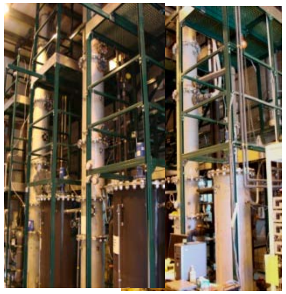
 

CO_2 Capture from IGCC Gas Streams Using the AC-ABC Process

2012 NETL CO_2 Capture Technology Meeting

July 8-12, 2012 Pittsburgh, PA.

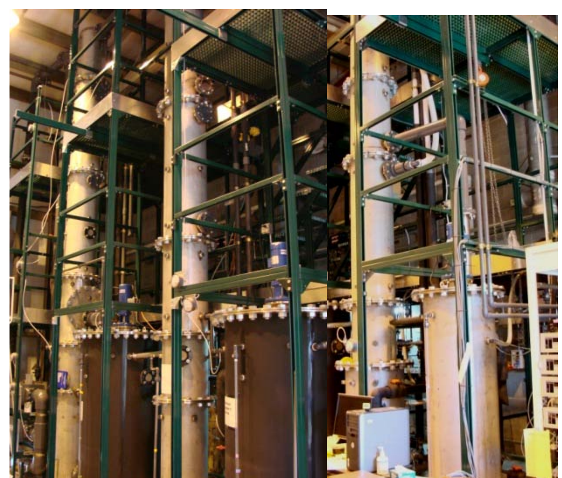
SRI- Who We Are
A world-leading independent R&D organization

- Founded by Stanford in 1946
  - Non-profit corporation; became independent in 1970
  - Name changed to SRI International in 1977
- 2,100 staff members; more than 20 locations worldwide
- 2011 revenues: ~$585 million.

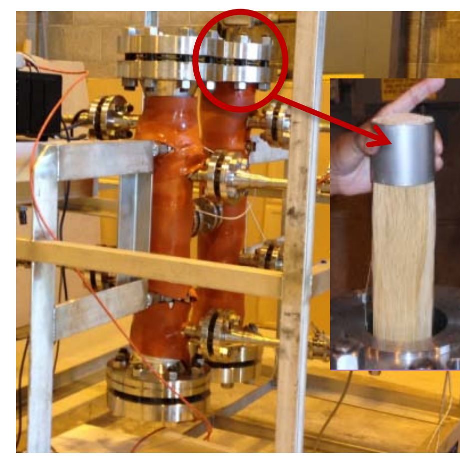
CO_2 Capture Programs at SRI

Pilot Unit for Capture of CO2 from Air

Advanced Carbon Sorbent Process Field Demonstration at U. Toledo



250 kW Chilled Ammonia Process Mini-pilot System



50 kW High Temperature PBI Membrane Skid.

Project Overview

- Project Participants:
  - SRI International.
  - Bechtel Hydrocarbon Treatment Solutions, Inc.
  - EIG, Inc.
  - National Carbon Capture Center
  - U.S. Department of Energy (National Energy Technology Center)
- Funding:
  - U.S. Department of Energy: $3,428,309
  - Cost Share (SRI and BHTS): $897,660
  - Total: $4,325,969
- Performance Dates:
  - September 2010 through September 2013.

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 with high pressure absorber and desorber.
- Specific objectives:
  - Test the technology on a bench scale batch reactor,
  - Determine the preliminary optimum operating conditions,
  - 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 Fundamentals

- Uses well-known reaction between carbon dioxide and aqueous ammonia :

