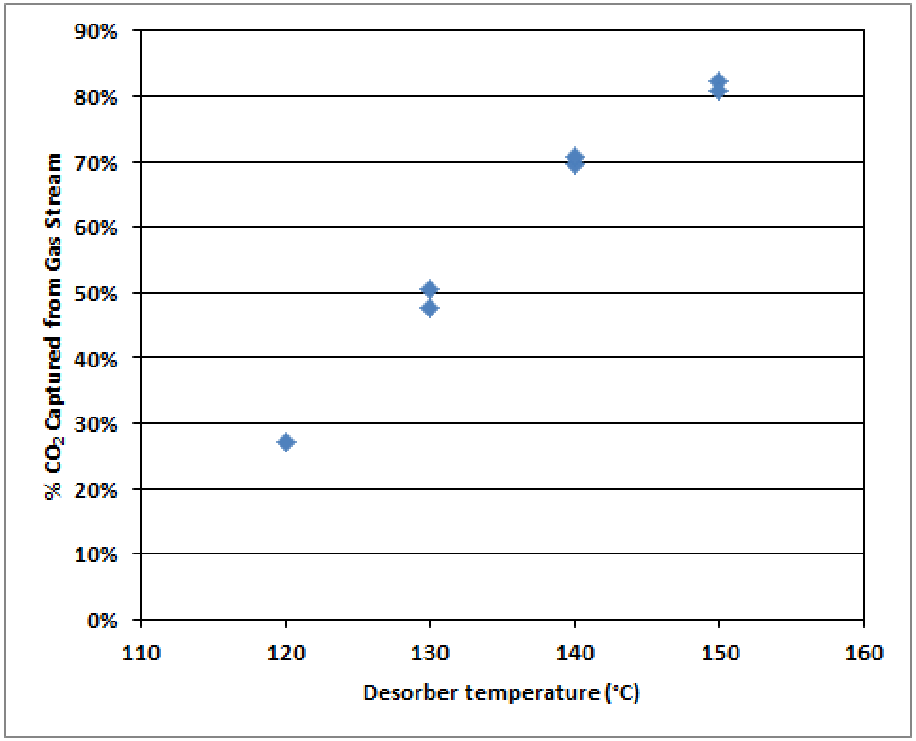
System Performance as a Function of Desorber Temperature





- Liquid flow rate = 0.5 LPM
- Gas flow rate = 112 SLPM
- CO_2 inlet flue gas conc. = 16%

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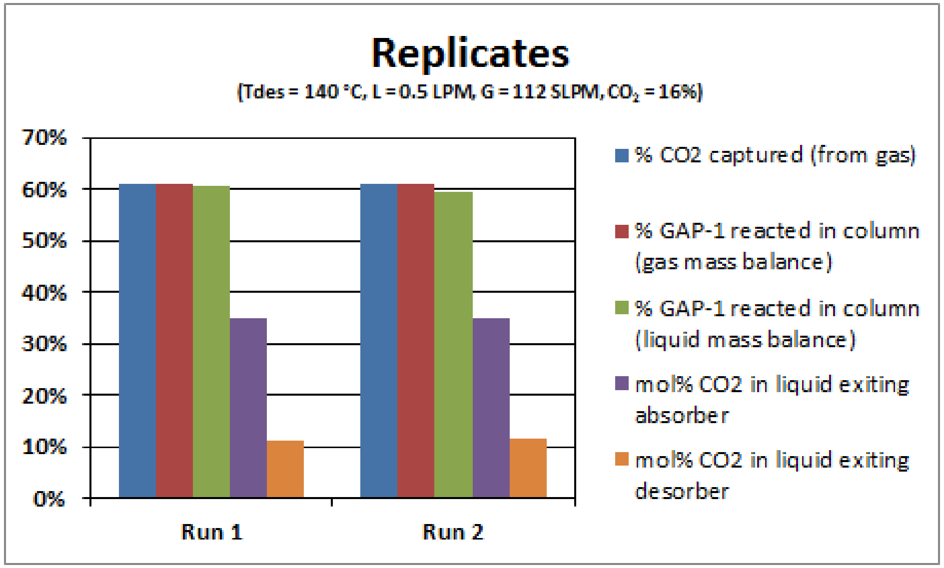
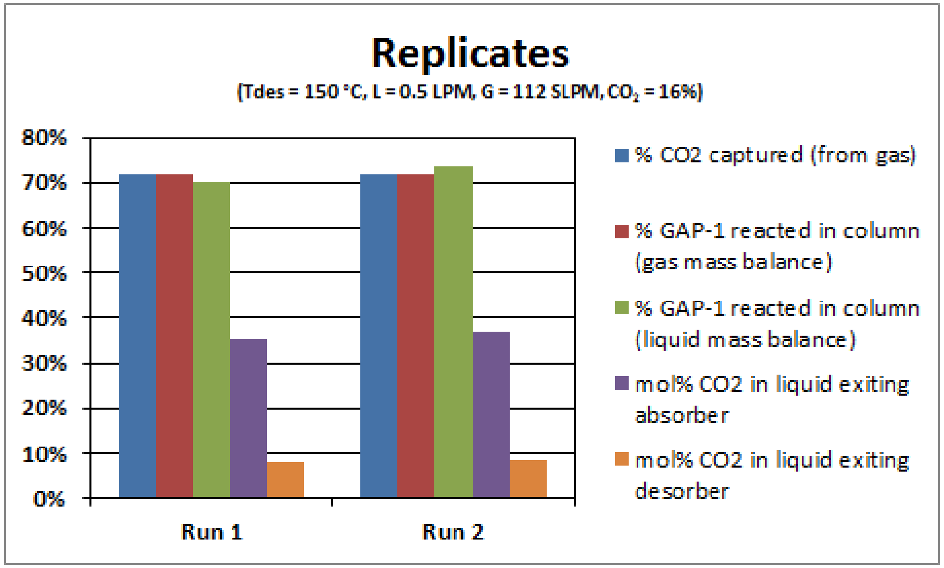
Bench-Scale System Performance Repeatability

