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CO_2 Capture from IGCC Gas Streams Using the AC-ABC Process

2011 NETL CO_2 Capture Technology Meeting

August 22-26, 2010 Pittsburgh, PA.

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Project Overview

- Partners:
  - DOE-National Energy Technology Center, Awarding Agency
  - SRI International, Menlo Park, CA
  - EIG, Sunnyvale, CA
  - New Partnerships, 2011
- Period of Performance:
  - 10-1-2009 through 3-30-2012
- Funding:
  - U.S.: Department of Energy: $3.42 million
  - Cost share: $1.08 million
  - Total: $4.5 million

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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.
  - 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.

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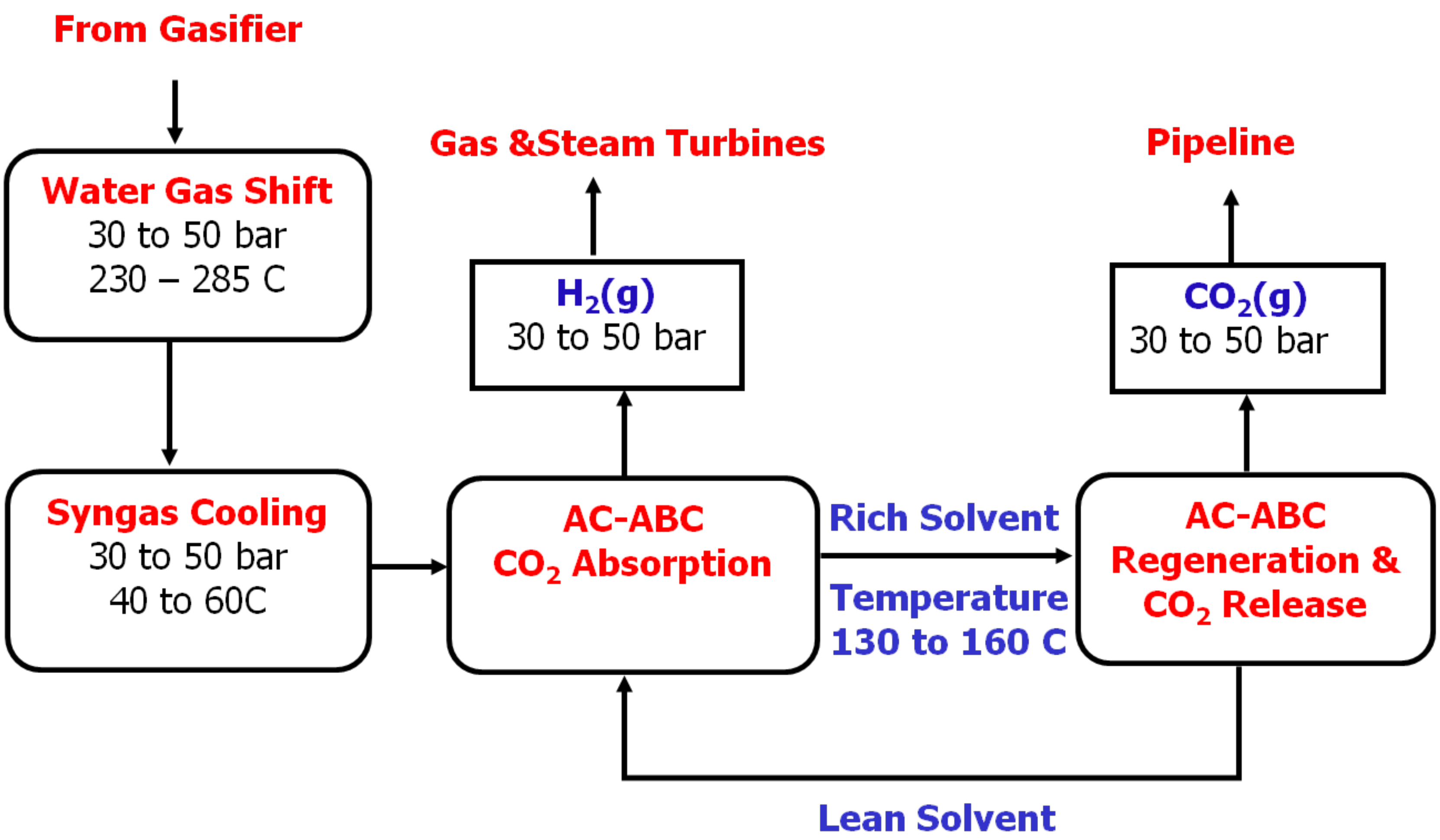
Process Flow Diagram



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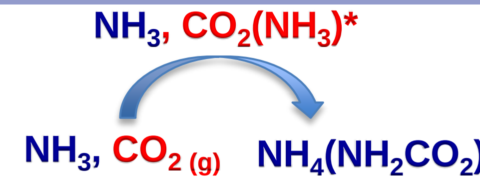
Sound Underlying Concepts



- Uses well-known reaction between CO_2 and aqueous ammonia

$$NH_4OH + CO_2 \leftrightarrow NH_4HCO_3$$
$$(NH_4)_2CO_3 + CO_2 + H_2O \leftrightarrow 2NH_4HCO_3$$
$$NH_4(NH_2CO_2) + CO_2 + 2H_2O \leftrightarrow 2NH_4HCO_3$$

- Reactions are reversible
  - Absorption reactions at lower temperature
  - Desorption reactions at higher temperature
- Relatively low heat of reaction (300-600 Btu/lb of CO_2 depending on the NH_3/CO_2 ratio in the solution).
- High pressure operation enhances absorption of CO_2.
- A similar set of reactions occur between H_2S and ammoniated solution.

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Process Highlights

- Concentrated ammoniated solution is used to capture CO_2 and H_2S from syngas at high pressure.
- Absorber operation at 40°-60° C temperature; No refrigeration is needed.
- CO_2 is released at high pressures:
  - The size of CO_2 stripper, the number of stages of CO_2 compression and inter-cooling and the electric power consumption for compression of CO_2 compression 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.

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Process Advantages

- Low cost and readily available reagent.
- 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.

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Project Tasks

1. Bench-scale Batch Tests

2. Pilot-Scale Integrated, Continuous Tests

3. Project Management

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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.

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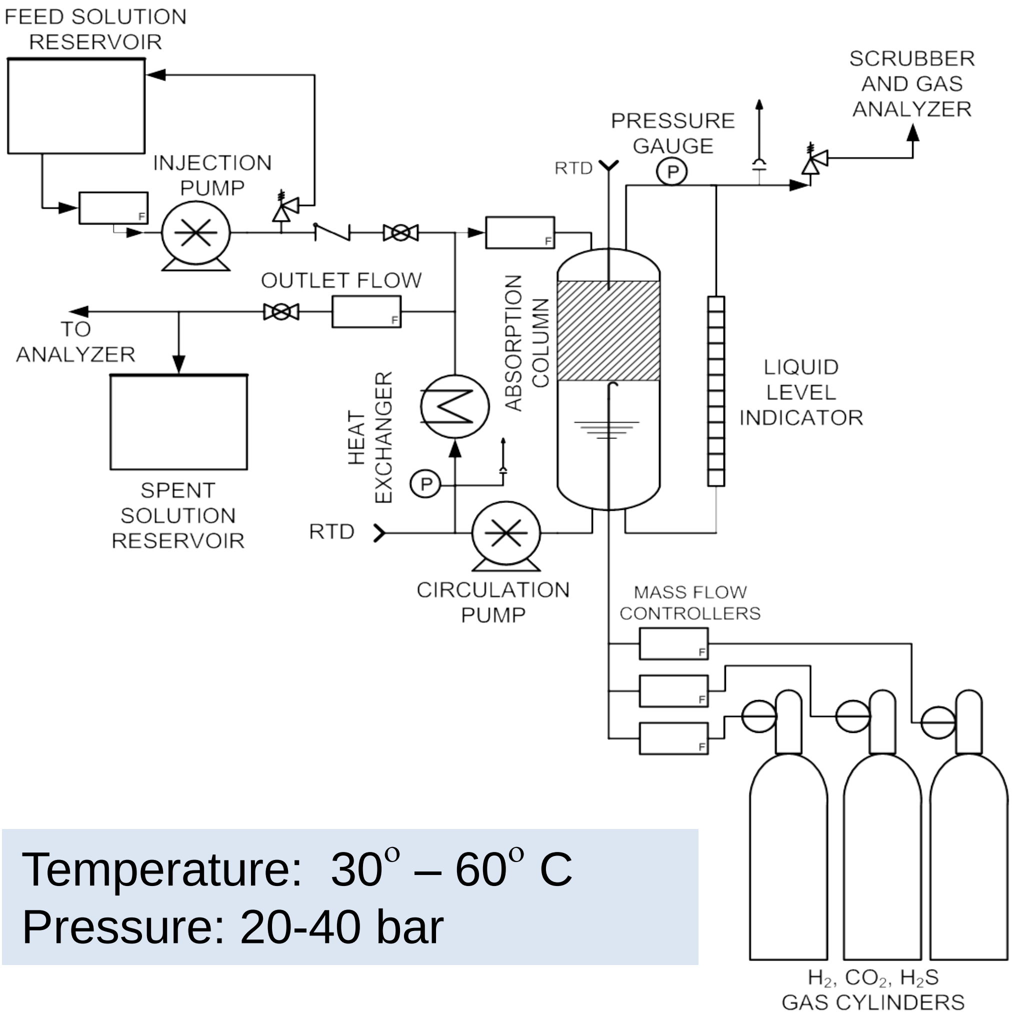
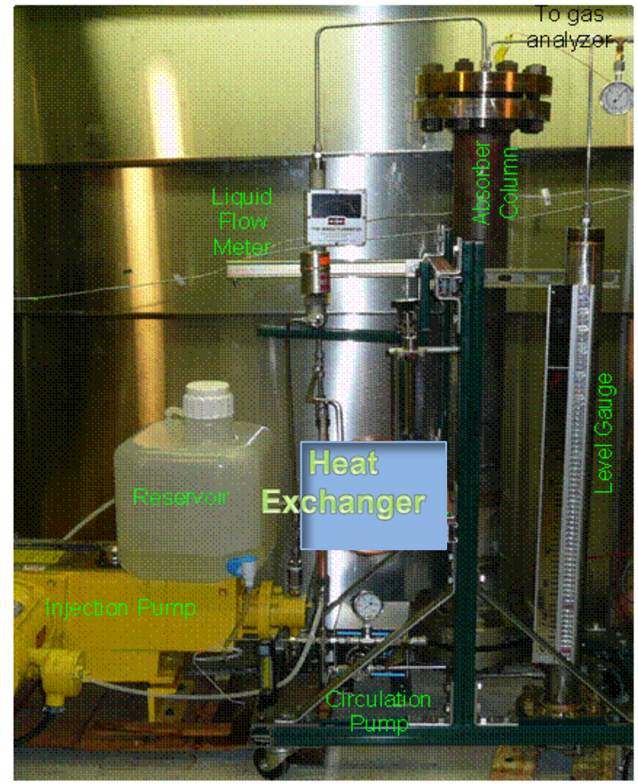
Bench-Scale Absorber System



