Phase Change Ionic Liquids for Post-Combustion CO_2 Capture

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ARPA-e IMPACCT
Innovative Materials for Advanced
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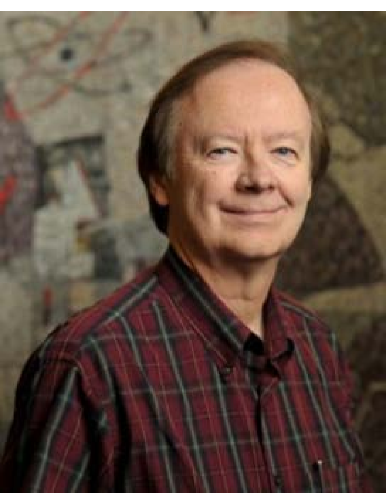
Outline

- Project Information
- Background on Ionic Liquids
- Process Concept
- Progress
  - PCIL development
  - Thermodynamic model
  - Process model
  - Laboratory Demonstration
- Plans

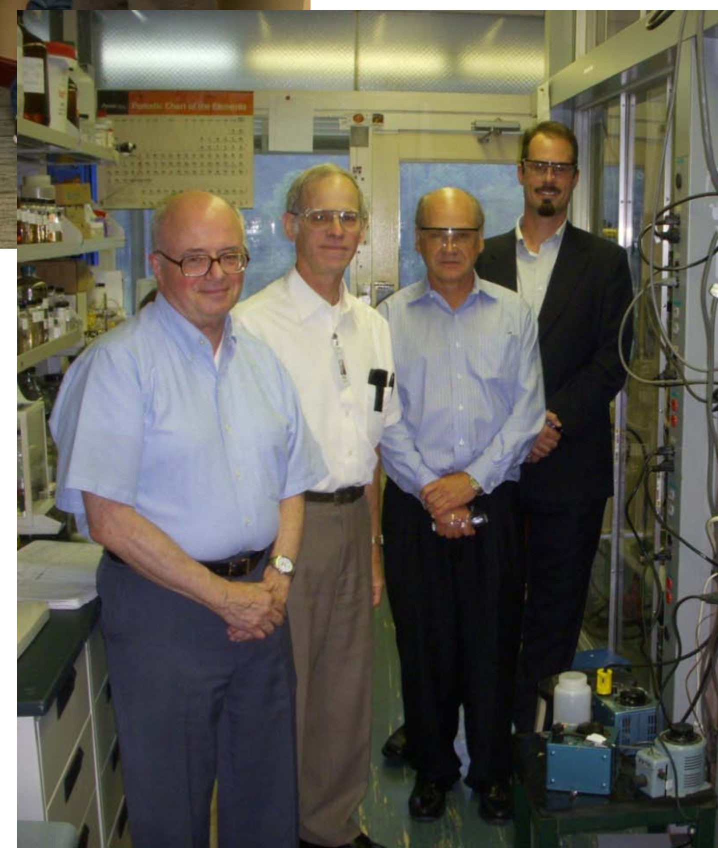
Project Information

- Funding
  - DOE ARPAe $2,559,562
  - Costshare $934,238
  - Total $3,493,800
- Dates
  - 7/1/10 – 12/31/13
- Participants
  - University of Notre Dame
  - MATRIC (Mid-Atlantic Technology, Research & Innovation Center)

University of Notre Dame team



Mark Stadtherr



MATRIC team

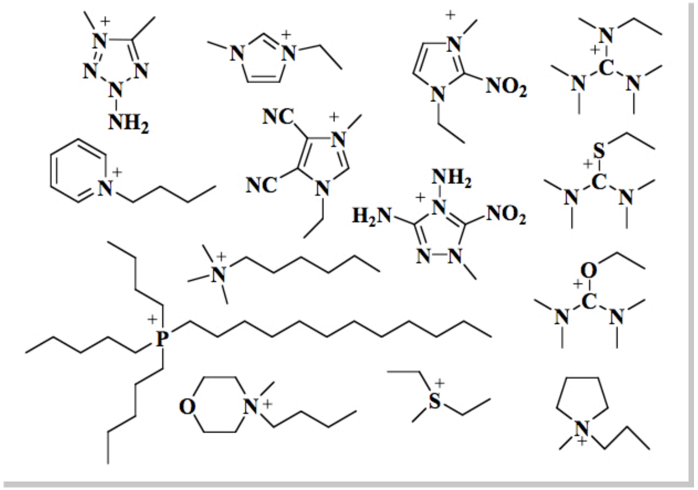
Overall Project Objectives

- Development of process for 90% post-combustion CO_2 capture using phase change ionic liquids

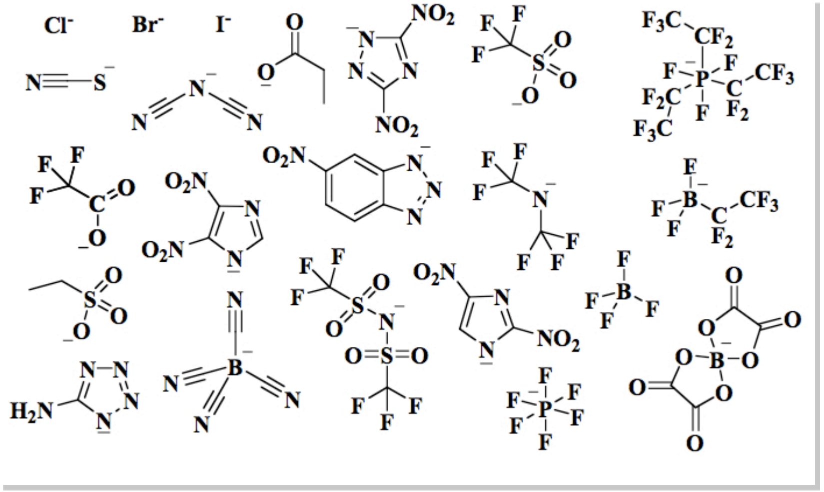
Background: Ionic Liquids

- Pure salts that are liquid around ambient temperature
  - Not simple salts like alkali halides
- Many favorable properties
  - Nonvolatile
  - Anhydrous
  - High thermal stability
  - Huge chemical diversity