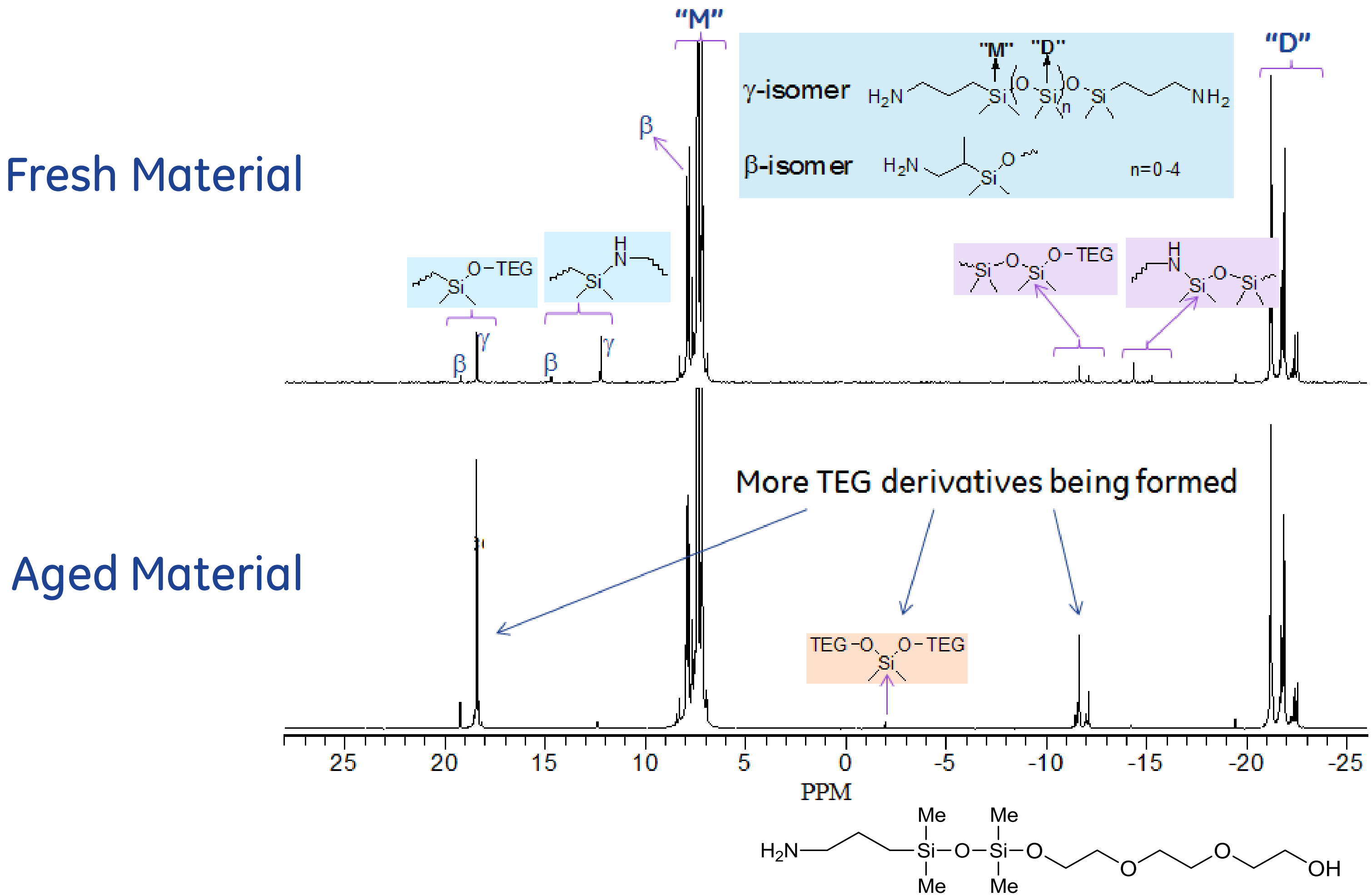




- Good repeatability of system performance
- Excellent agreement between gas analysis (CO_2 analyzer) and liquid analysis (IR)

Solvent Decomposition

^{29}Si NMR study of Aged 60/40 GAP-1/TEG

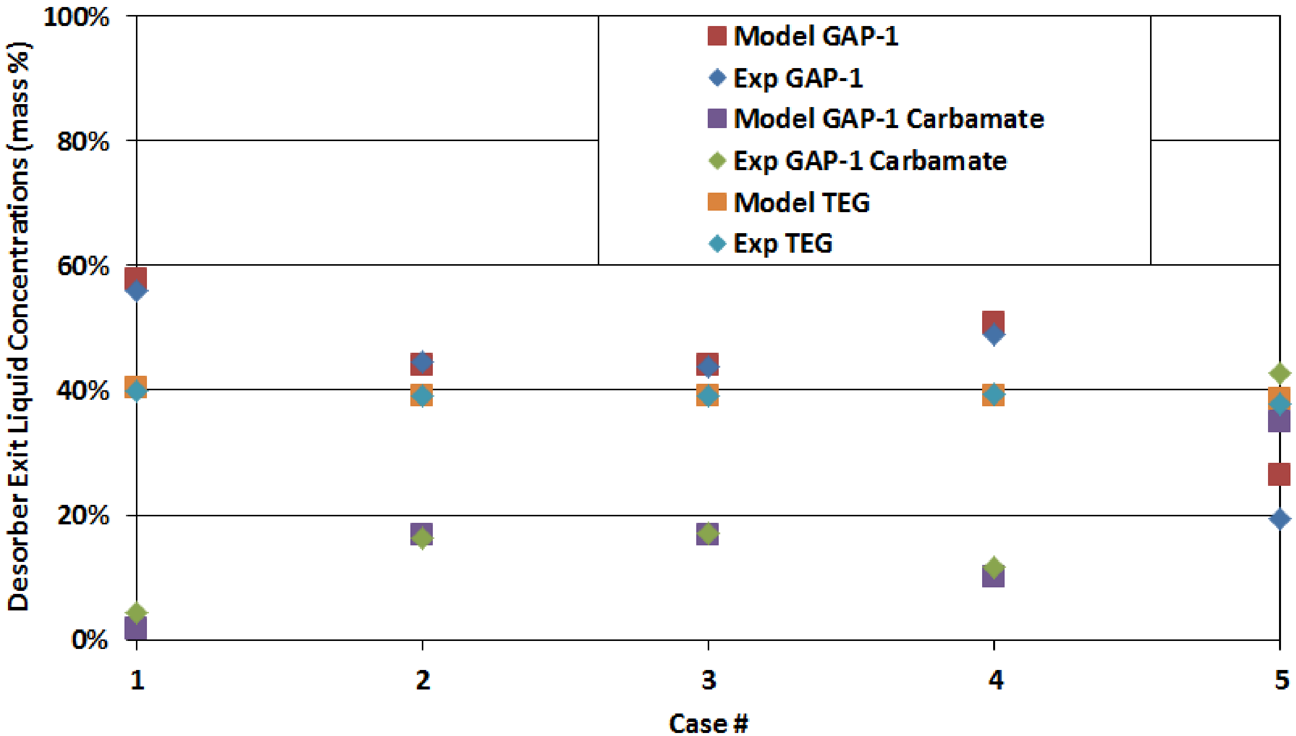


Potential hybrid material being formed

ASPEN Plus Bench-Scale System Model

- ASPEN Plus model includes
  - A desorber model with an experimentally based kinetic model incorporated into a CSTR reactor model
  - An absorber model with mass transfer rates estimated by ASPEN Plus
  - Solvent physical property data obtained from experiment
- Good agreement between experiment and model (except at 120 °C)