Temperature: $30^{o} – 60^{o}$ C
Pressure: 20-40 bar



Reactor ID: 4-in
Low Pressure Drop
Specific Area: 425 m^2/m^3
Packing Height: 2-ft
Liquid Loading : 5 – 10%

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Determination of Fuel Gas Component Solubility

Gas Type	Gas Component Concentration (%v/v)	Dissolved Gas (g/kg solution at 40 atm)
H_2	50.0	6.53×10^{-3}
CO	2.0	3.62×10^{-4}
CH_4	2.0	4.67×10^{-4}
N_2	1.0	1.11×10^{-4}

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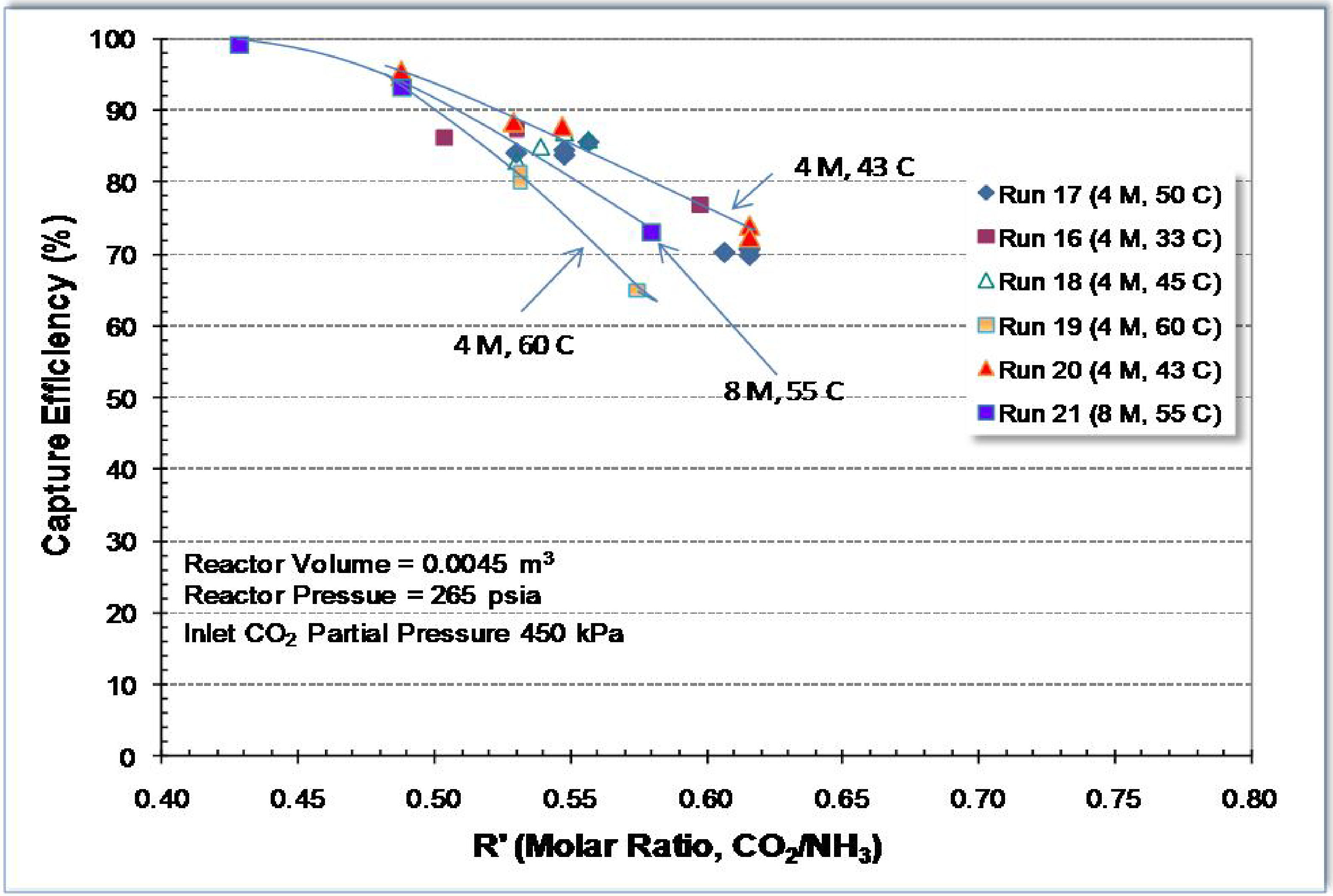
CO_2 Capture Efficiency vs Solution Composition

CO_2 Capture Efficiency Exceeds 90%



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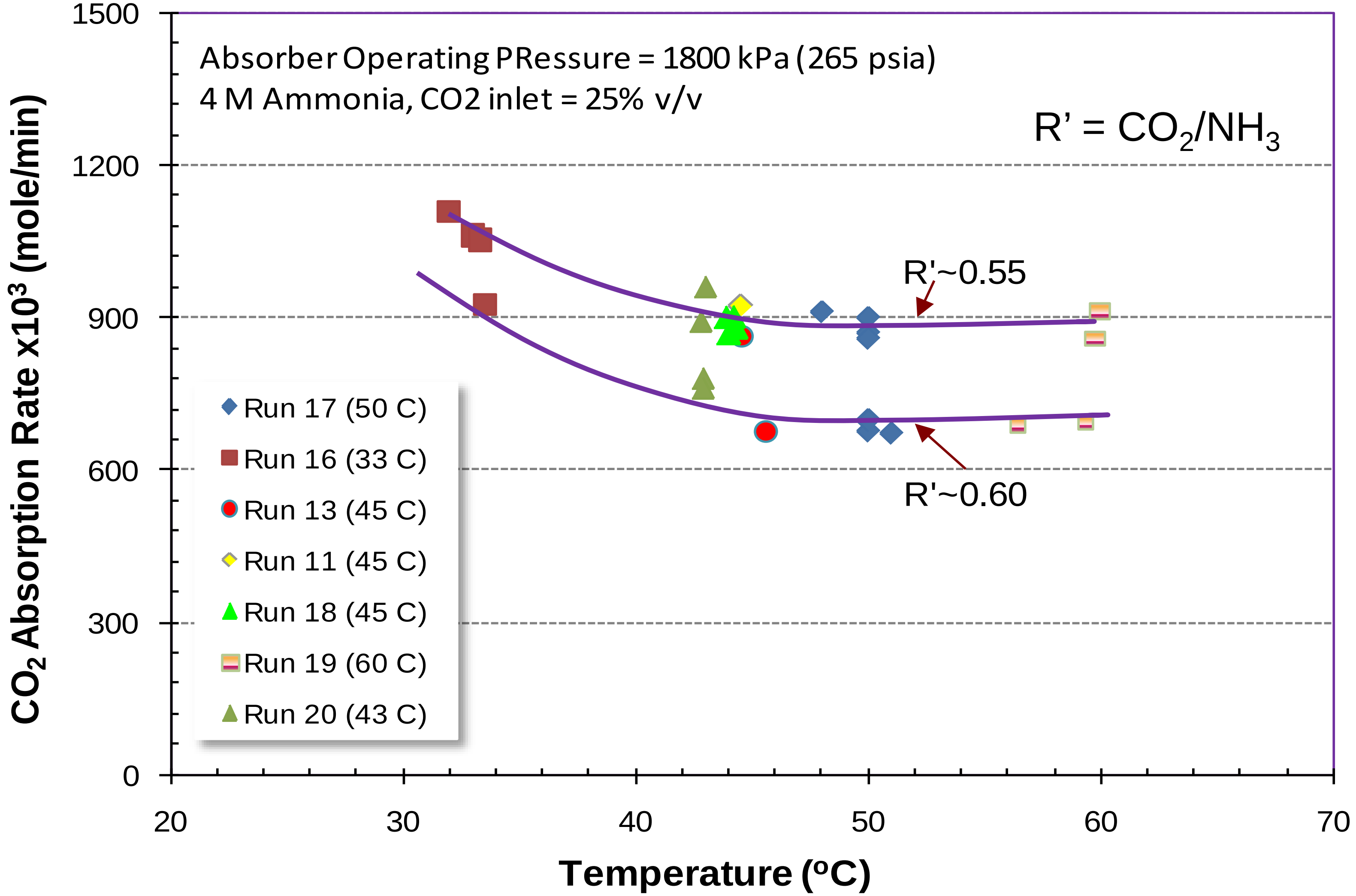
No Significant Decrease in the Rate of Absorption at Elevated Temperatures