Examples of cations

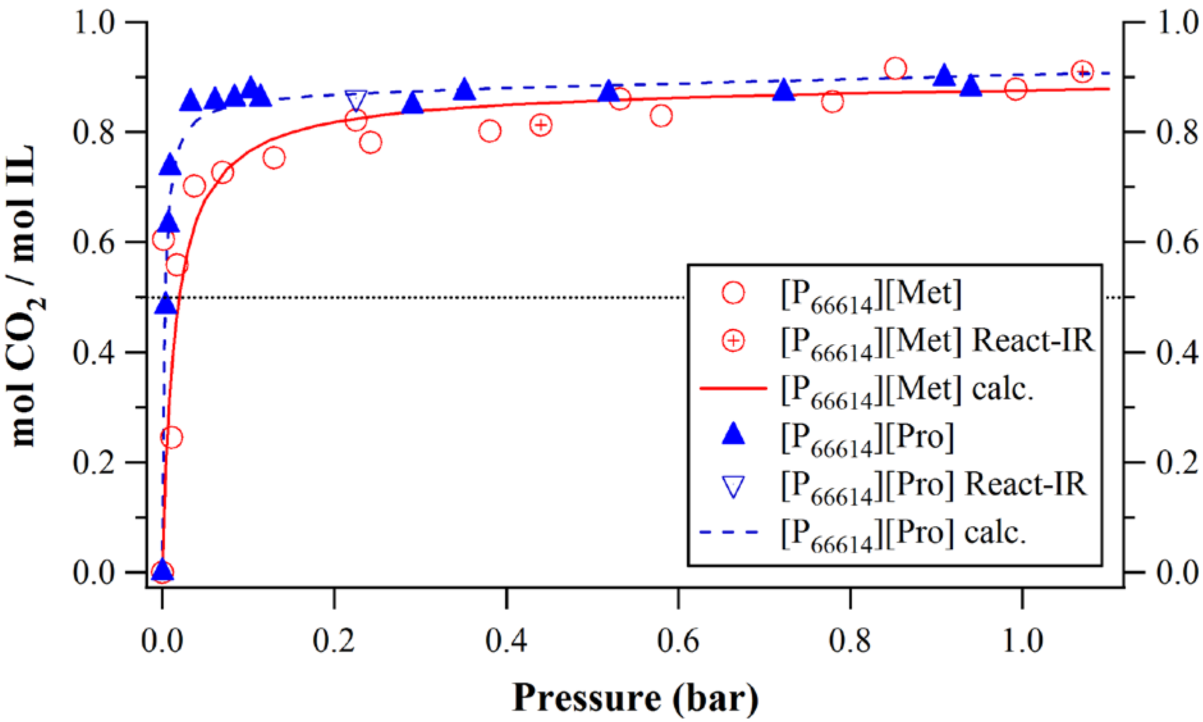


Examples of anions



Background: 1/1 Binding

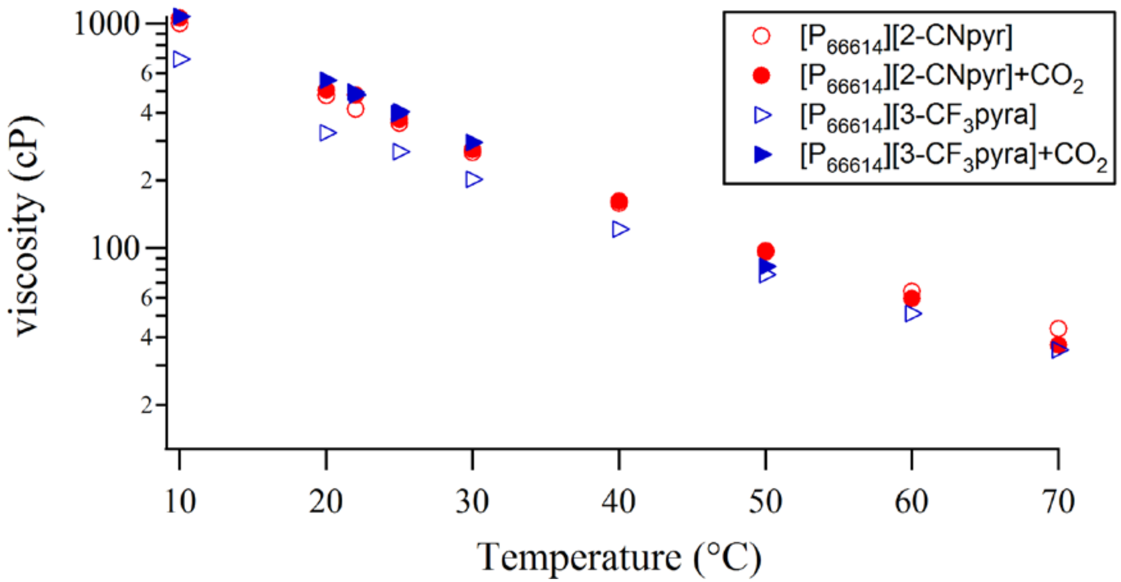
- Demonstrated binding of one CO_2 per one ionic liquid



CO_2 uptake of [P_{66614}][Prolinate] and [P_{66614}][Methioninate] at 22 °C, showing close to one CO_2 per mole of IL.

