CO_2 CAPTURE FROM IGCC GAS STREAMS USING THE AC-ABC PROCESS

2010 NETL CO_2 Capture Technology Meeting

September 16, 2010 Pittsburgh, PA.

SRI International®

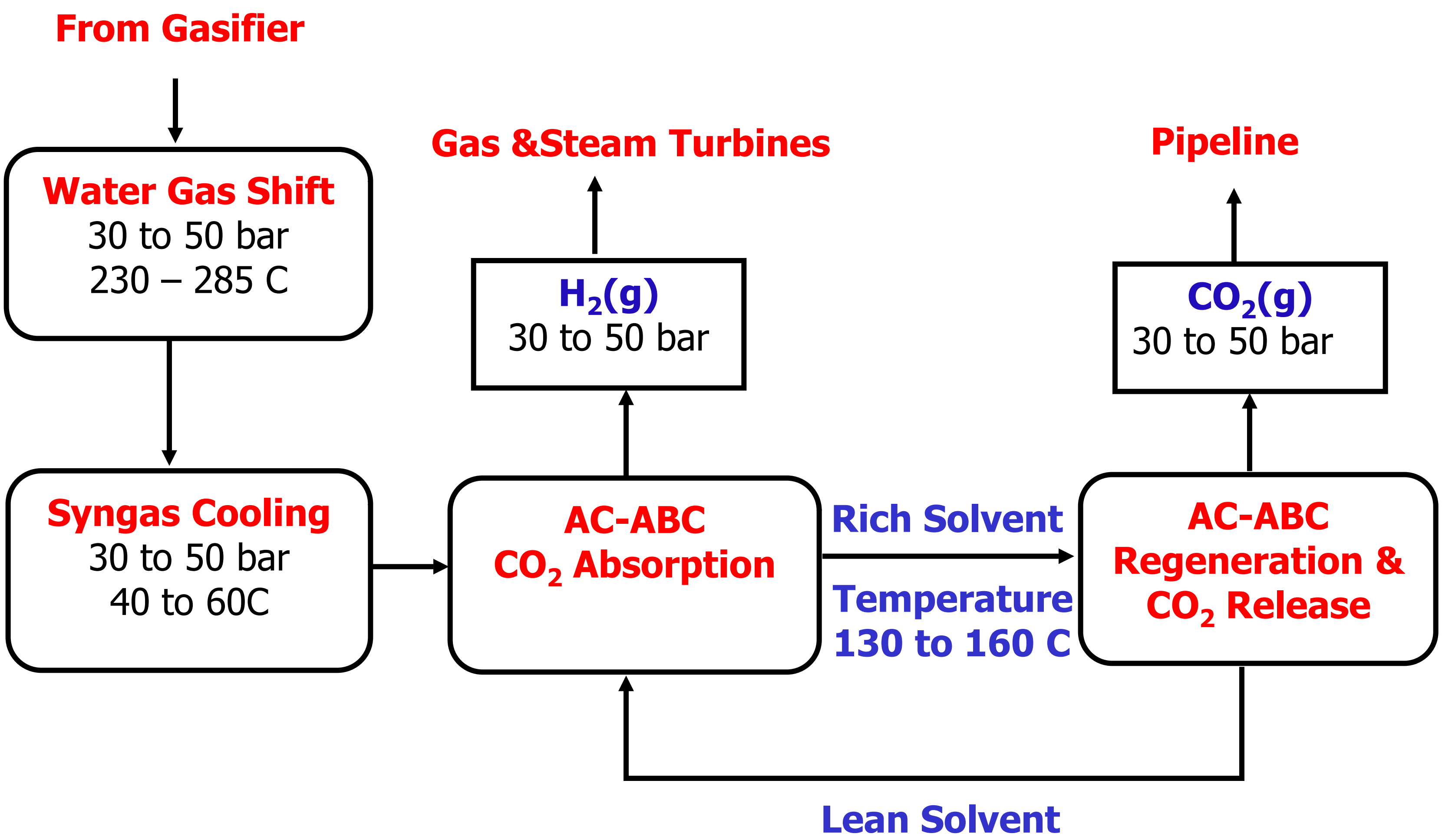
Project Overview

- Partners:
  - SRI International, Menlo Park, CA
  - Great Point Energy, Cambridge, MA
  - DOE-National Energy Technology Center
- Period of Performance:
  - 10-1-2009 through 1-30-2012
- Funding:
  - U.S.: Department of Energy: $3.4 million
  - Cost share: $1.1 million
  - Total: $4.5 million

Project Objectives

- Overall objective:
  - To develop an innovative, low-cost CO_2 capture technology based on absorption on a high-capacity and low-cost aqueous ammoniated solution.
- Specific objectives:
  - Test the technology on a bench scale batch reactor to validate the concept,
  - To determine the optimum operating conditions for a small pilot-scale reactor,
  - Design and build a small pilot-scale reactor capable of continuous integrated operation,
  - Perform tests to evaluate the process in a coal gasifier environment,
  - Perform a technical and economic evaluation on the technology.

Process Block Diagram



Process Highlights

- Concentrated ammoniated solution is used to capture CO_2 and H_2S from syngas at high pressure.
- Operates at or above ambient temperature; No refrigeration is needed.
- CO_2 is released at a high pressure:
  - The size of CO_2 stripper (regenerator) and the electric power consumption for compression of CO_2 to the pipeline pressure is reduced.
- High net CO_2 loading, up to 20% by weight.
- H_2S is released at conditions suitable for sulfur recovery.

Process Advantages

- Low cost and readily available reagent.
- Very little solvent makeup is required
  - Reagent is chemically stable under the operating conditions.
- Low heat consumption for CO_2 stripping (<600 Btu/lb CO_2).
- Extremely low solubility of H_2, CO and CH_4 in absorber solution
  - Minimizes losses of fuel species.
- Absorber and regenerator can operate at similar pressure.
  - No need to pump solution cross pressure boundaries. Low energy consumption for pumping.

Chemical Reactions (Aqueous Phase)

- **NH4OH+CO2 ←→ NH4HCO3**
- **(NH4)2CO3+CO2 + H2O ←→2NH4HCO3**
- **NH4(NH2CO2)+CO2 +2H2O ←→2NH4HCO3**
- **NH4HCO3 ←→ NH4HCO3 (precipitate)**

- All the reactions are reversible and they go from left to right in the absorber (lower temperature) and from right to left in the stripper regenerator (higher temperature).
- Heat of reaction is in the 300-600 btu/lb of CO_2 range and it depends on temperature and the CO_2/NH_3 ratio of the solution.

- **2NH4OH + H2S ←====→ 2NH4HS + H2O**
- **(NH4)2CO3 + H2S ←====→ NH4HS + NH4HCO3**
- **NH4HCO3 + H2S ←====→ NH4HS + H2O + CO2**
- No precipitation of Sulfide salts.

Technical Challenges

- Precipitation of solids
  - Benefit: Increases the CO_2 loading of solution flowing to the regenerator.
  - Risk: Potential fouling of packing and heat exchanger surfaces.
  - Solutions:
    - Operate at elevated temperatures under non-precipitation conditions.
    - Use open, smooth structural packing.
    - Use slurry pumps to transfer from absorber to regenerator

Technical Challenges (continued)

- Excessive residual ammonia in the fuel gas stream leaving the absorber
  - Source of Risk:
    - Absorber operation at an elevated temperatures
  - Solutions:
    - Install a small absorber (wash) column to capture the residual ammonia
    - The wash water will be reclaimed in a stripper and the ammonia is cycled back to the absorber.
    - Tests at SRI has shown that ammonia levels can be reduced to ppm levels.