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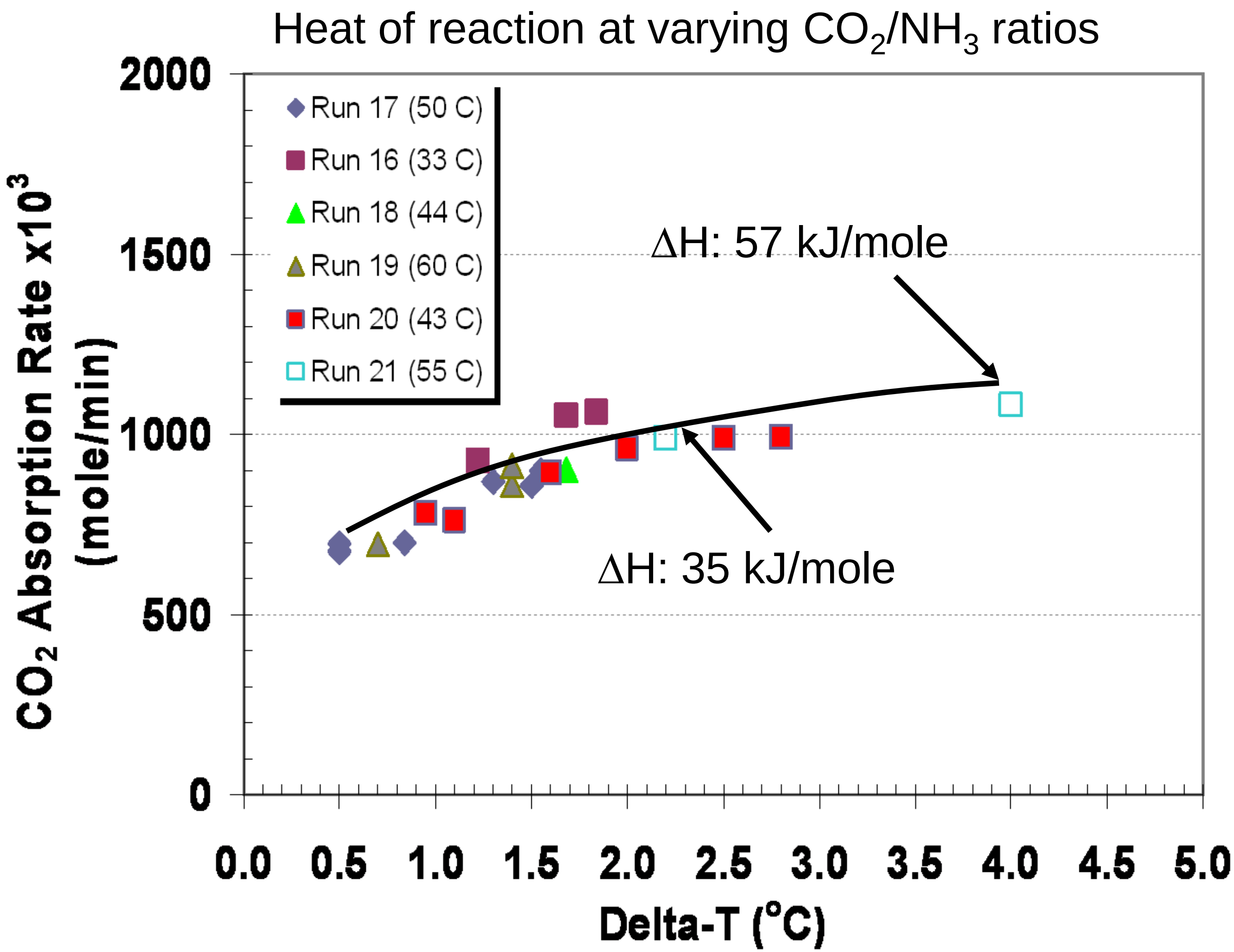
Moderate Heat of Absorption to Reduce Cooling Requirements



Target: <60 kJ/mole

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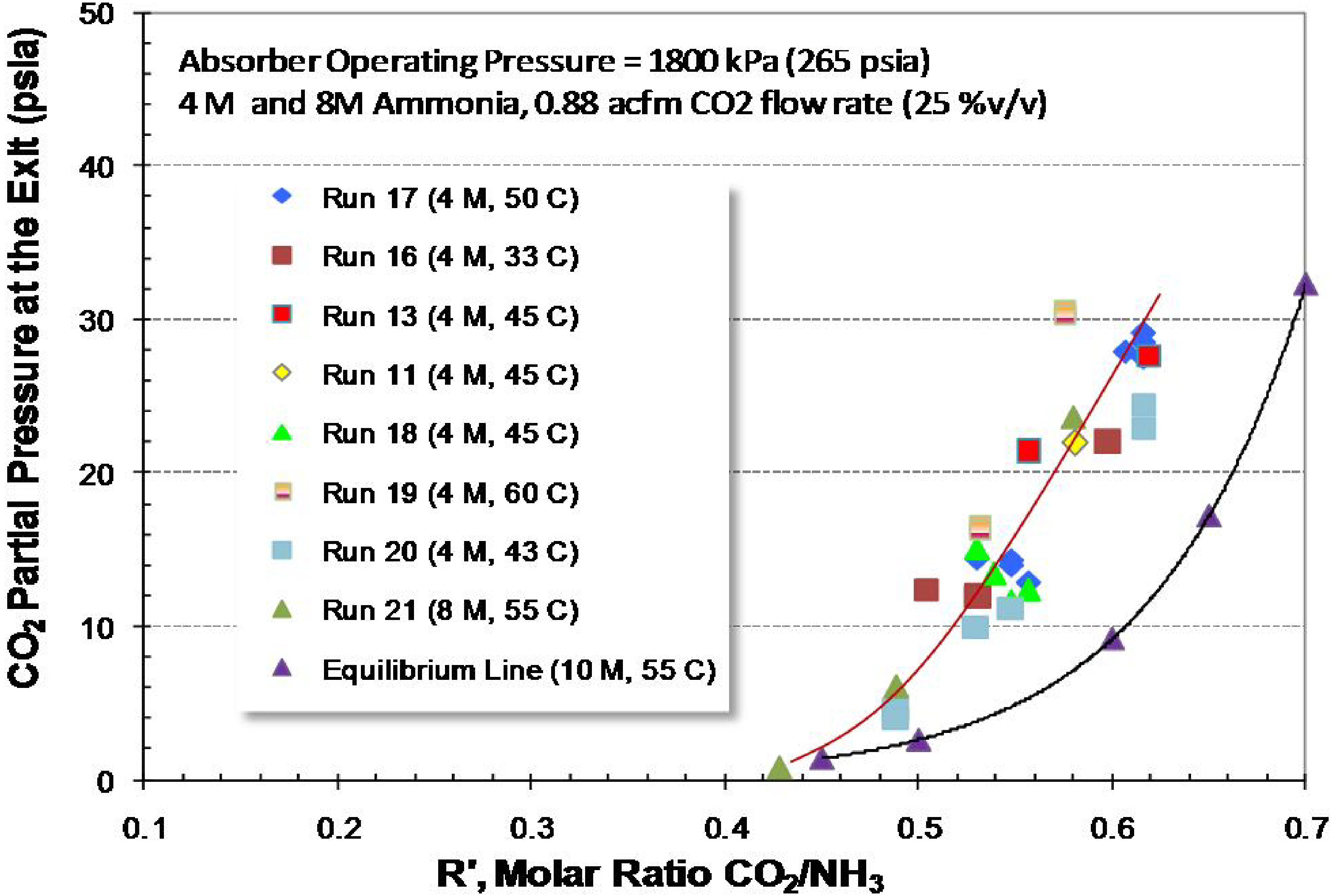
Rapid Rate of Reactions Approaching Equilibrium