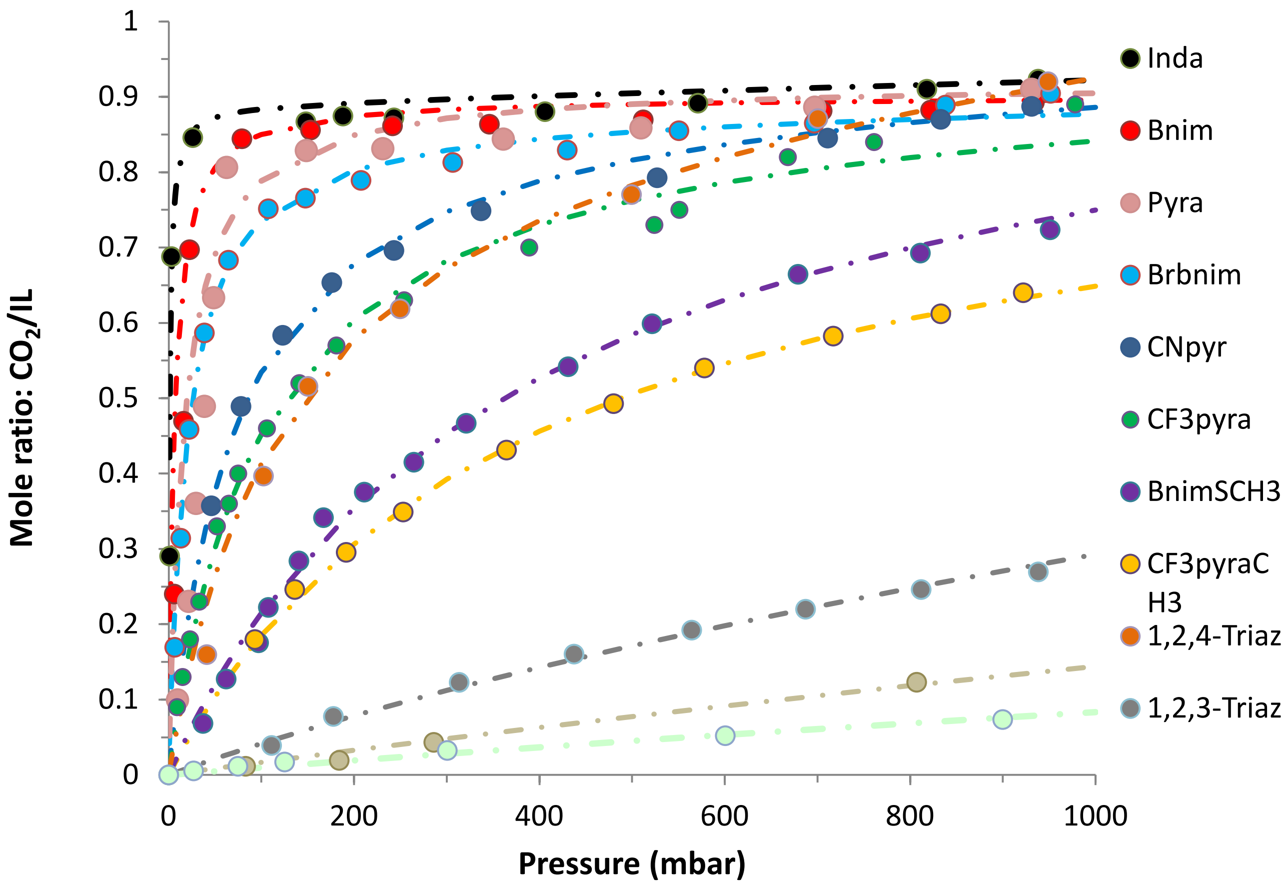
Background: Eliminate Viscosity Increase

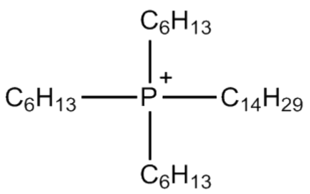
- Eliminated increase in viscosity upon reaction with CO_2



Viscosity of two AHA ILs before and after reaction with CO_2, demonstrating negligible viscosity increase.