Project Tasks

1. Bench-scale Batch Tests

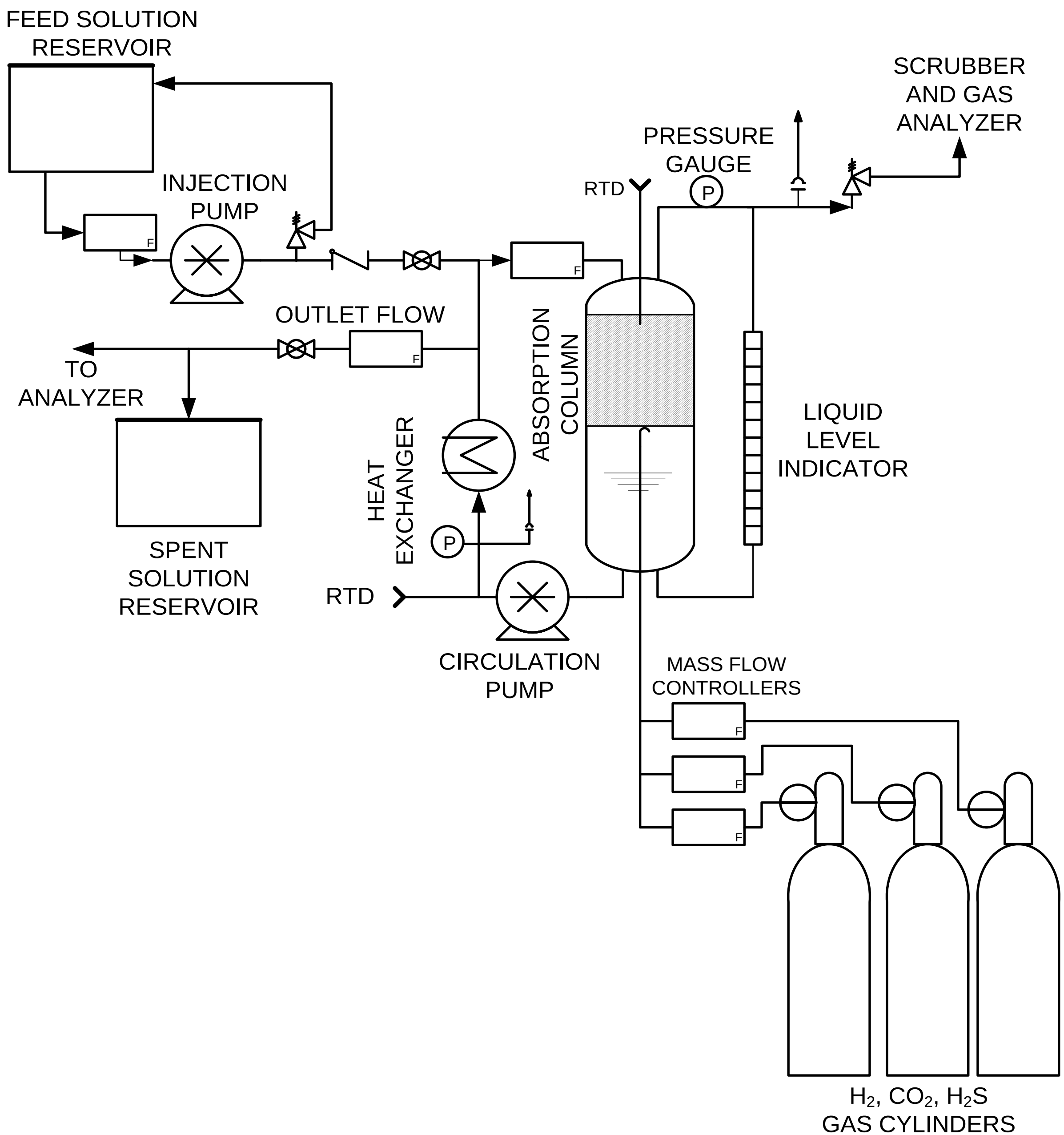
2. Pilot-Scale Integrated, Continuous Tests

3. Project Management

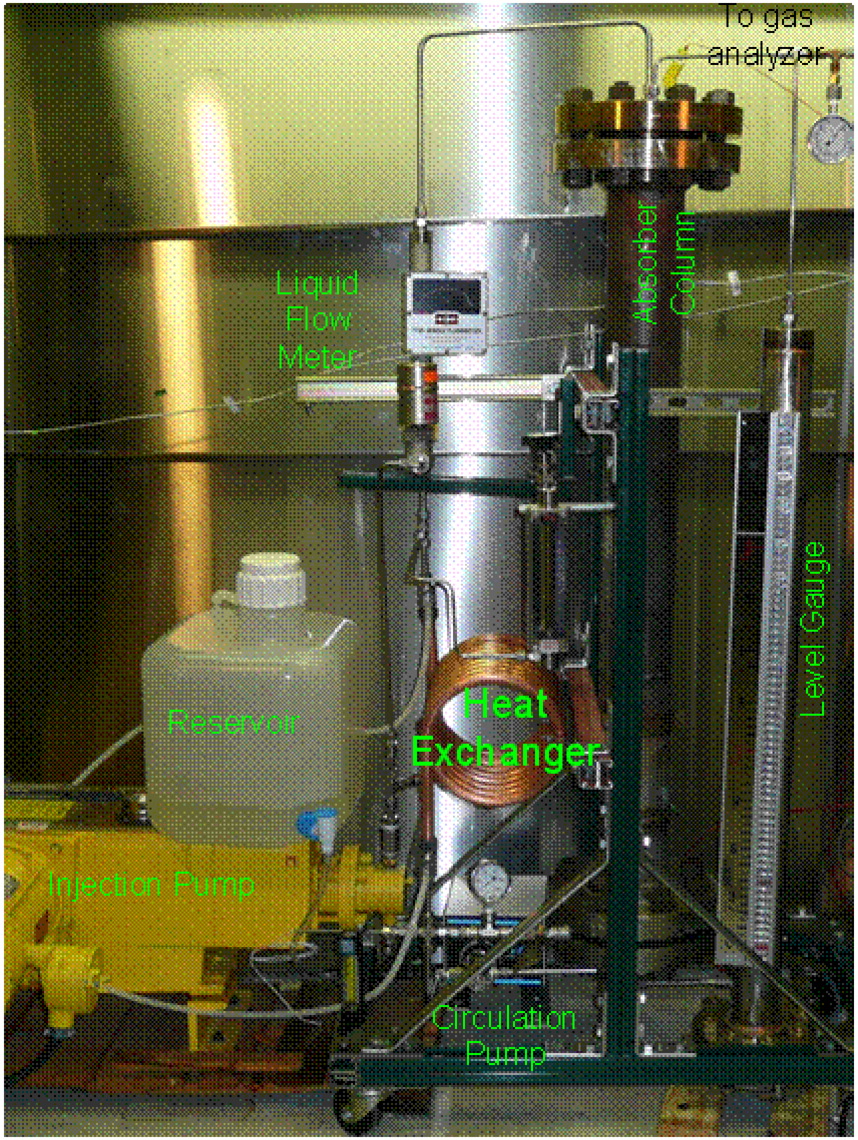
Bench-Scale Absorber Testing

- Determination of solubility:
  - Shifted-gas components (H_2, CO, N_2, Ar)
- Determination of reactivity of CO_2 and H_2S:
  - Function of composition, pressure, and temperature.
- Mixed-gas testing to determine the relative reaction kinetics.