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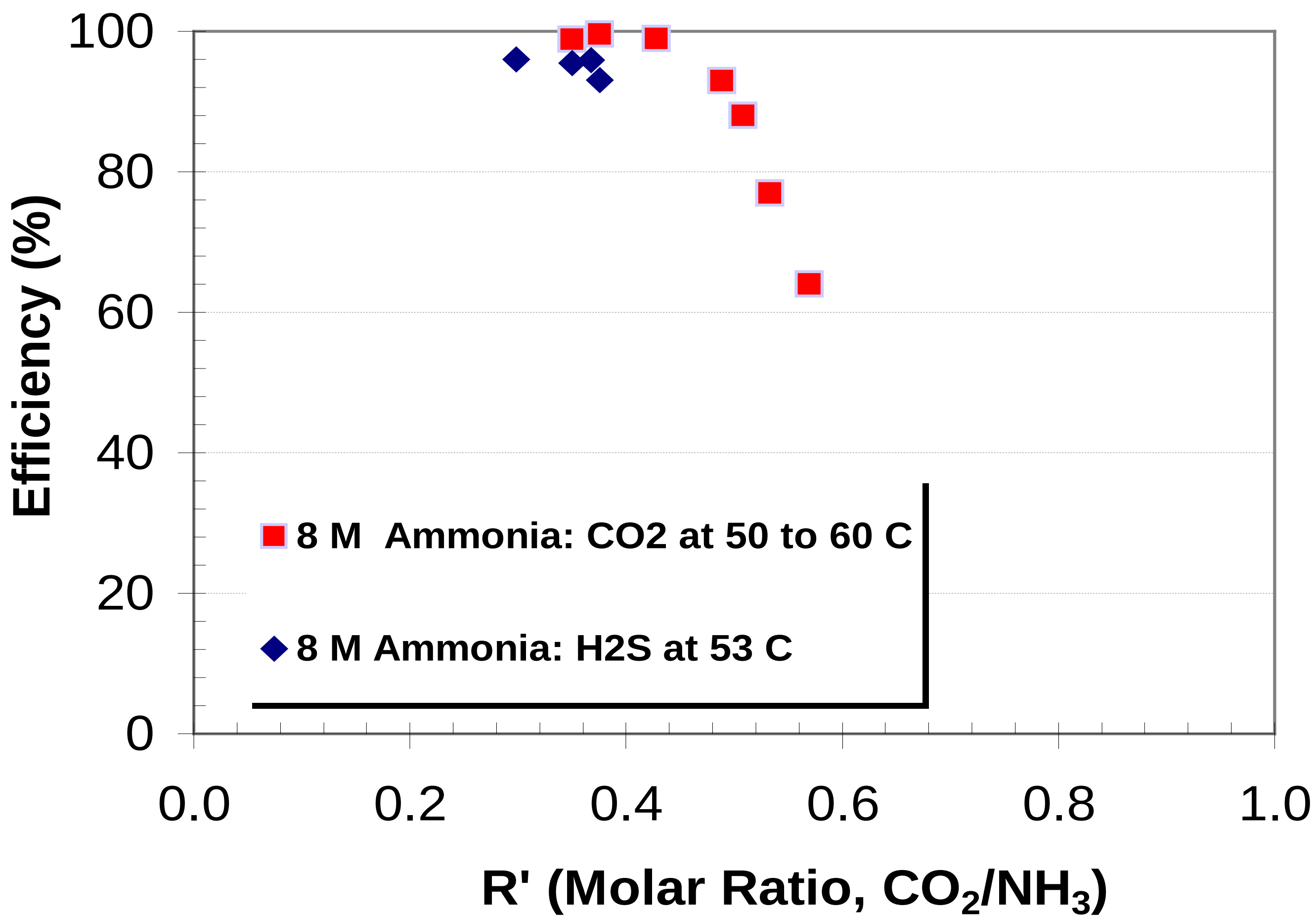
High Efficiency of H_2S Capture

(2-ft, Single Stage Absorber Column)



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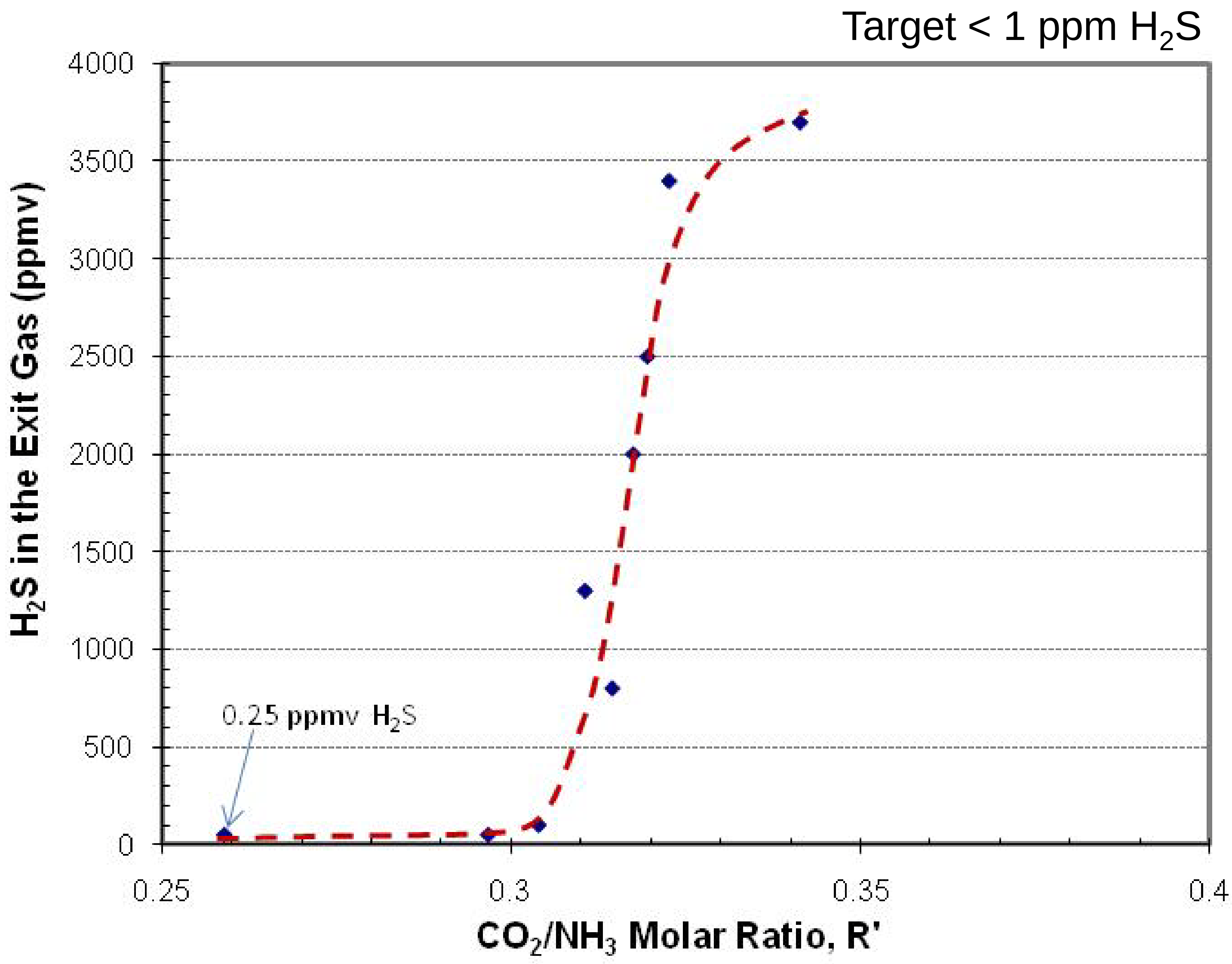
High Efficiency of H_2S Capture