Background: Tunable Enthalpy



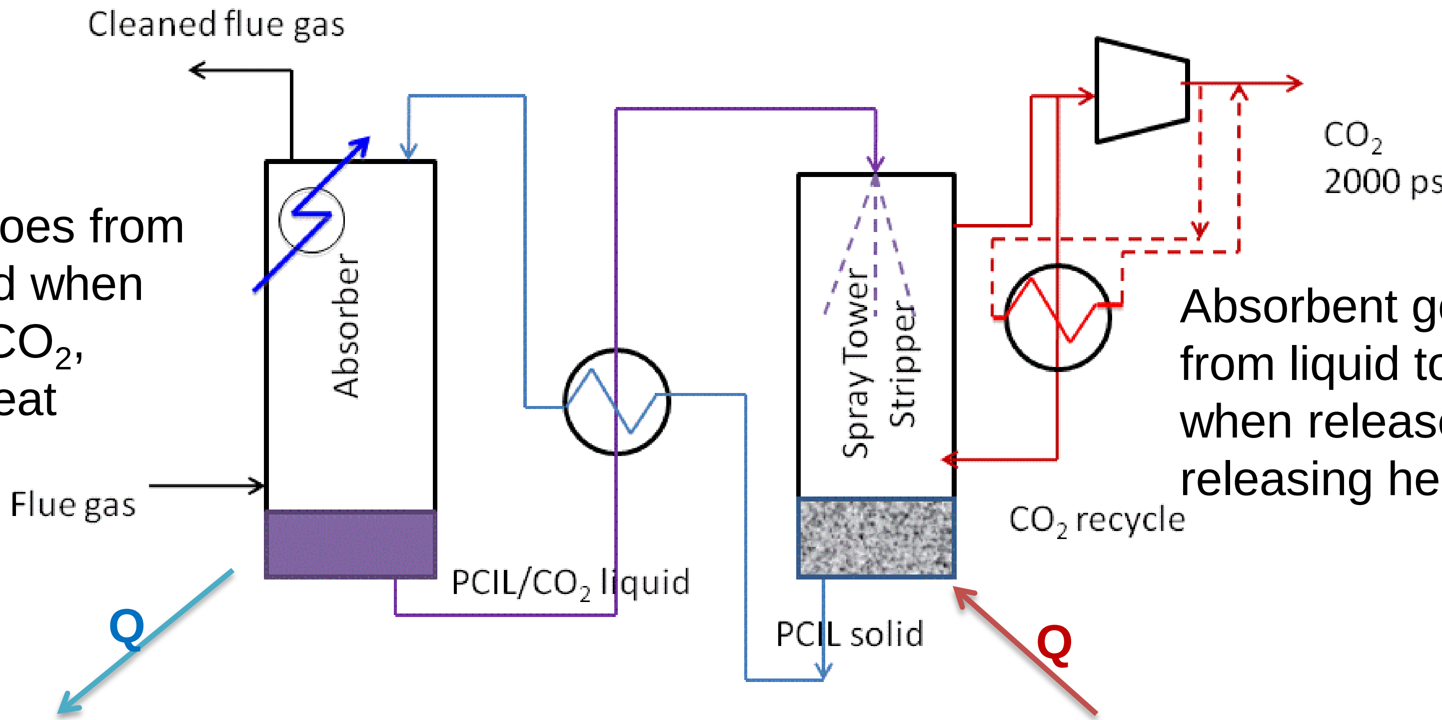


All uptake curves at room temperature

Seo et al., manuscript in preparation

ARPAe Process Concept

Absorbent goes from solid to liquid when reacts with CO_2, absorbing heat



Absorbent goes from liquid to solid when releases CO_2, releasing heat

'Melting' of absorbent reduces cooling duty

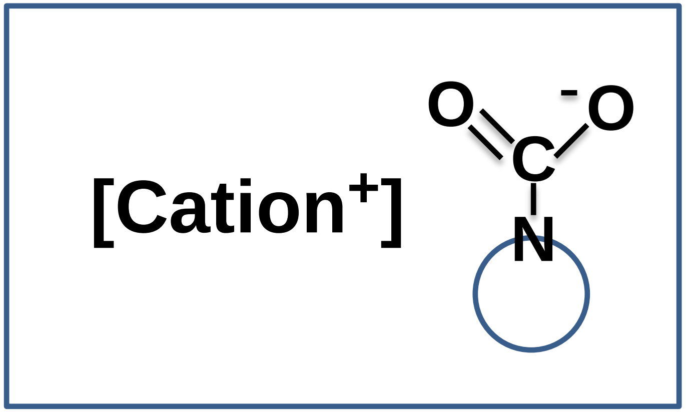
Heat duty in stripper reduced by the heat of fusion of the phase change material

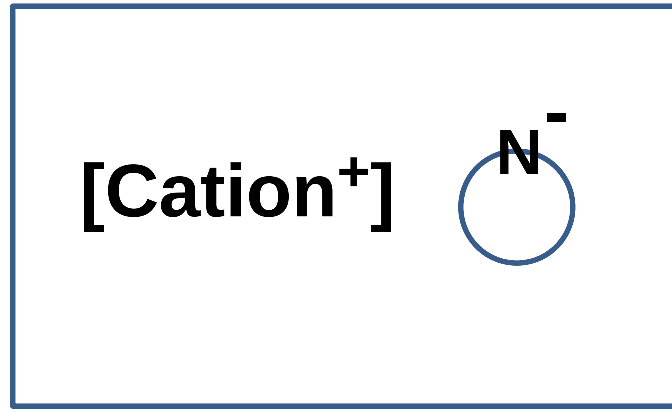
Phase Change Ionic Liquid

Benefits

- Opportunity for greatly reduced energy use
  - ΔH_{fus} can be 40% of ΔH_{rxt}
- Small ΔP and ΔT between absorber and regenerator to achieve large Δcapacity
- Low volatility absorbent – no emissions
- No added water
- Reduced corrosion

Challenges





- Finding material where

$$T_m^{complex} < T_m^{IL}$$

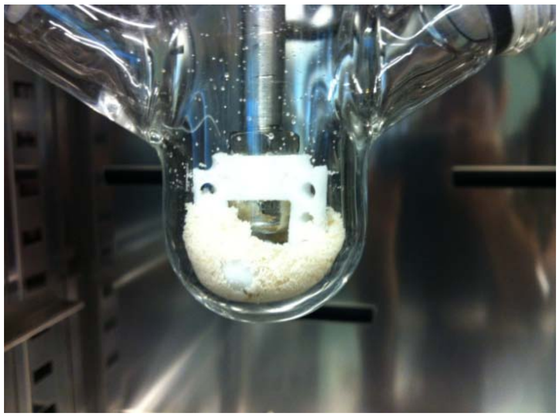
  - with appropriate T_m's, ΔH_{fus}, ΔH_{rxt}, other physical properties (e.g., liquid viscosity)
- Effect of water – must turn back to solid in spray drier
- Solids handling

Progress – PCIL Development

- Combination of computation, synthesis and testing
- Iterative process
- > 40 ionic materials synthesized and tested
  - Determine melting point
  - Measure CO_2 uptake at $T<T_m$
  - Visually observe phase change
  - Determine ΔH_{fus} and ΔH_{rxt}