Schematic Diagram of the Absorber System



Photograph of the Absorber System

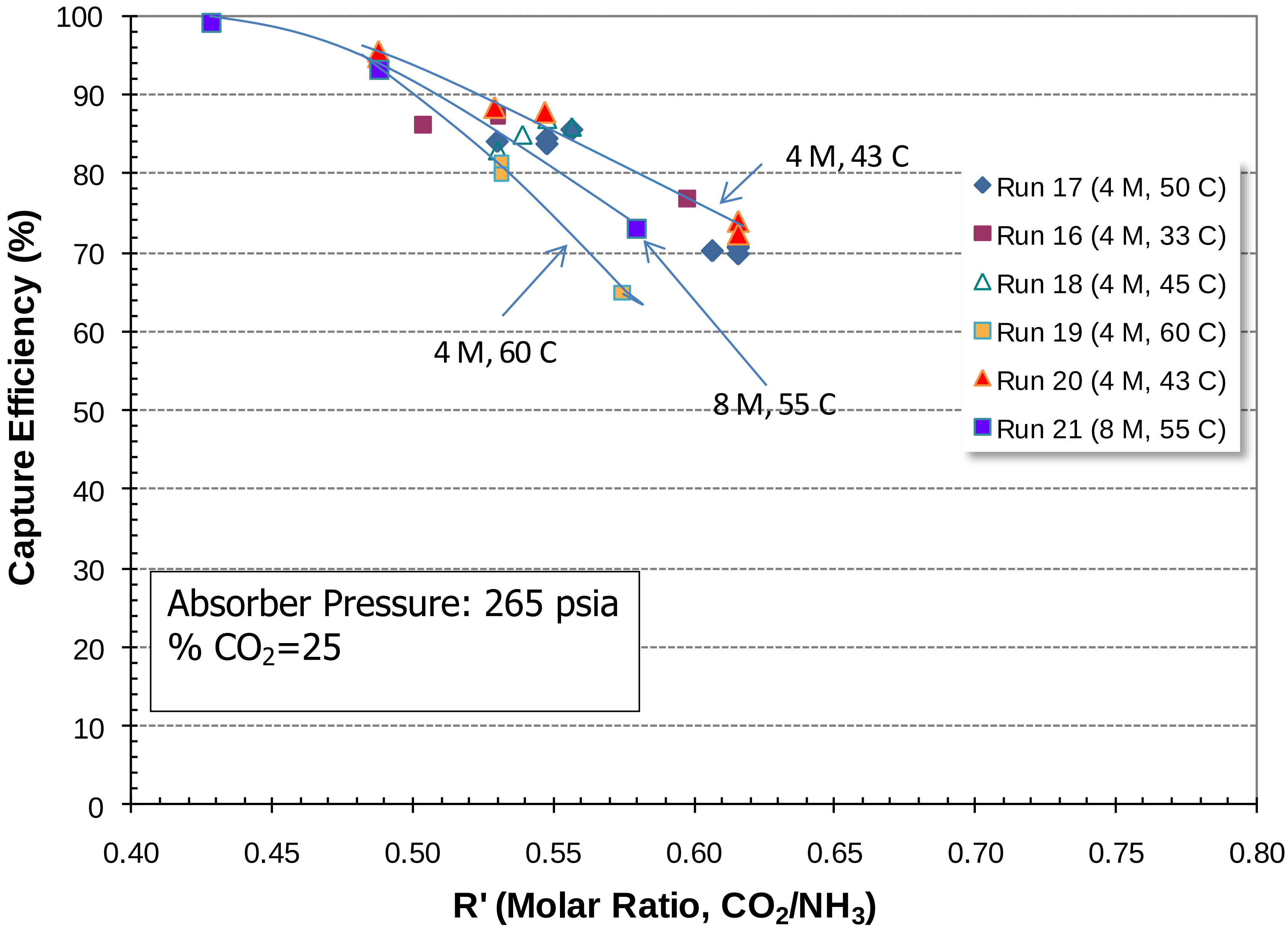


Reactor ID: 4-in
Low pressure drop
Koch structural packing:
  Specific area: 425 m^2/m^3
Packing height: 2-ft

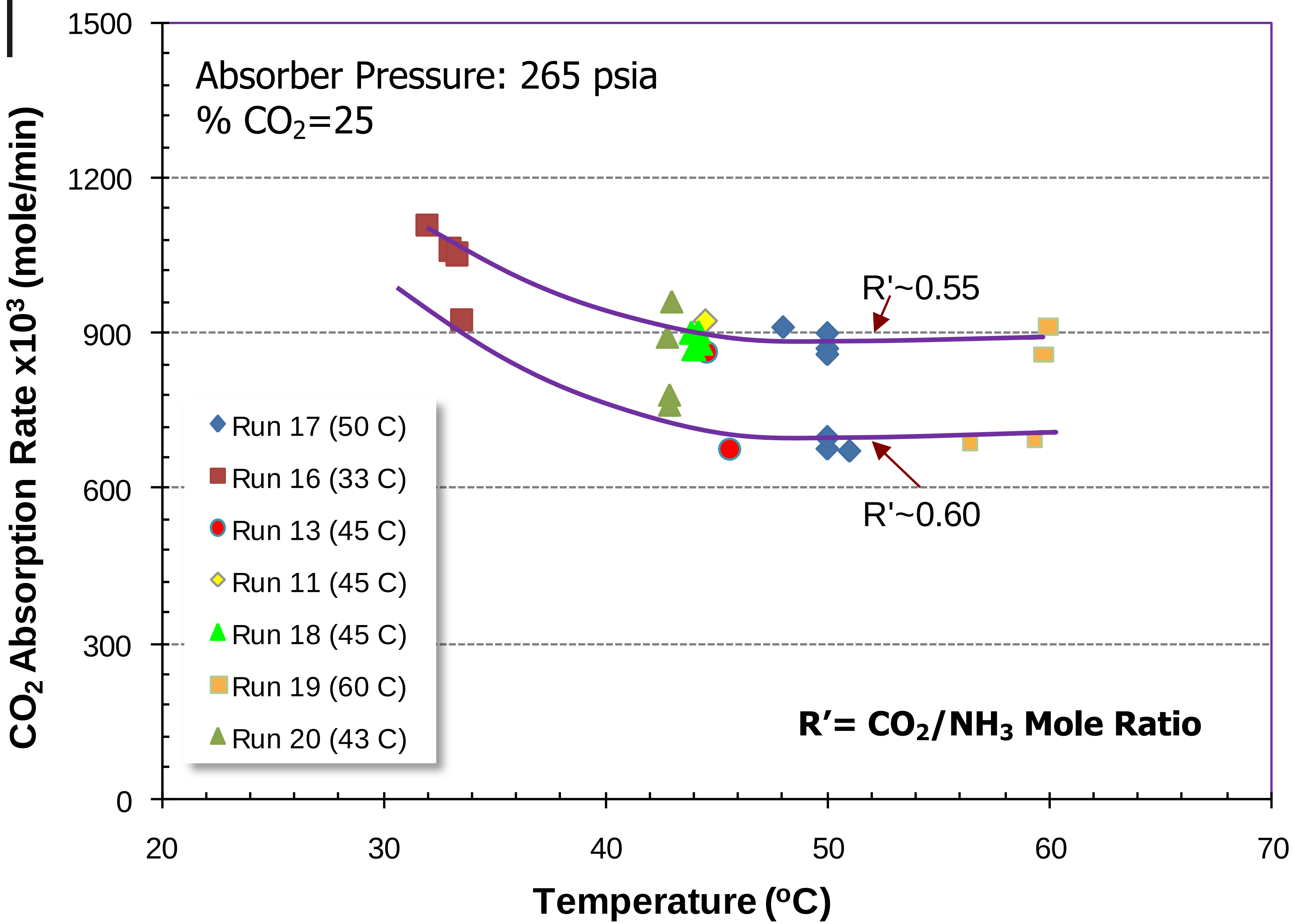
Solubility of Non-Reacting Gases in the Solution

Gas	Gas Component Concentration (%v/v)	Dissolved Gas (g/kg Solution) at 40 atm Total Pressure
H_2	50.0	6.53E-03
CO	2.0	3.62E-04
CH_4	2.0	4.67E-04
N_2	1.0	1.11E-04