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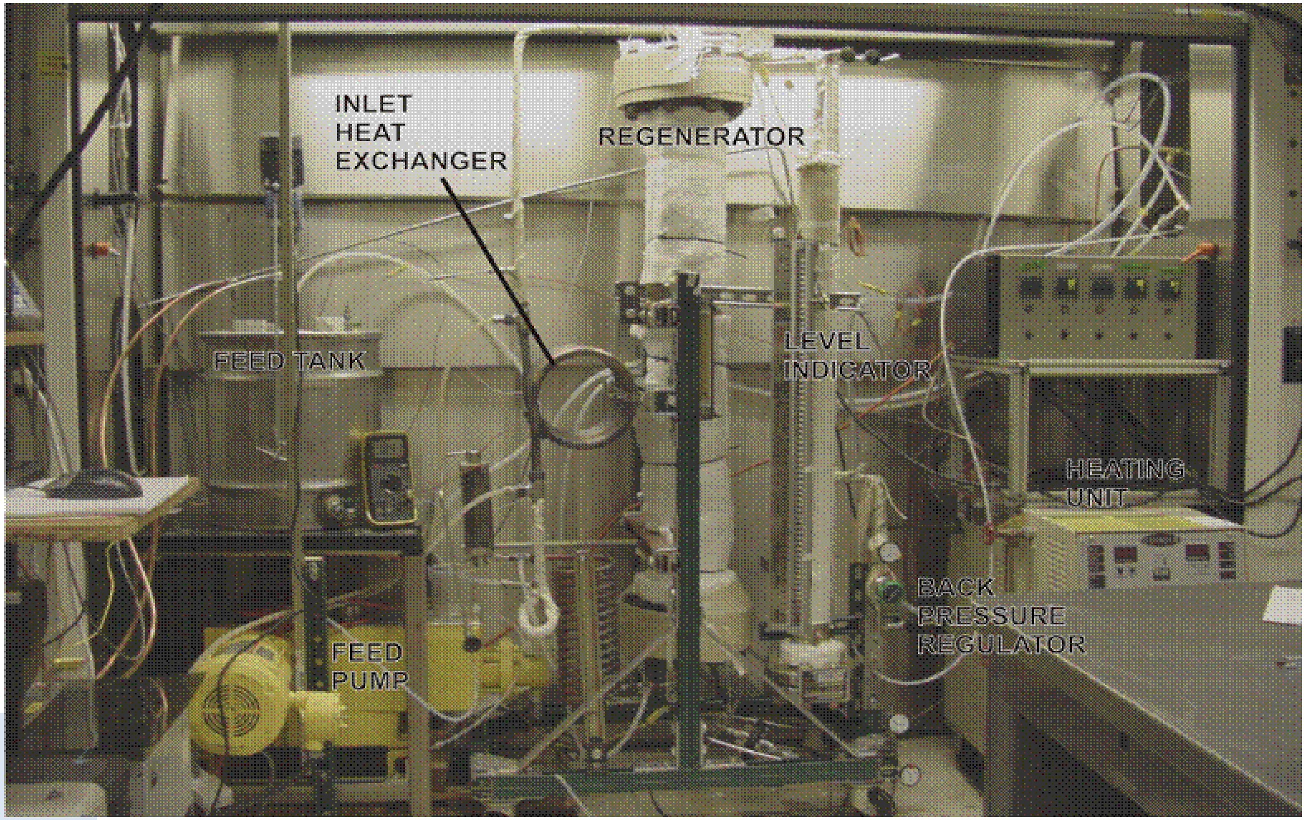
Bench-Scale Regenerator Testing

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



T: 100 - 170 C
P: 10-40 bar
Feed CO_2 Loading: 10-20 wt%

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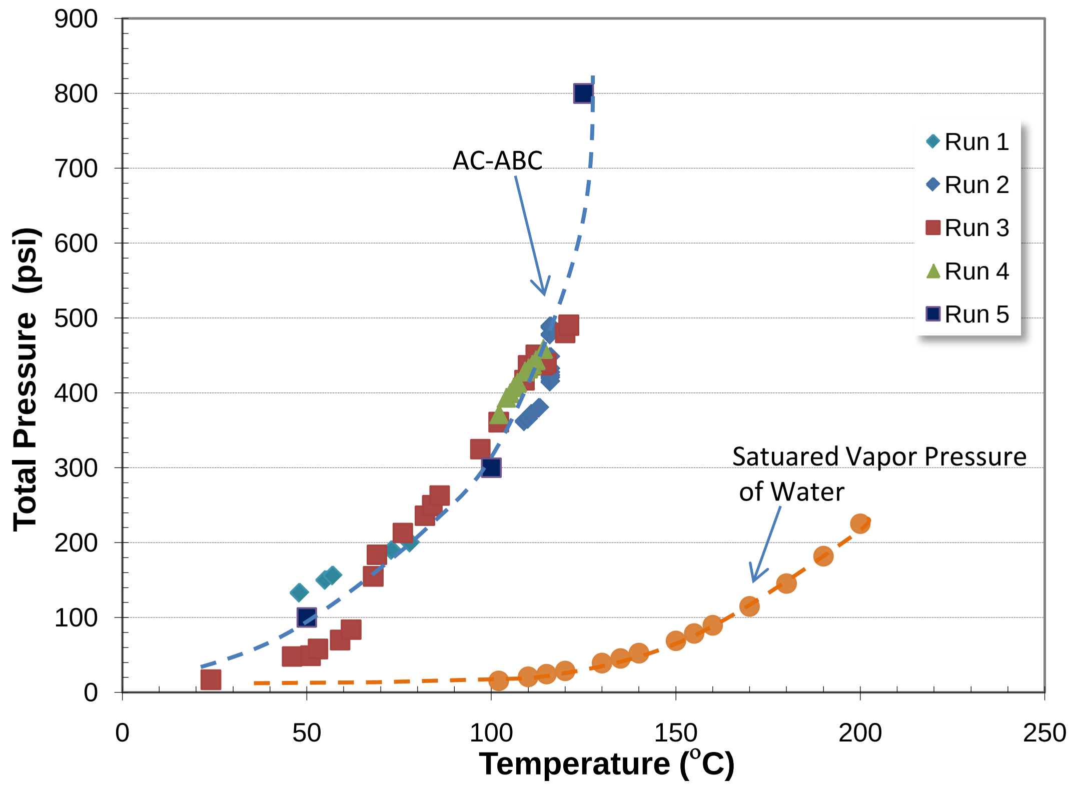
Measured CO_2 Attainable Pressure Function of Temperature



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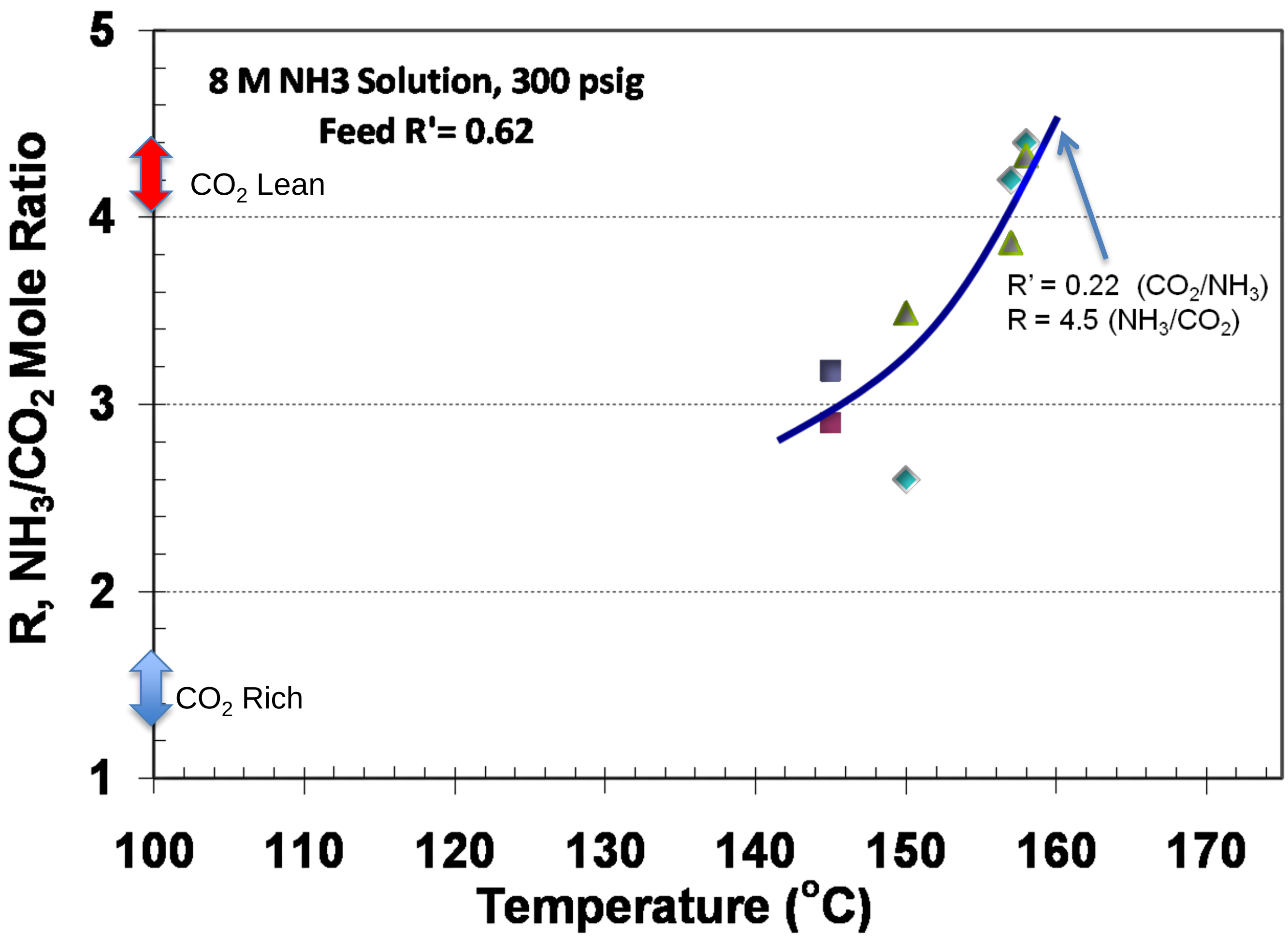
High Levels of Solvent Regeneration at Moderate Temperatures