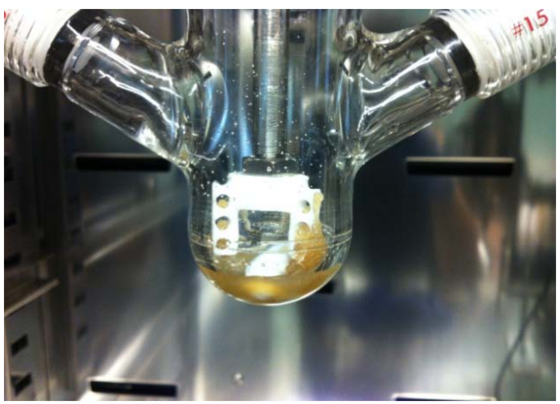
Progress – PCIL Development

70 °C

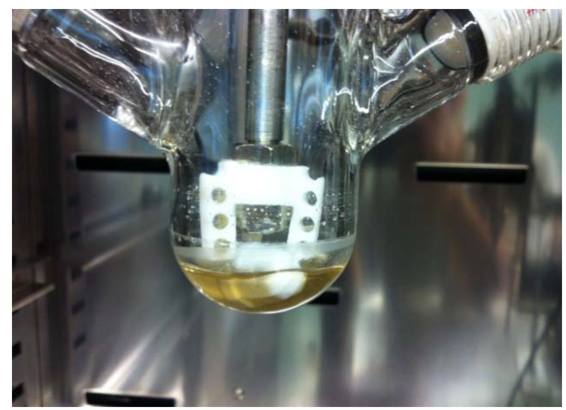


Pure material; T_m=166 °C; no CO_2

60 mbar CO_2

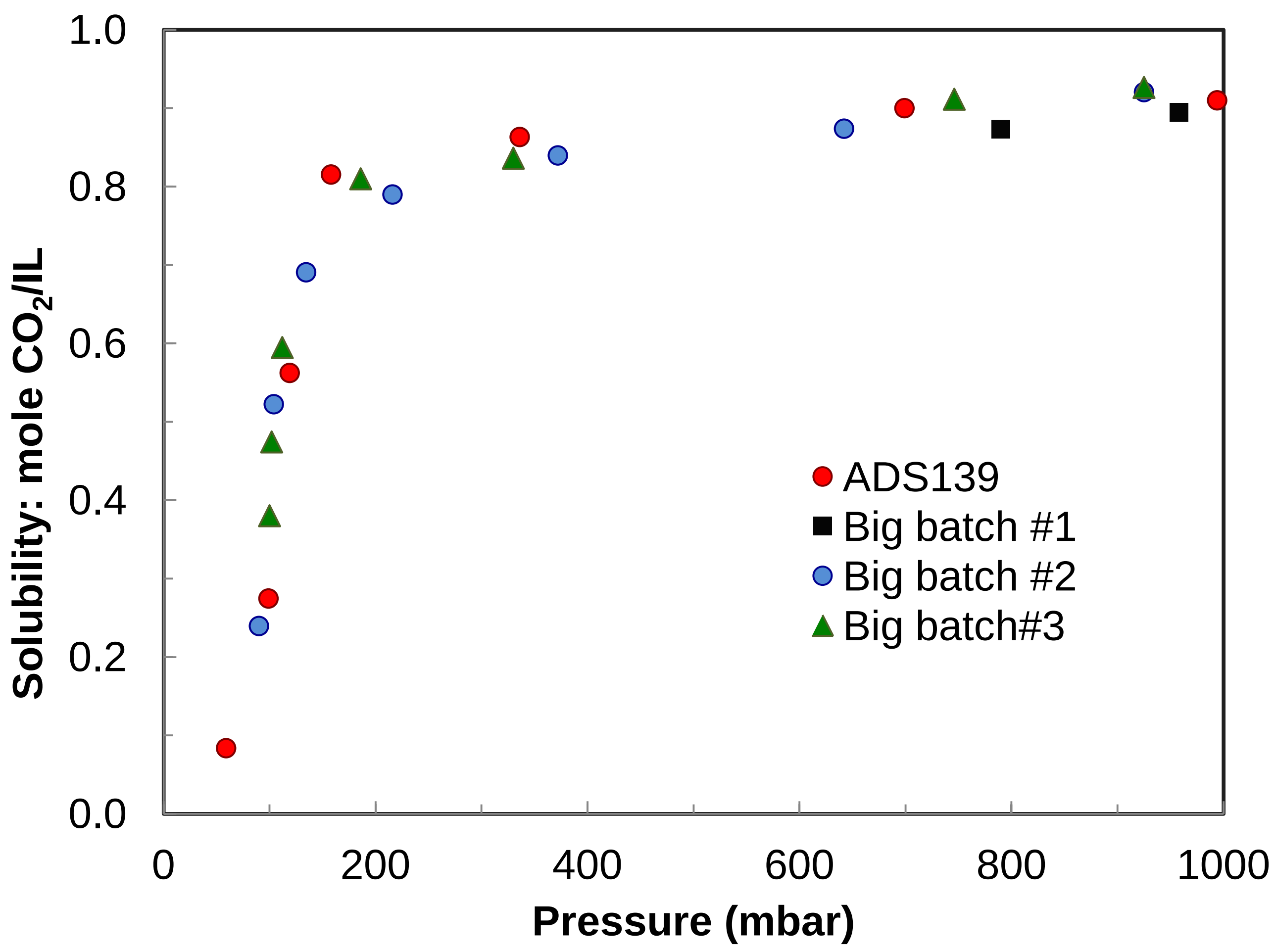


100 mbar CO_2