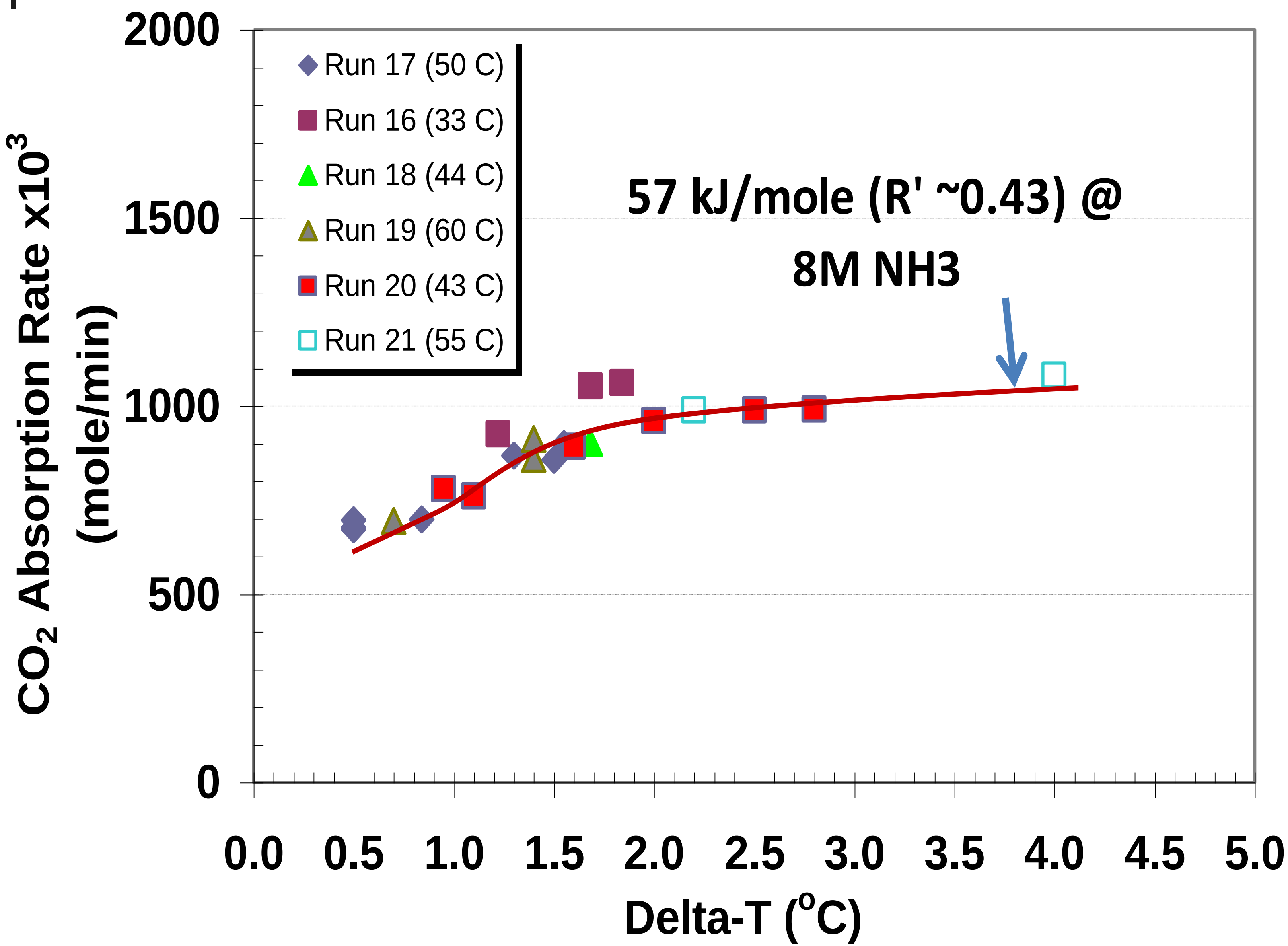
CO_2 Capture Efficiency vs Solution Composition



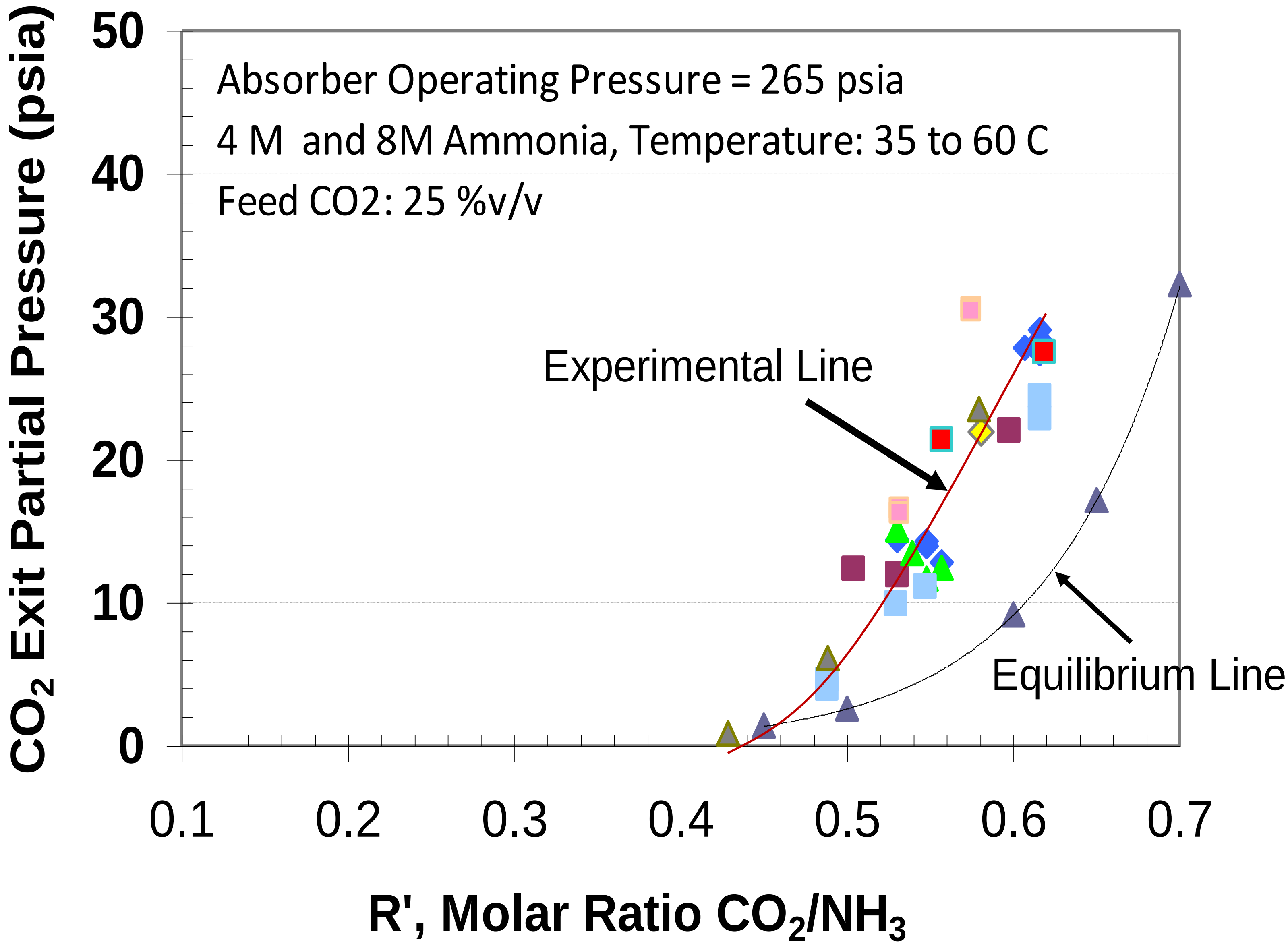
Effect of Temperature on Absorption Rate