Target R Value: >4

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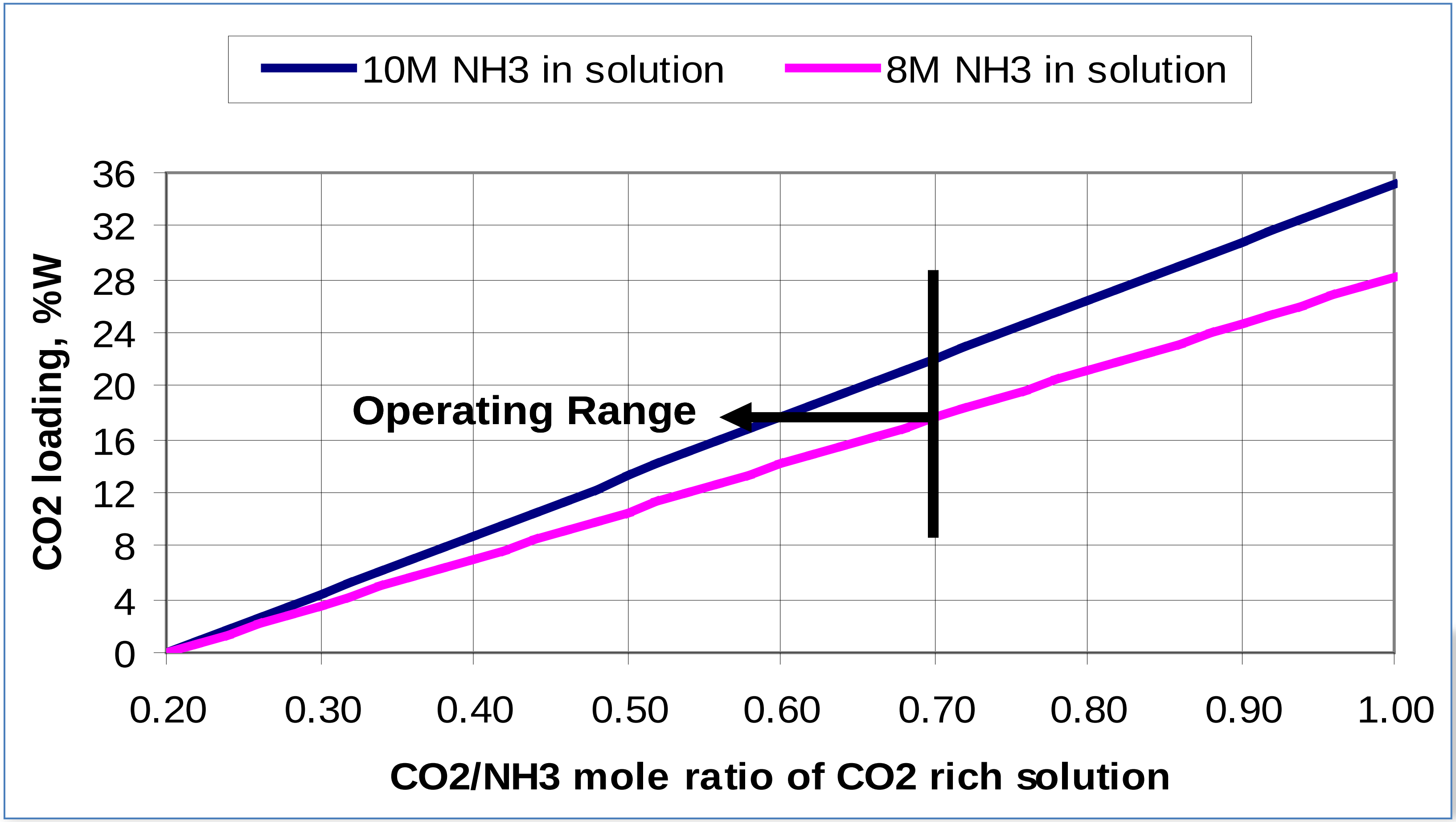
CO_2 Capacity: Function of Solution Composition

Target: >15 wt% CO_2 loading



Solubility of NH_4HCO_3 at 50°C: 70 wt%

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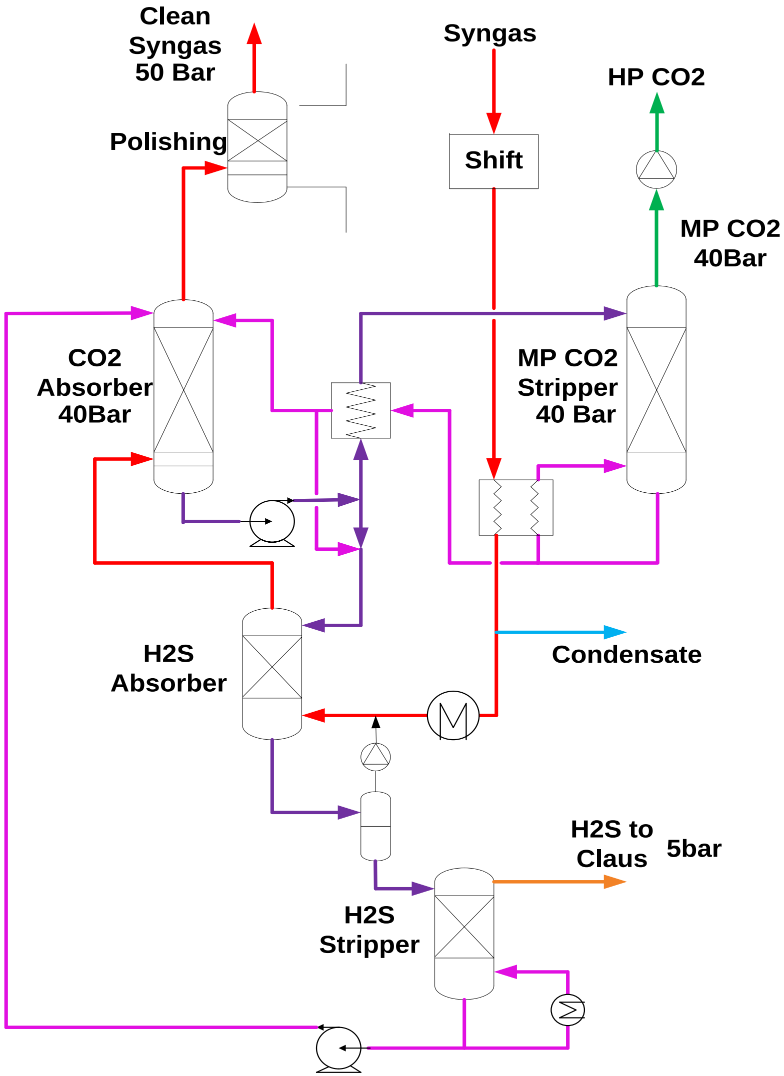
Technical and Economic Analysis