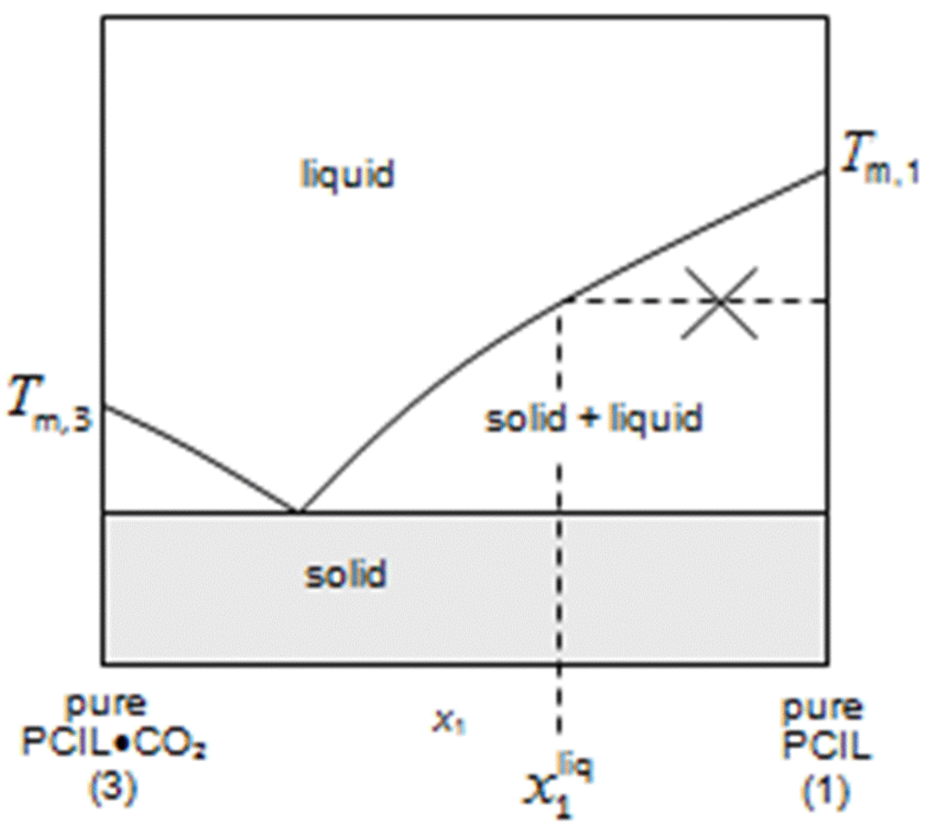


150 mbar CO_2

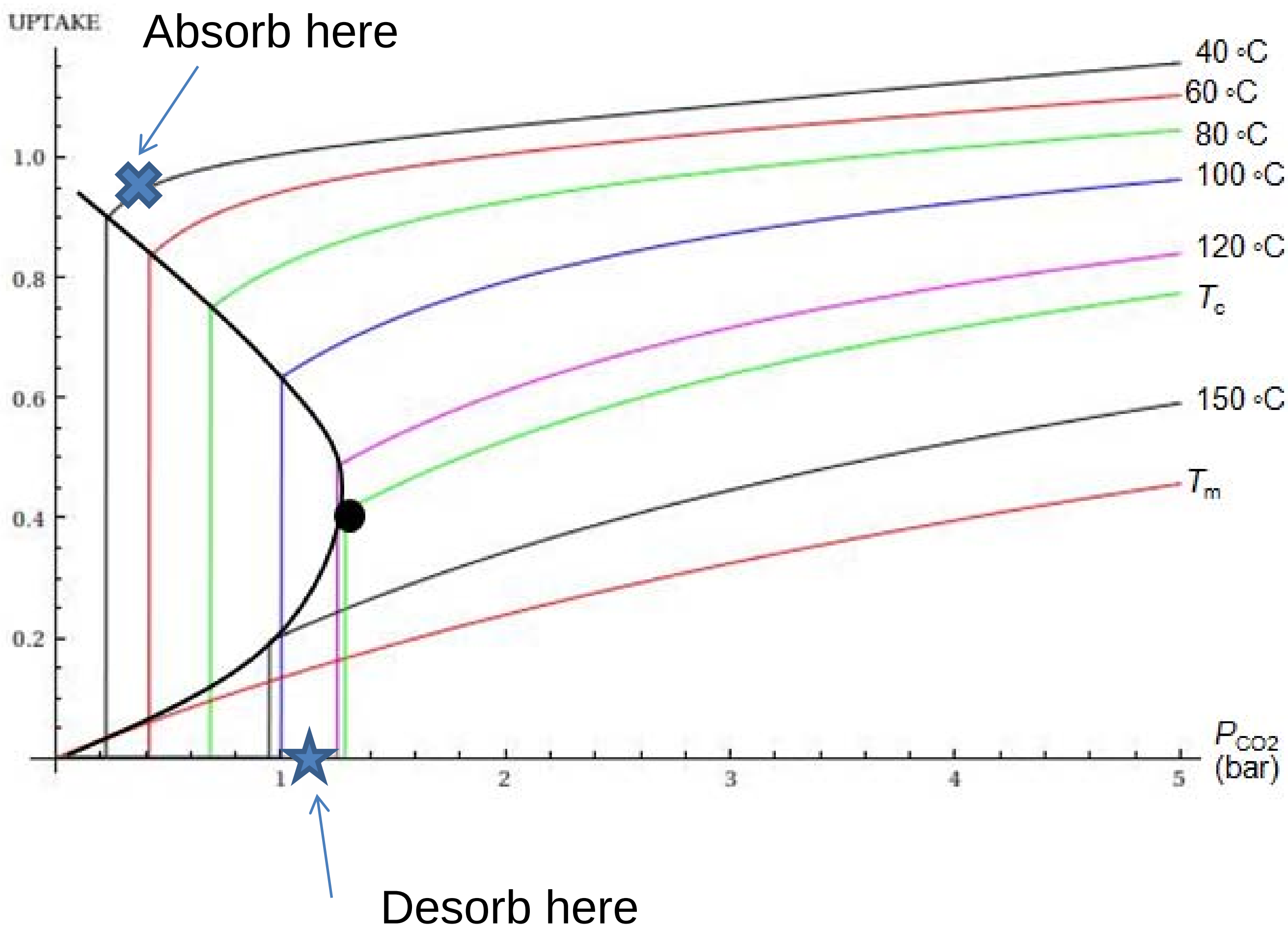
Progress – PCIL Development



Progress – Thermo Model

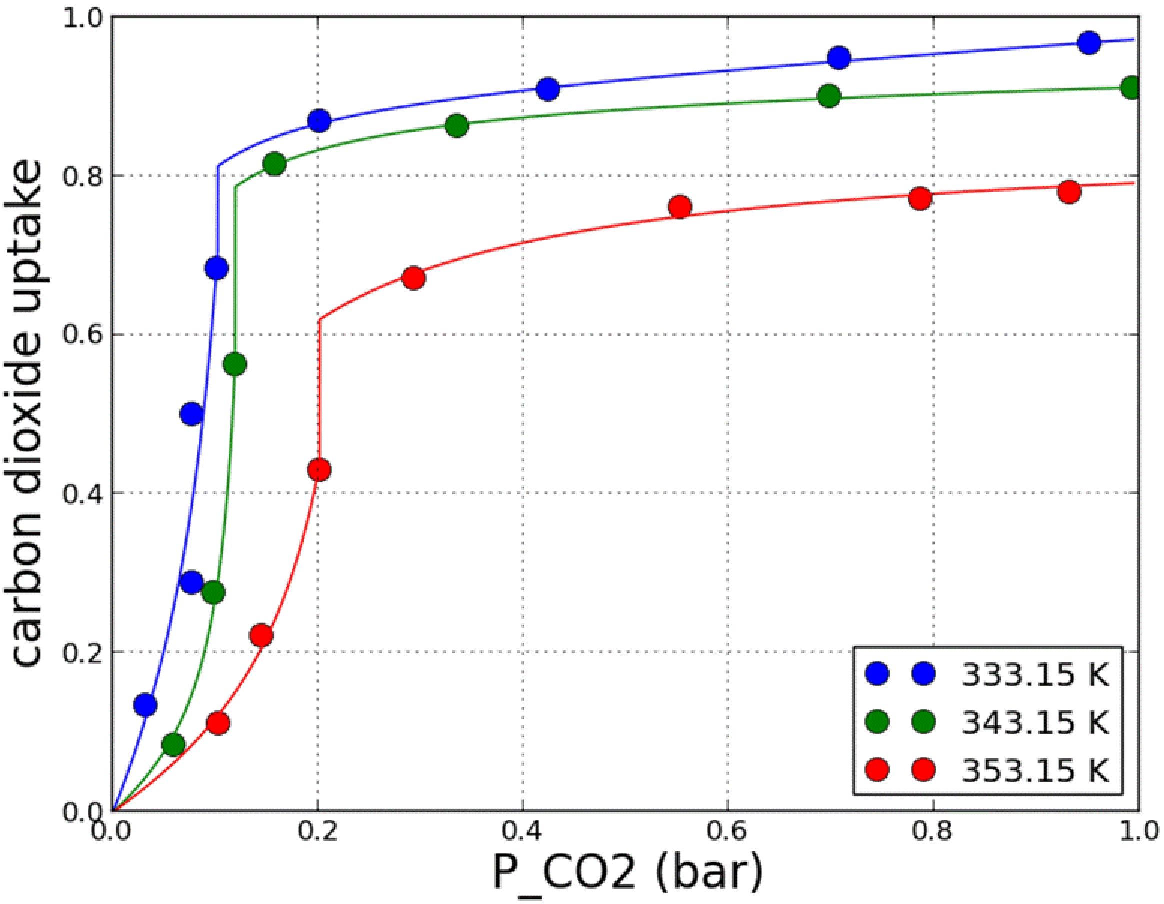


Progress – Thermo Model