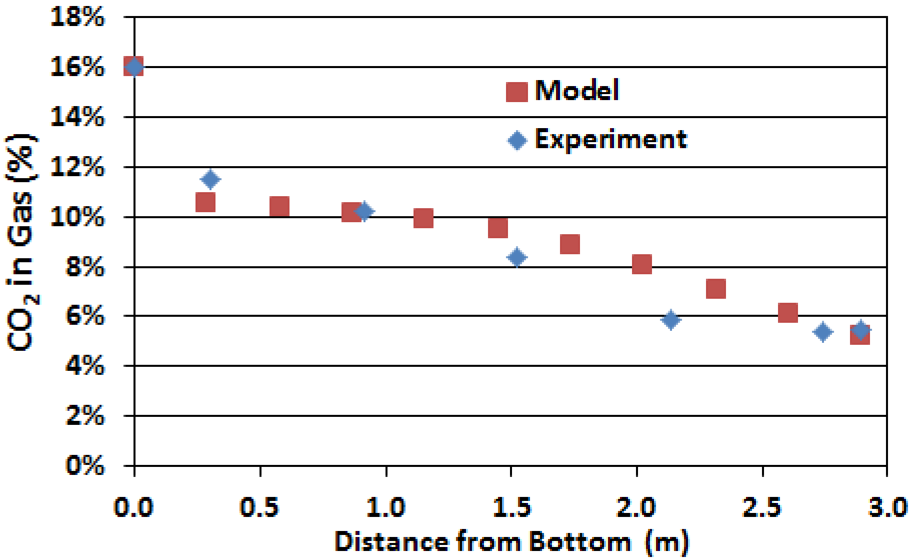
Case #	Desorber Temperature (°C)	Desorber Pressure (psig)	Actual CO_2 % Inlet to Absorber
1	140	0	16.5%
2	140	45	16.0%
3	140	45	15.7%
4	150	45	15.9%
5	120	45	16.2%

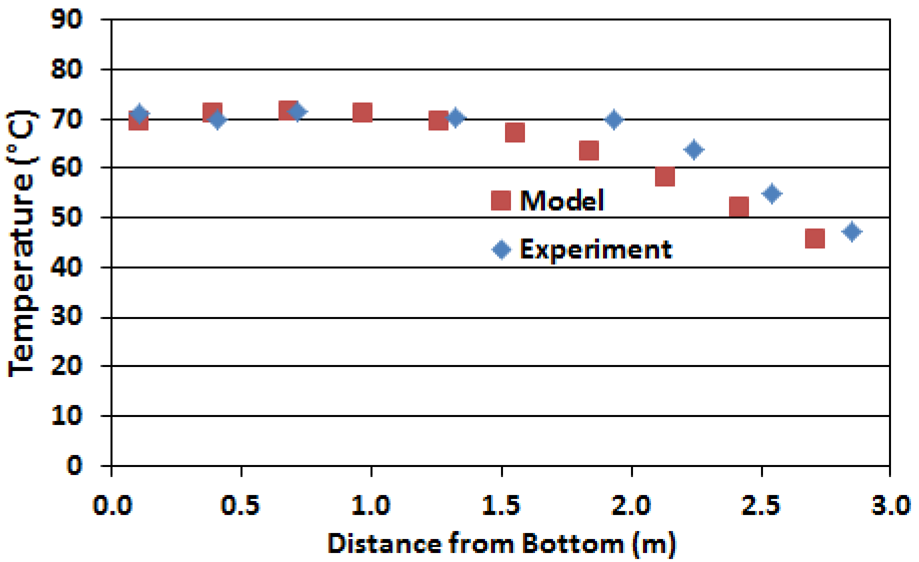


- Liquid flow rate = 0.5 LPM
- Gas flow rate = 112 SLPM

Comparison of Experimental and Model Absorber Performance

Case 2





Case #	Desorber Temperature (°C)	Desorber Pressure (psig)	Actual CO_2 % Inlet to Absorber
1	140	0	16.5%
2	140	45	16.0%
3	140	45	15.7%
4	150	45	15.9%
5	120	45	16.2%

- Liquid flow rate = 0.5 LPM
- Gas flow rate = 112 SLPM

Future Work

- Finish bench-scale tests studying the effects of H_2O, SO_2, and NO_x
- Use bench-scale process model as basis for larger-scale model
    - Perform final Technical and Economic Feasibility Study
- Complete Technology EH&S Risk Assessment (Milliken/SiVance)

- Look for opportunities to take process to pilot scale

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Thanks

- David Lang (program manager)
- Lynn Brickett and Shailesh Vora
- GE GRC team members
- GE GRC Partners
  - GE Energy
  - Milliken/SiVance

Acknowledgment: This material is based upon work supported by the Department of Energy under Award Number DE-FE0007502.