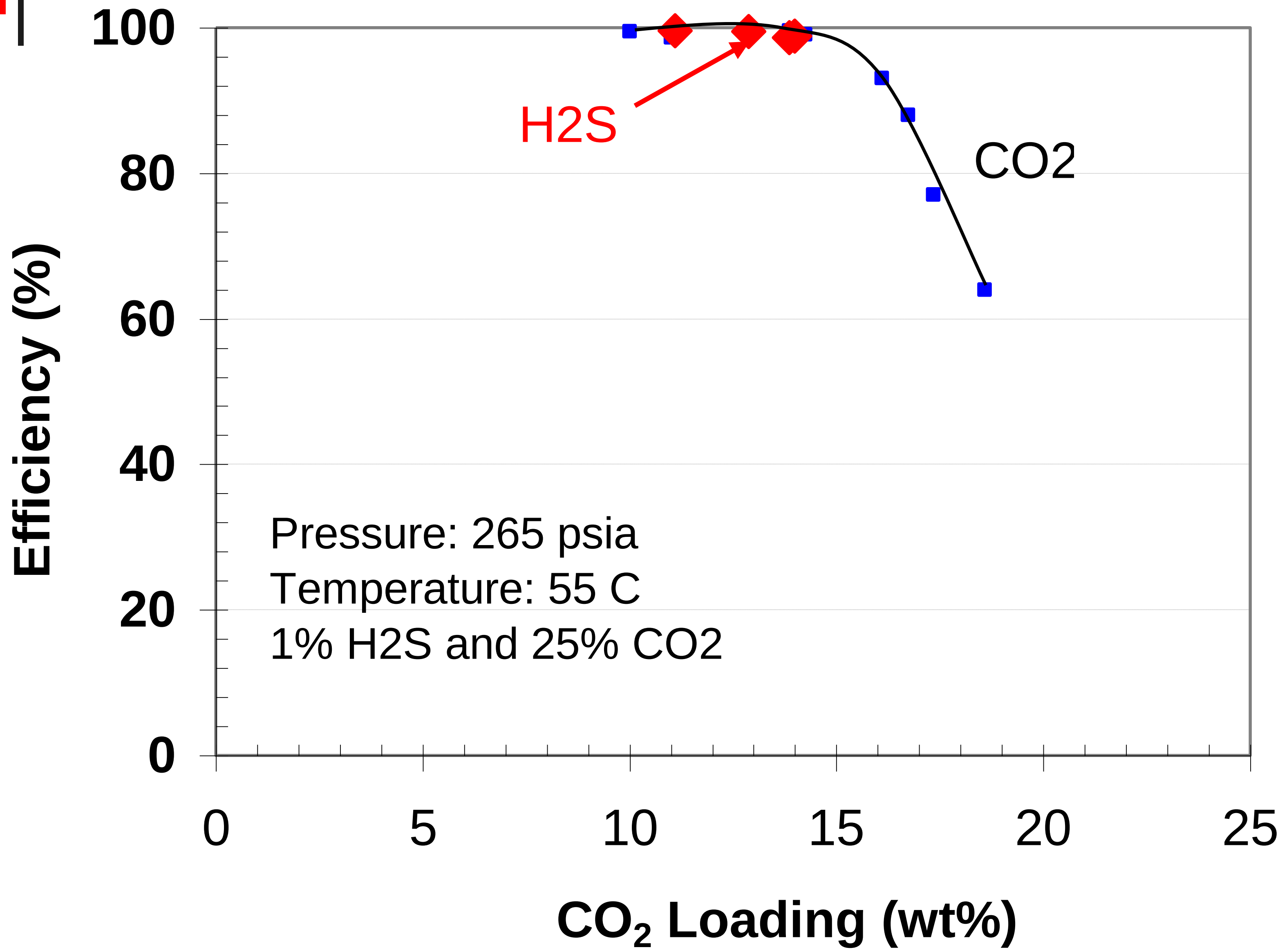
Temperature Raise on Absorption



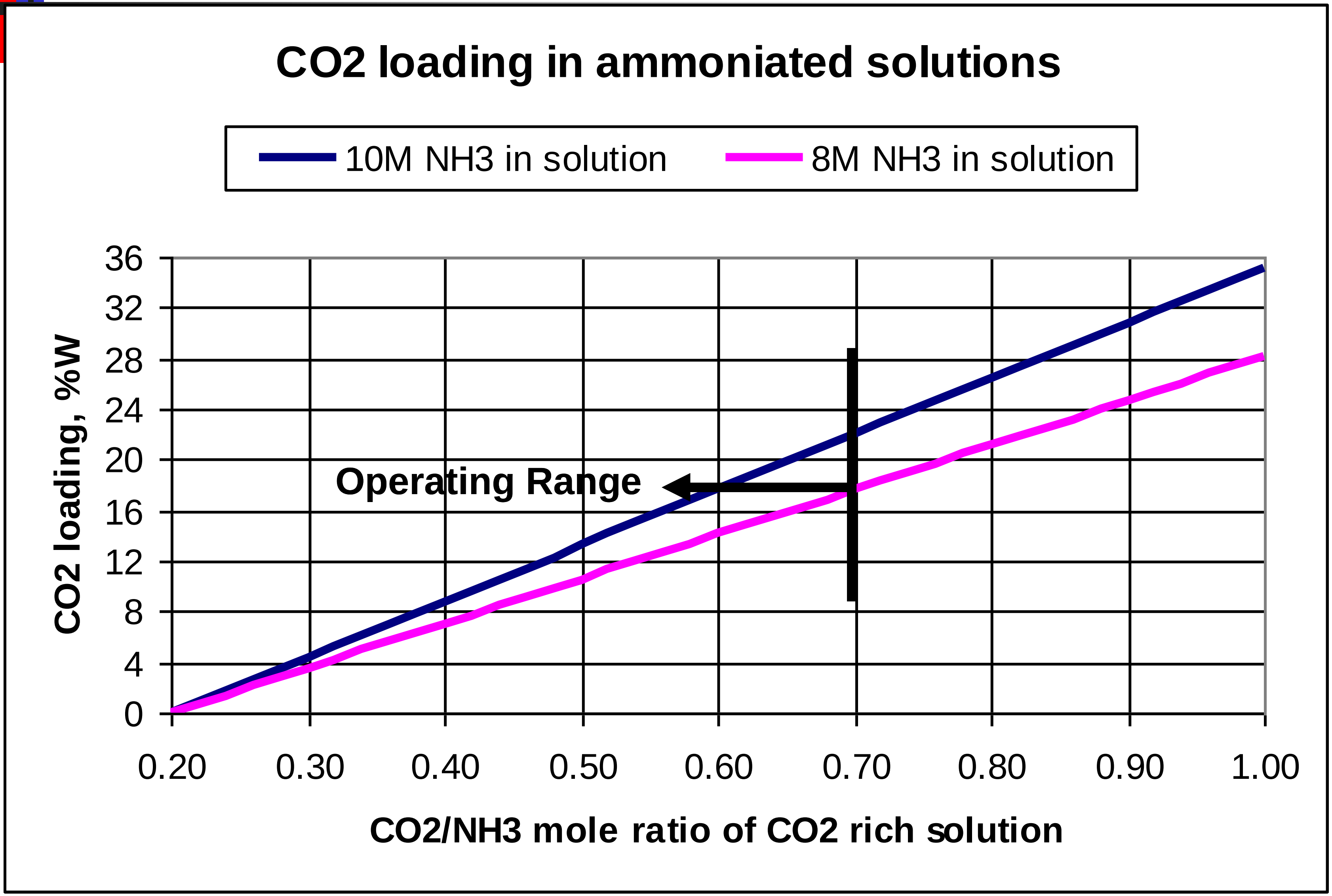
Tendency Toward Equilibrium Absorption



H_2S and CO_2 Absorption Efficiencies



CO_2 Capacity: Function of Solution Composition

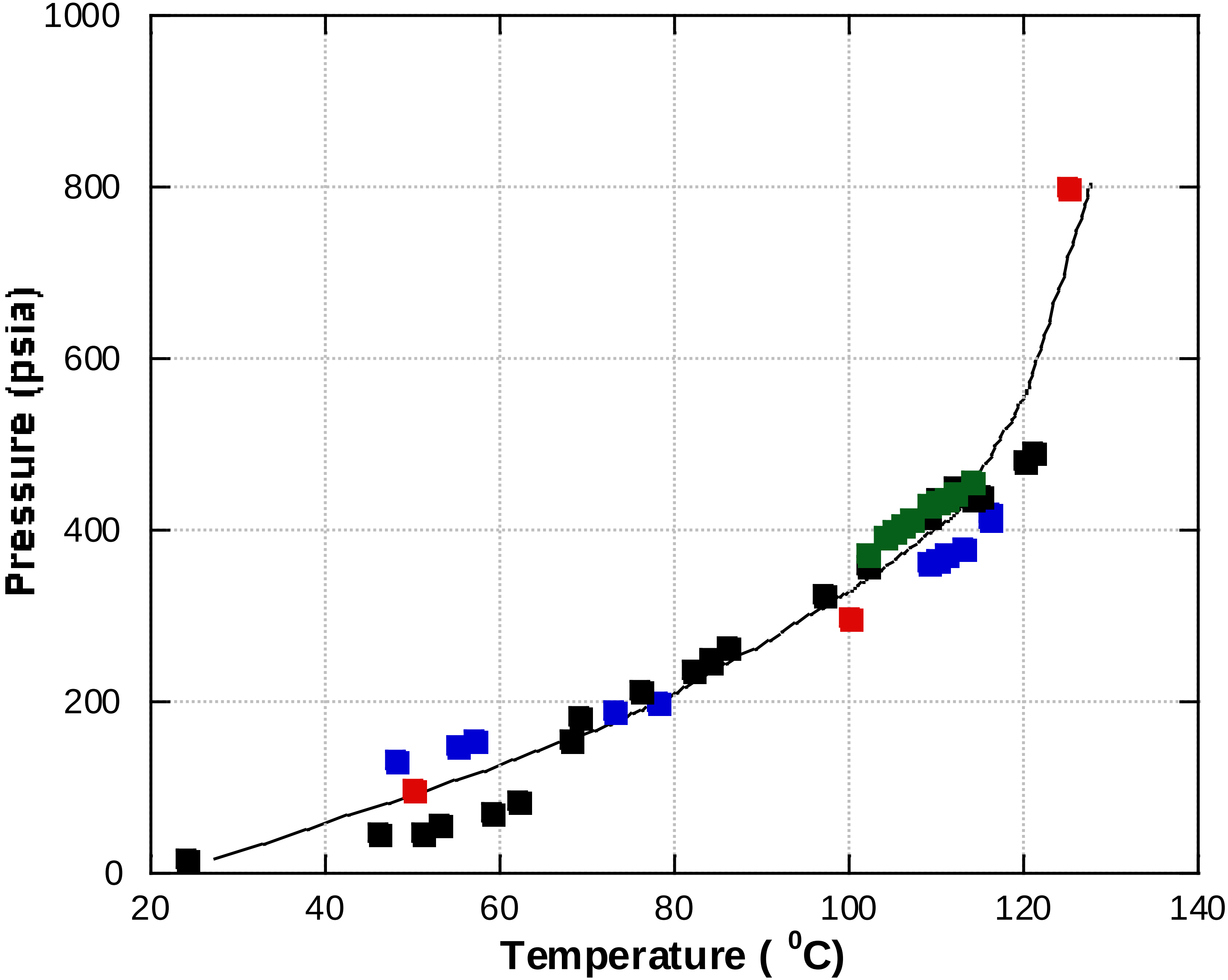


Solubility of NH_4HCO_3 at 50°C: 70 wt%