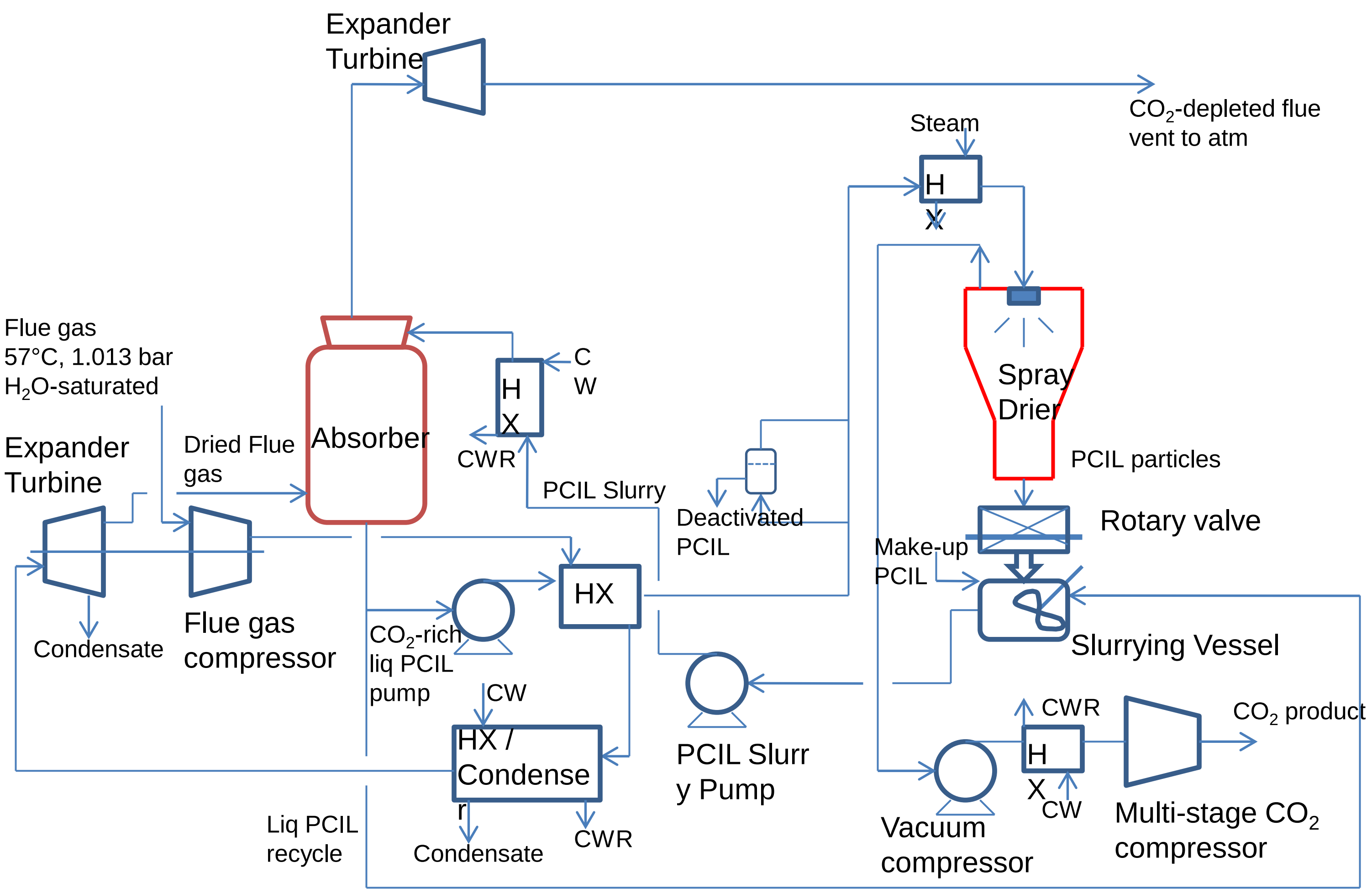
Simoni, Brennecke and Stadtherr, manuscript in preparation

Progress – Thermo Model



Model with physical adsorption on to solid provides excellent representation of experimental data