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



Schematic of the CO_2 and H_2S Capture System

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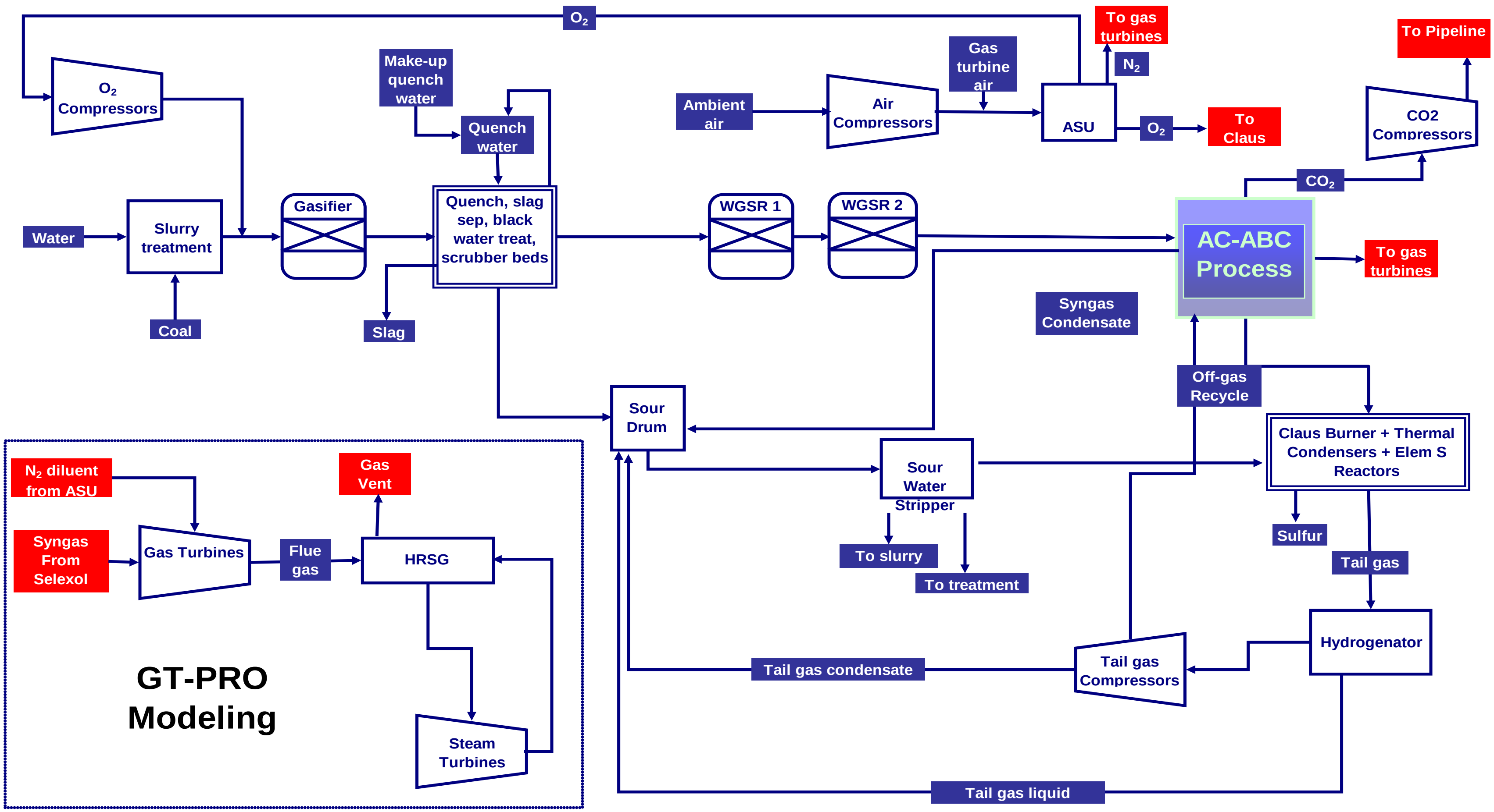
Block Flow Diagram



Process Energy Requirements: CO_2 stripping, solution pumping, and CO_2 compression

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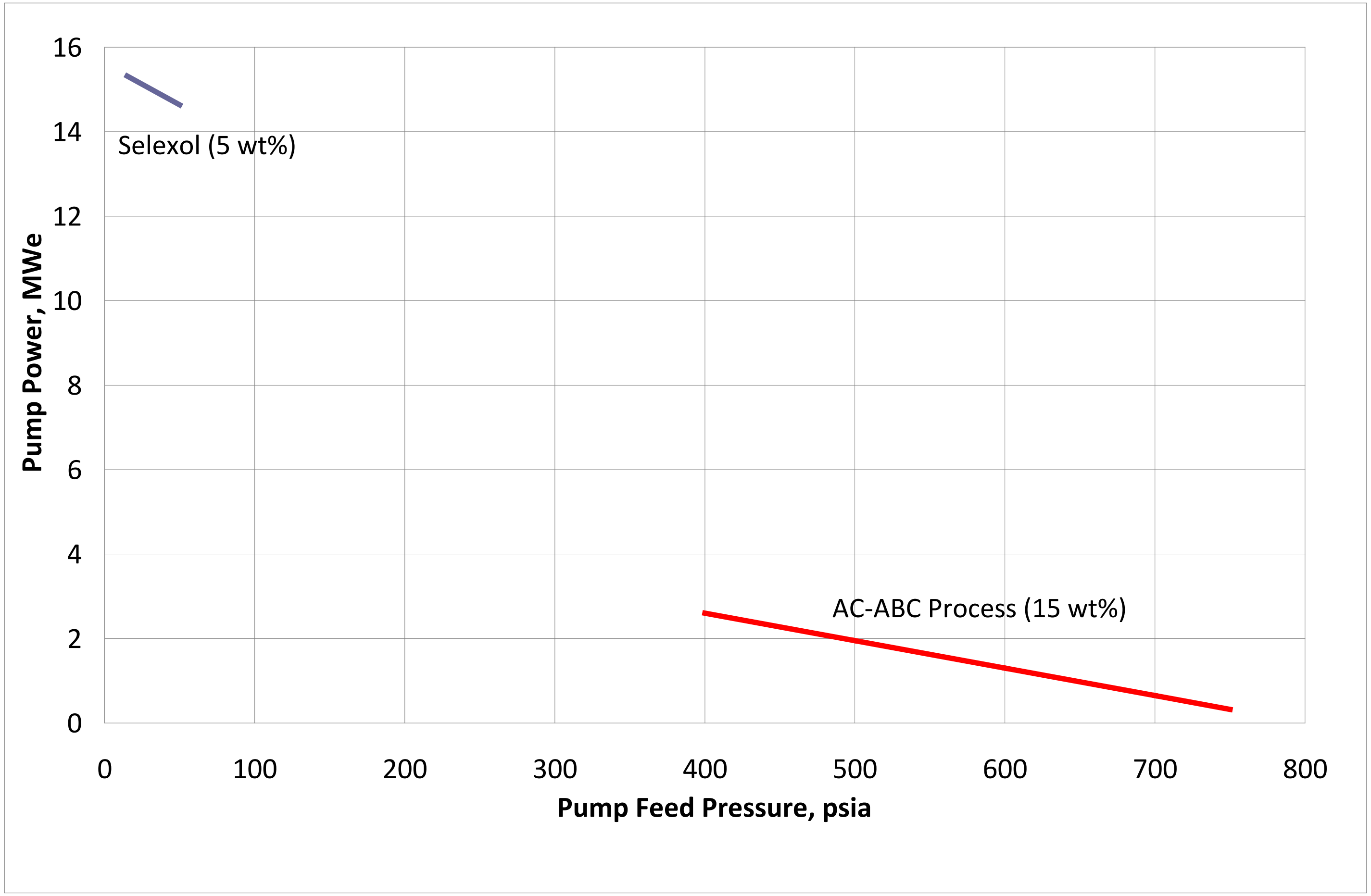
Energy Saving in Solution Recirculation



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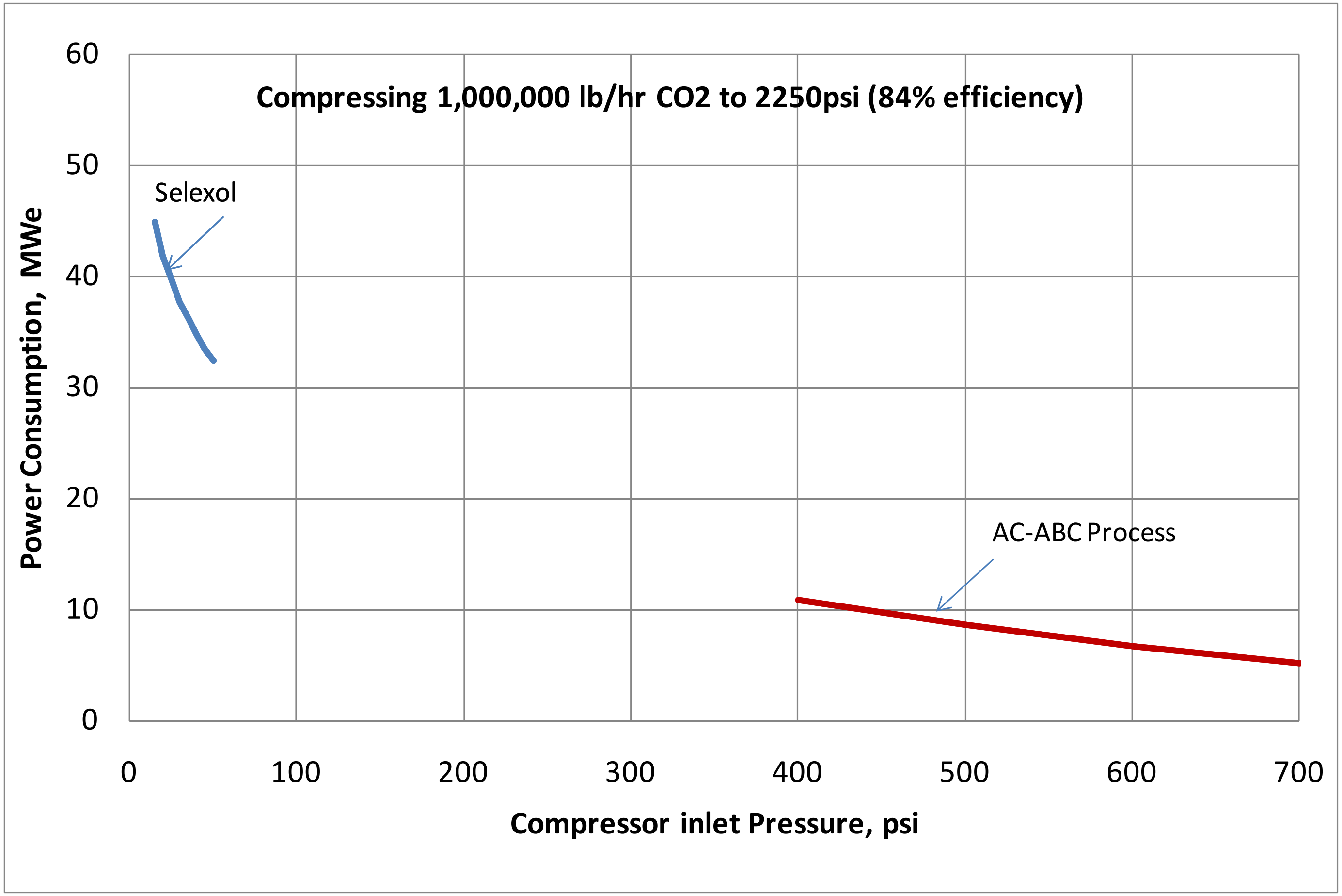
CO_2 Compression Power Saving