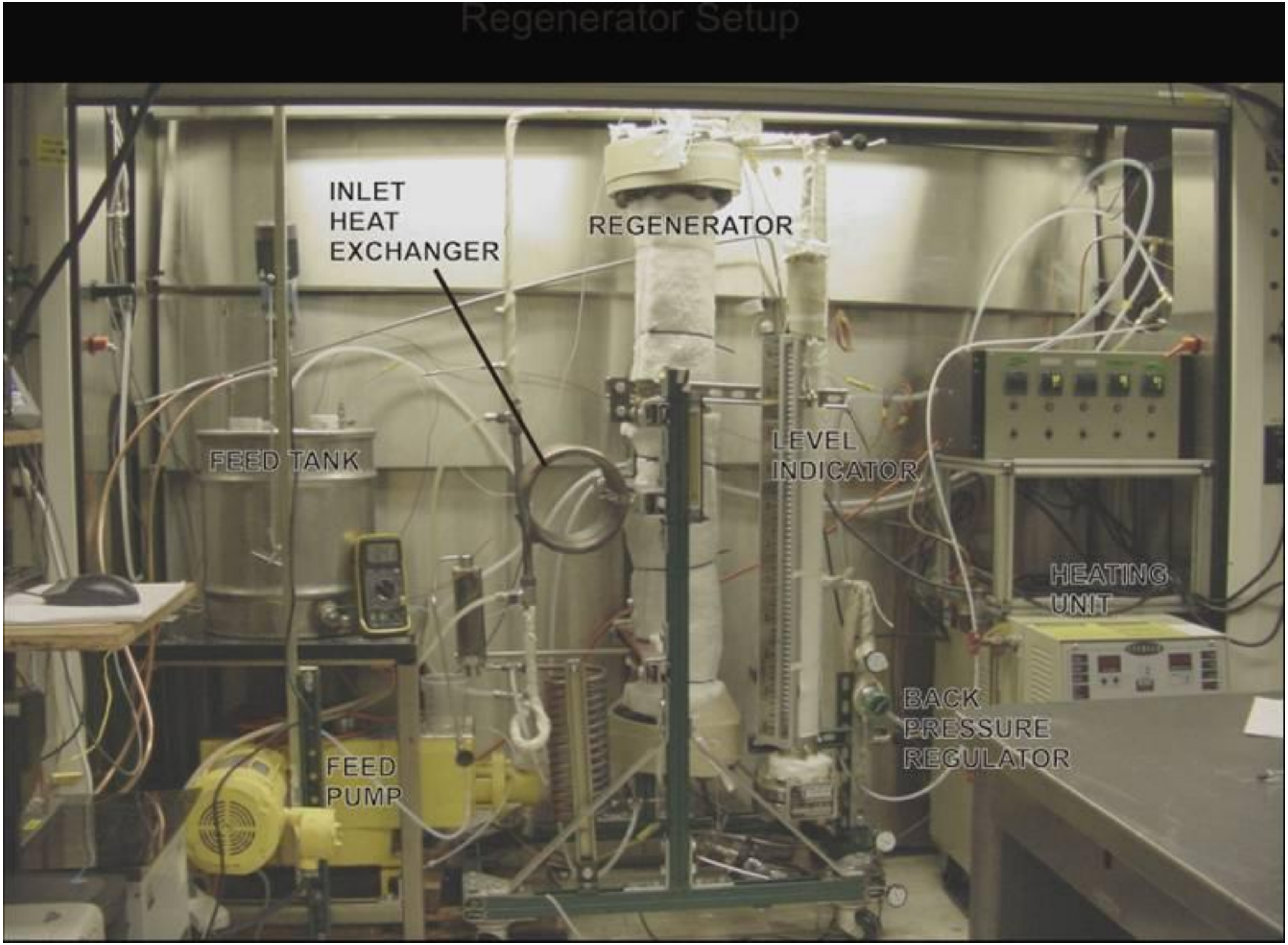
Bench-Scale Regenerator Testing

- Determination of CO_2 release characteristics
  - Function of temperature, pressure and solution composition
- Determination of H_2S release characteristics
  - Function of temperature, pressure and solution composition
- Relative kinetics of CO_2 and H_2S release