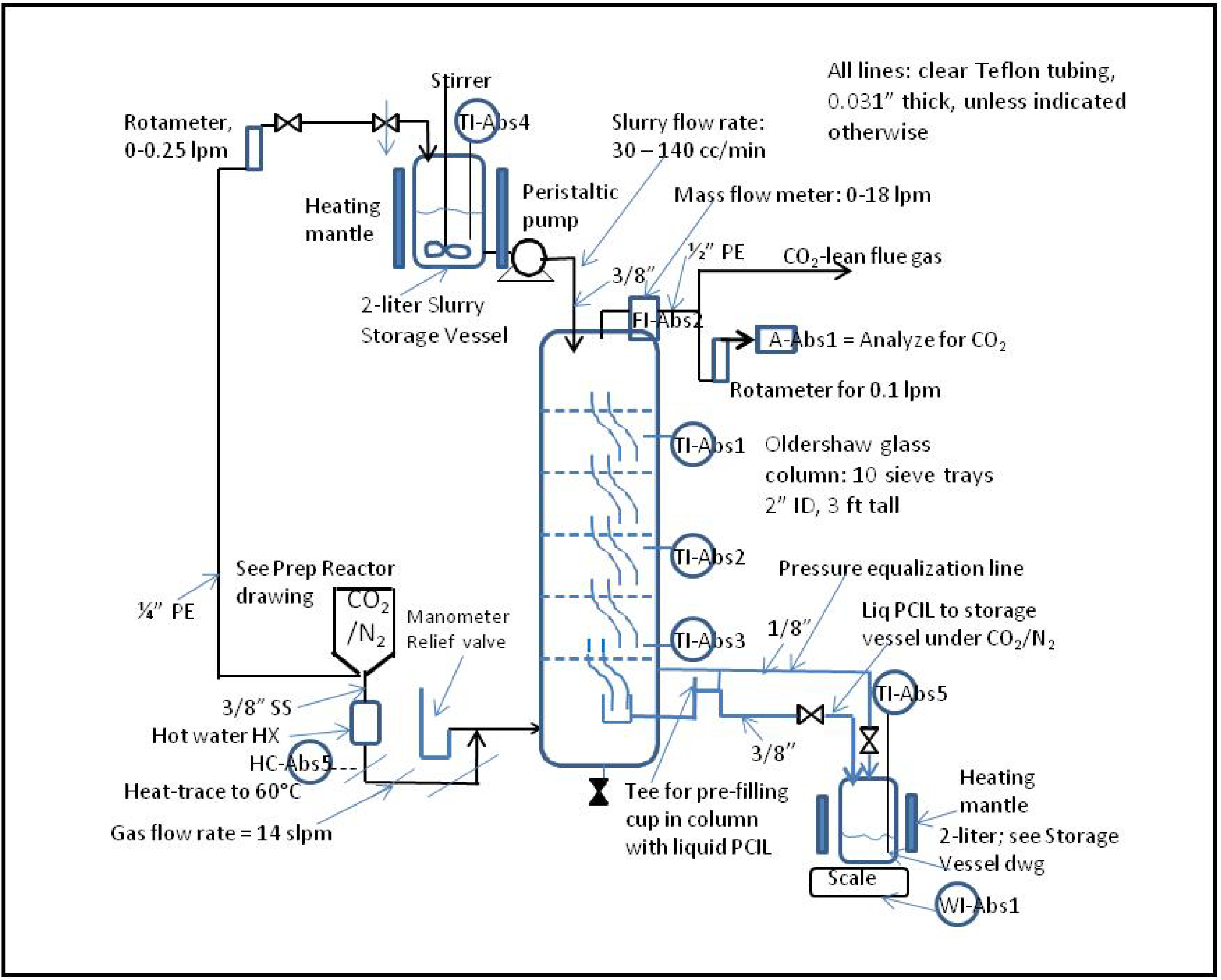
Progress - Process Modeling



Progress - Process Modeling

- 550 MW_e net pulverized coal power plant
- 90% CO_2 capture
- Installed cost = $925,000,000
- Parasitic power = 157 MW_e
- Increase in COE = 4.84 cents /kWhr
- Further improvements to come
  - Update process model and economics based on laboratory demonstration unit and recent experimental work
  - Assumed pre-drying of flue gas to 6 mbar H_2O in spray drier
  - Now know that only need to dry to 60 mbar
  - Dramatically reduce capital ($173,000,000 for flue gas drier compressor)
  - Dramatically reduce operating costs (40% of parasitic power)

Progress – Demo Unit

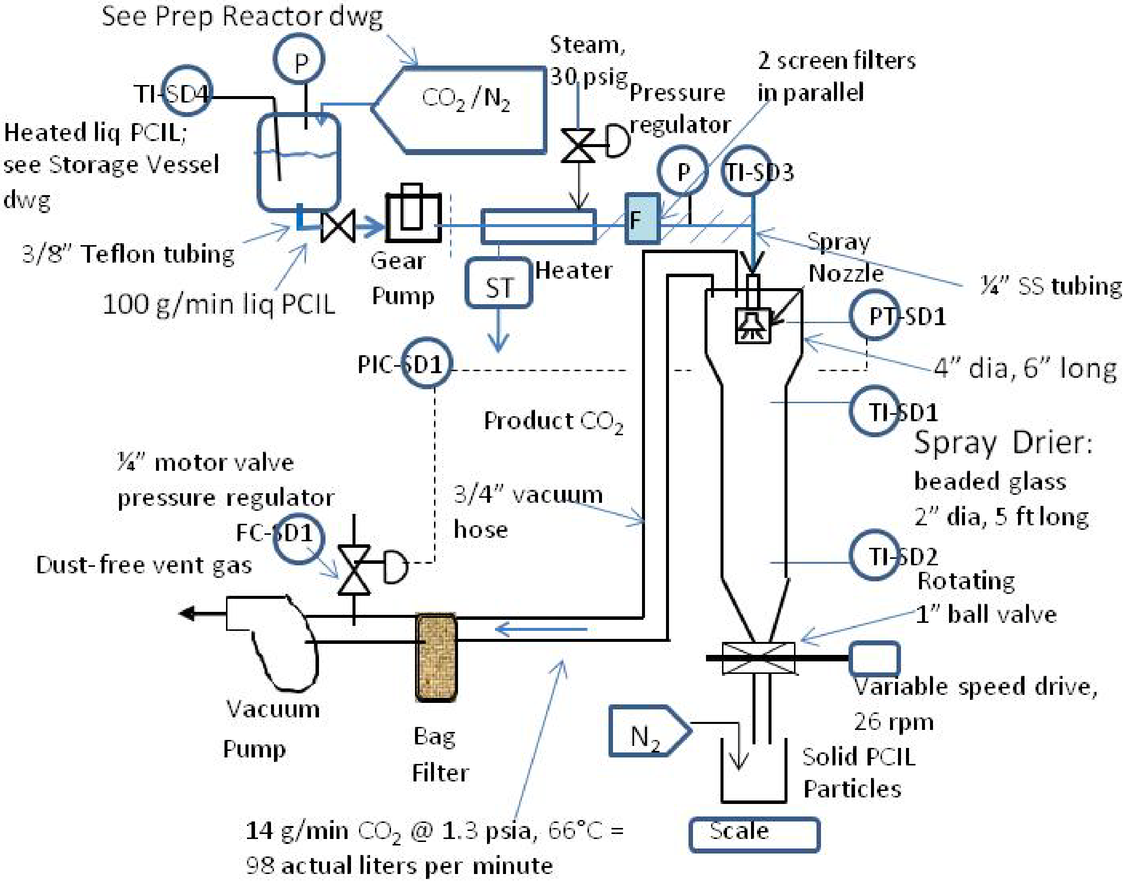


- **Absorber**
- Slurry preparation vessel
- Operate absorber and spray drier continuously but separately
- ~ 5 kg of PCIL available for testing

Progress – Demo Unit

- Construction and commissioning complete
- Determination of operable solid/liquid slurry ratio
- Determination of liquid and gas flowrates to obtain operability
- Initial run demonstrating CO_2 removal

Progress – Demo Unit



- **Spray drier**
- Construction and commissioning complete
- Testing and selection of spray nozzle

Plans

- Completion of tests in laboratory demonstration unit
- Updating of process modeling and economics based on lab demo unit results and recent other experimental results
- Pursue scale-up opportunities in collaboration with

Ionic
Research Technologies

http://ionicresearchtechnologies.com/

Acknowledgements

Advanced Research Projects Agency • ENERGY

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