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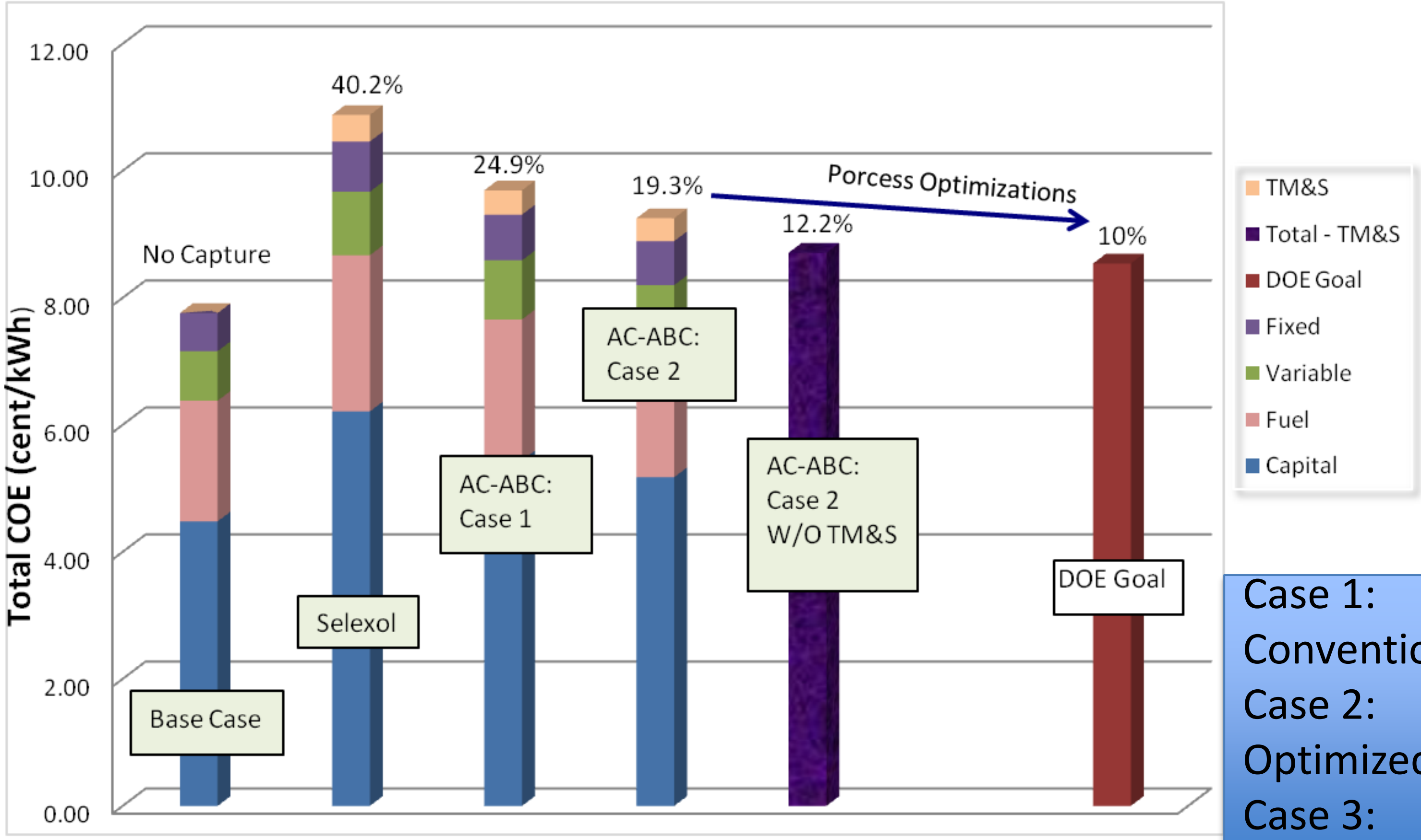
Performance and Economic Factors: Preliminary Cost of CO_2 Capture



Case 1:
Conventional Claus
Case 2:
Optimized Shift
Case 3:
High Pressure Claus

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

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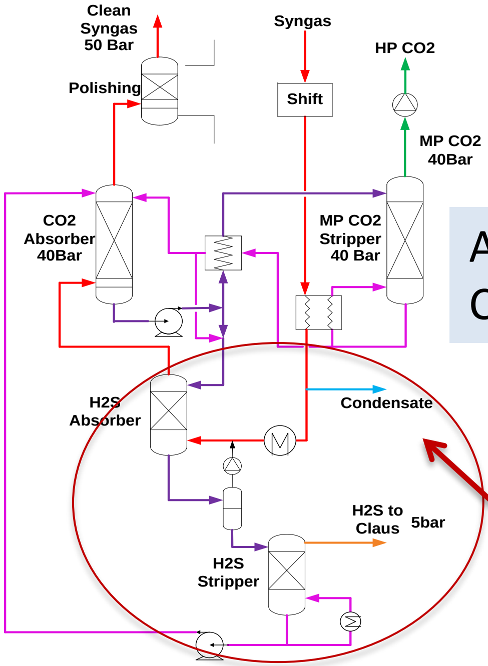
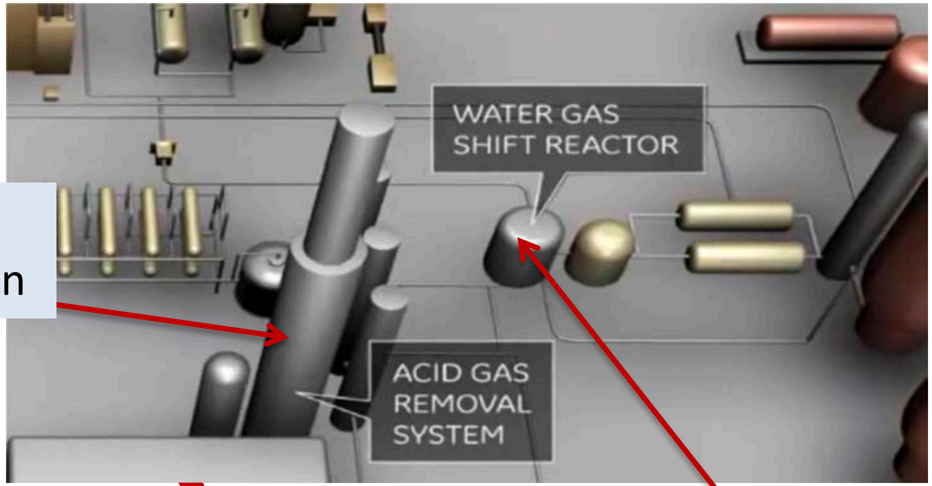
Performance Improvements to Reach The DOE Goal of 10% COE



AGR size reduction
Capital cost reduction



Lower CO_2 compression cost

Shift optimization

- Sulfur recovery from the high pressure CO_2 stream
  - No need for selective CO_2 and H_2S absorption
  - Single stage absorber for both H_2S and CO_2 Capture
  - H_2S and CO_2 regenerated together

AC-ABC: Case 3

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Bench-Sale Testing

COMPLETED

- Smooth operation of bench-scale system without fouling (20 bar, 170 C, 20 wt% loading)
- Very high levels of CO_2 and H_2S capture efficiencies (>90%)
- Rapid CO_2 absorption and regeneration
- Preliminary estimation of the cost of CO_2 capture in IGCC systems using the AC-ABC process
- Selection of the gasifier location & operator for conducting pilot-scale tests

Pilot –Scale Testing

FUTURE WORK

- 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 based on pilot-scale tests
- Continued process economic analysis
- Technology transfer to commercial sector

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Anticipated Benefits, if Successful

- Demonstration of a technology under a real-world condition in the early stages of development at a minimum cost and time.
- Potential for capturing other trace acidic compounds such as HCl vapor.
- Rapid development to a commercial scale CO_2 capture technology that has the potential to achieve the goal at an affordable cost.

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Acknowledgements

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Thank You

Menlo Park Headquarters

SRI International
333 Ravenswood Avenue
Menlo Park, CA 94025-3493
650.859.2000

Washington, D.C.

SRI International
1100 Wilson Blvd., Suite 2800
Arlington, VA 22209-3915
703.524.2053

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