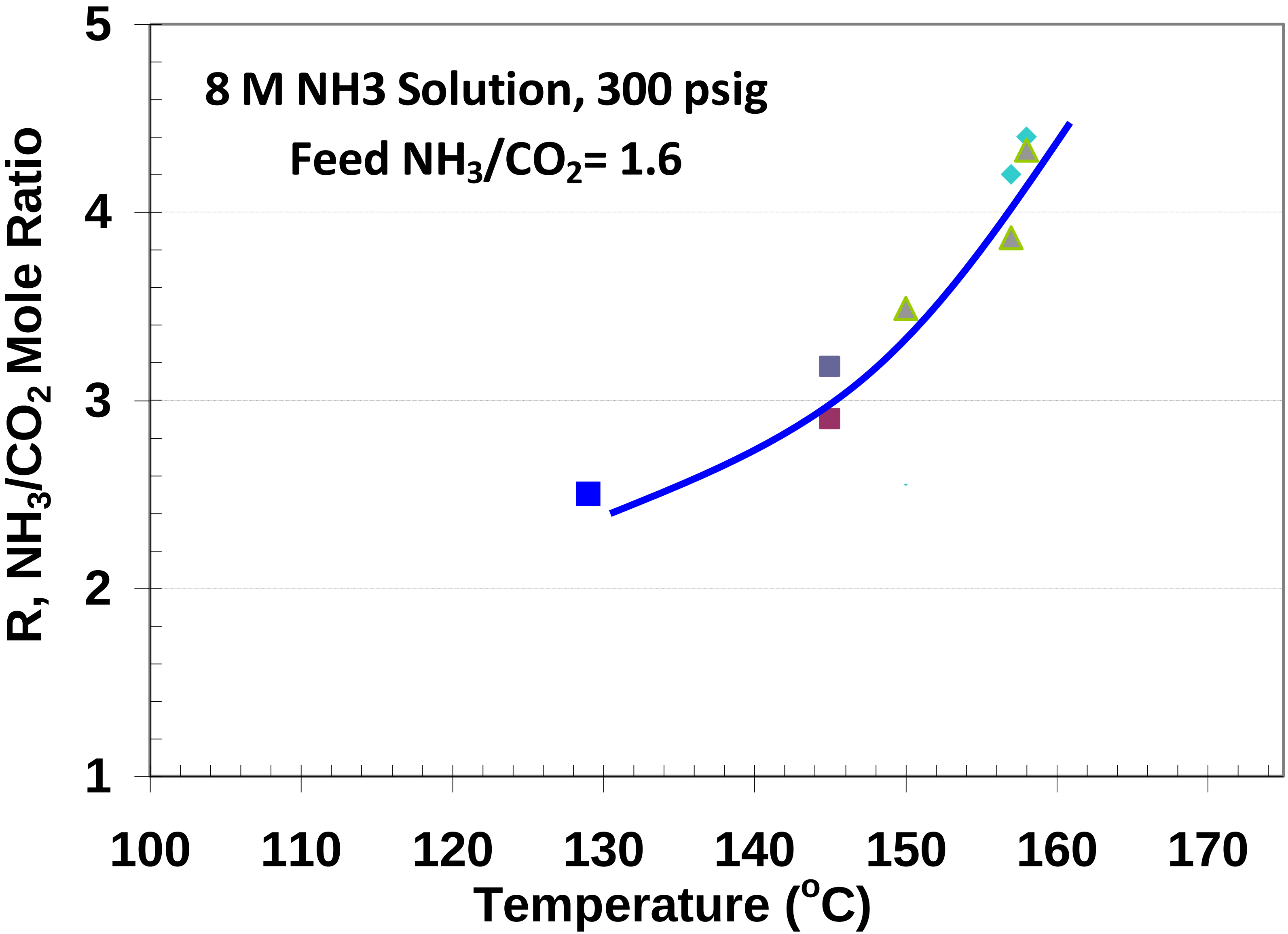
CO_2 Attainable Pressure Function of Temperature



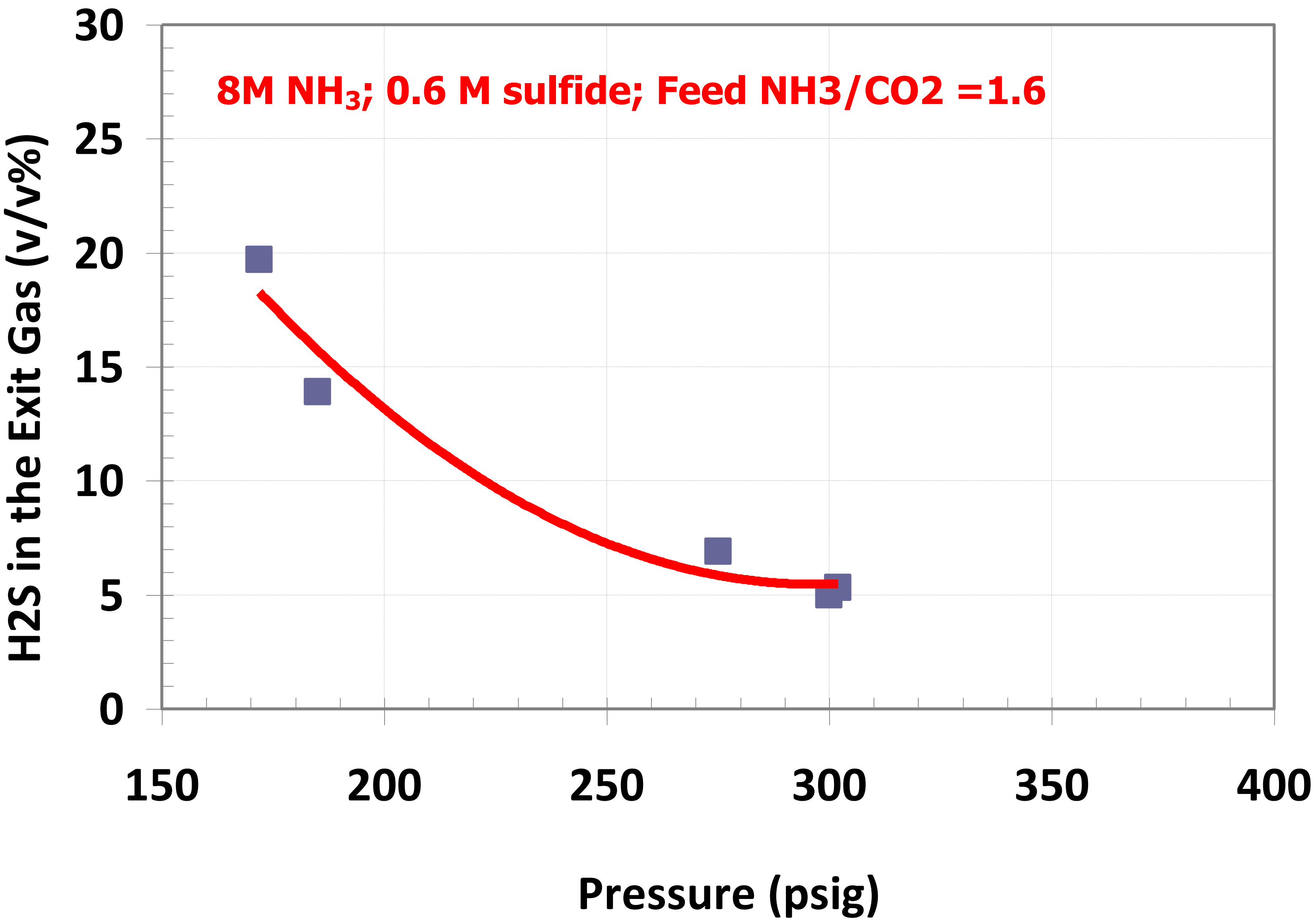
Photograph of the Regenerator System



High Pressure Regeneration of CO_2



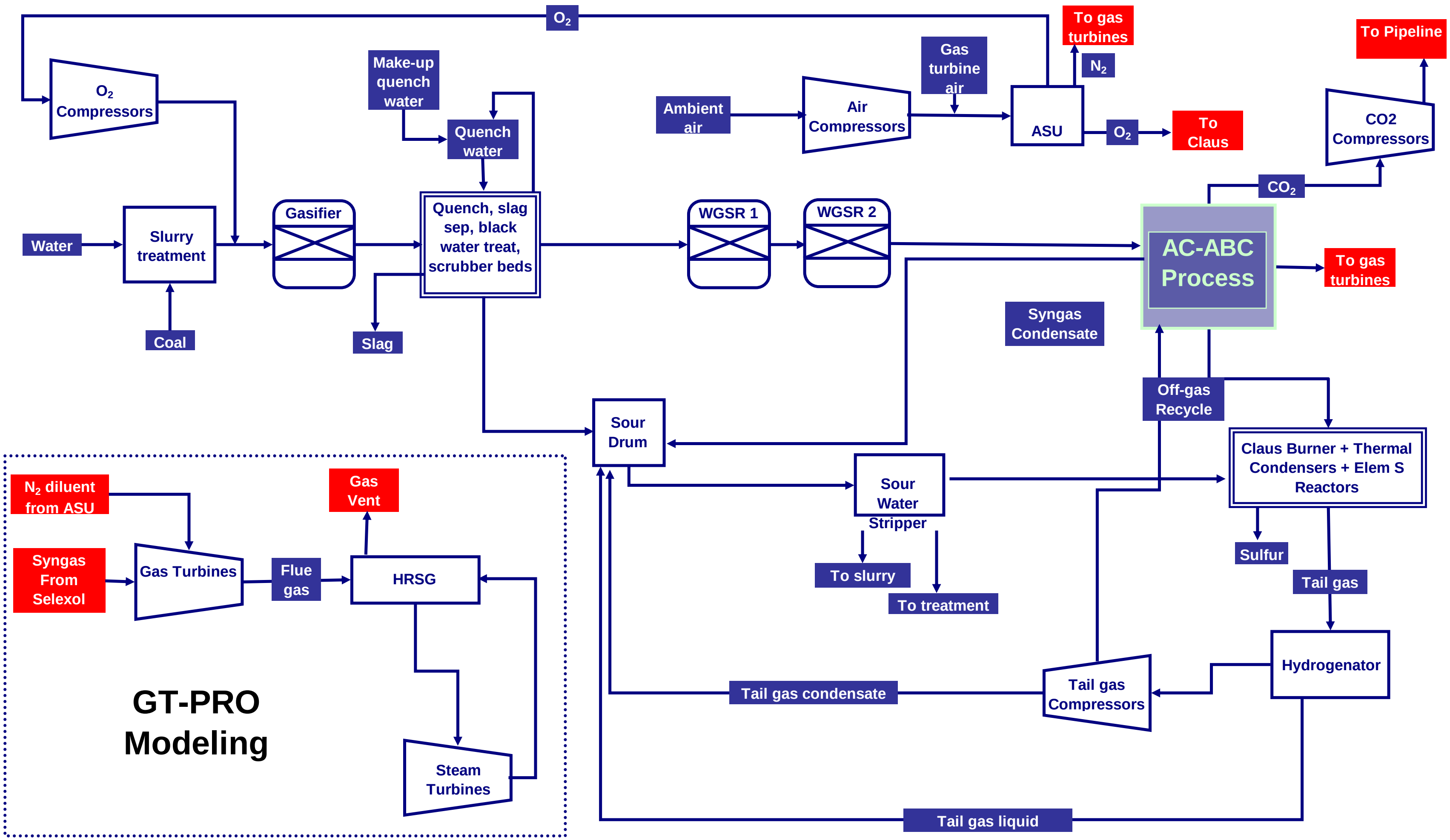
Release of H_2S During Regeneration



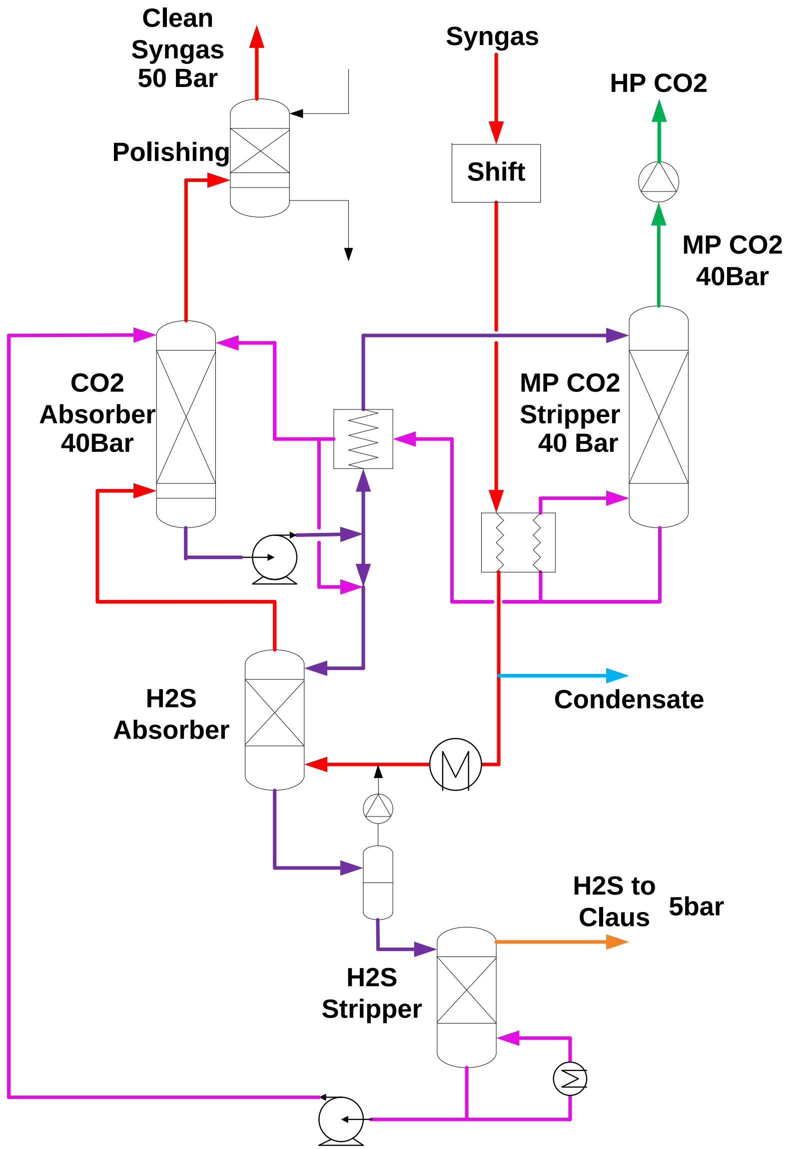
Technical and Economic Analysis

- Aspen and GT-Pro modeling were used to generate the equipment sizing and heat and material flows.
- Use DOE spread sheet to generate cost
- Base case will be an IGCC plant (750 MW nominal) with no CO_2 capture.
- Compare the AC-ABC process with a similar-size plant using CO_2 capture with Selexol subsystem.

Block Flow Diagram



Block Flow Diagram of the CO_2 and H_2S Capture System



Preliminary Cost Comparison

	Units	Base Case: No CO_2 Capture	Base Case: Selexol CO_2 Capture	AC-ABC: 600 BTU/lb	AC-ABC: H2S Removal as Gypsum
Power Production @ 100% Capacity	GWh/yr	5,445	4,461	4,888	4,888
Power Plant Capital	c/kWh	4.48	6.21	5.44	5.38
Power Plant Fuel	c/kWh	1.90	2.46	2.22	2.22
Variable Plant O&M	c/kWh	0.78	1.00	0.93	0.93
Fixed Plant O&M	c/kWh	0.60	0.79	0.72	0.72
Cost of Electricity (COE)*	c/kWh	7.76	10.46	9.31	9.25
Cost of Electricity (COE)	c/kWh	7.76	10.88	9.69	9.62
Increase in COE*	%	0.0%	34.8%	20.0%	19.2%
Increase in COE	%	0.0%	40.2%	24.9%	24.0%
Net Efficiency (HHV)	%	39.2%	30.3%	33.2%	33.2%

* Exludes transportation, storage, and monitoring costs

CO2 capture: 3.3 million tons/year; Plant operting life: 30 years; Capacity factor: 80%; Capital charge factor: 17.5%

Accomplishments

- Operation of bench-scale system:
  - High pressure (20 bar) and
  - Elevated temperatures (up to 160 C).
- Demonstration of very high levels (>90%) of CO_2 and H_2S capture efficiency.
- Regeneration of solution and release of CO_2 and H_2S at high pressures.
- Preliminary analysis shows a significant cost improvement over the Selexol case.

Future Plans: Pilot-Scale Continuous Integrated Tests

- Design of a pilot-scale continuous, integrated test system
- Construction of the pilot-scale system
- Development of pilot-scale test plans
- Performance of pilot-scale tests
- Process modeling
- Economic analysis
- Technology transfer to commercial sector

Pilot-Scale Testing with a Gasifier Stream

- Use the gas stream from the Great Point Energy's 1 ton/day gasifier
  - The stability of integrated operation will be evident in the field test more readily because not all variables are closely controlled as in the simulated tests.
  - Long test duration**:** The field tests will provide about 10 times longer total test time than with the simulated tests (up to 600 h total).
  - Effect of trace contaminants: The field test will use a gas stream from an operating gasifier that has undergone minimum cleanup and the gas stream will contain trace contaminants.

Team

- SRI International
  - Dr. Gopala Krishnan – Associate Director (MRL) and PI
  - Dr. Angel Sanjurjo – Materials Research Laboratory Director and Project Supervisor
  - Dr. Indira Jayaweera, Dr. Jordi Perez, and Mr. Anoop Nagar
- Great Point Energy, Inc,
  - Dr. Pat Raman
- DOE-NETL
  - Ms. Susan Maley, Ms. Jenny Tennant