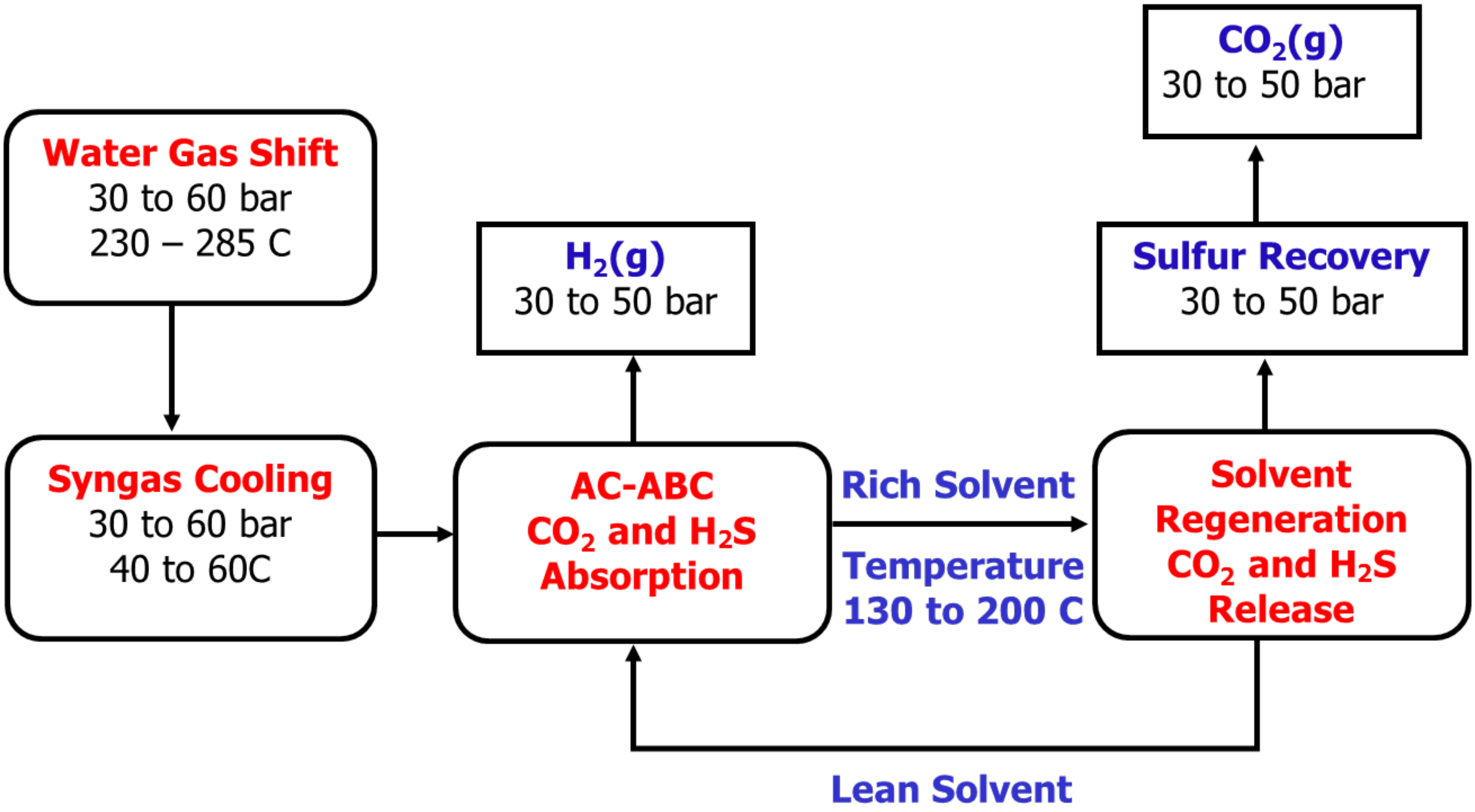
$$NH_4OH + CO_2 \leftrightarrow NH_4HCO_3$$

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

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

- Reactions are reversible
  - Absorption reactions at lower temperature
  - Desorption reactions at higher temperature
- High pressure operation enhances absorption of CO_2.
- A similar set of reactions occur between H_2S and ammoniated solution.
- H_2S from the regenerated gas is converted to elemental sulfur at high pressures.

Process Block Flow Diagram



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 (40 bar) at <200°C:
  - The size of CO_2 stripper, the number of stages of CO_2 compression, and the electric power for compression of CO_2 to the pipeline pressure are reduced.
- High net CO_2 loading, up to 20% by weight.
- The stripper off-gas stream, containing primarily CO_2 and H_2S, is treated in the BPSC process to remove the sulfur

Process Advantages

- Low cost and readily available reagent (aqueous ammonia).
- Reagent is chemically stable under the operating conditions.
  - Ammonia does not decompose under the operating conditions.
- High efficiency for CO_2 capture
  - Reduces water-gas shift requirements - Reduced steam consumption.
- No loss of CO_2 during sulfur recovery
  - High pressure conversion; No tail gas treatment
- 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.
- Process can be applied to existing and new IGCC power plants.

Project Tasks

Task 1: Bench-scale Batch Tests:

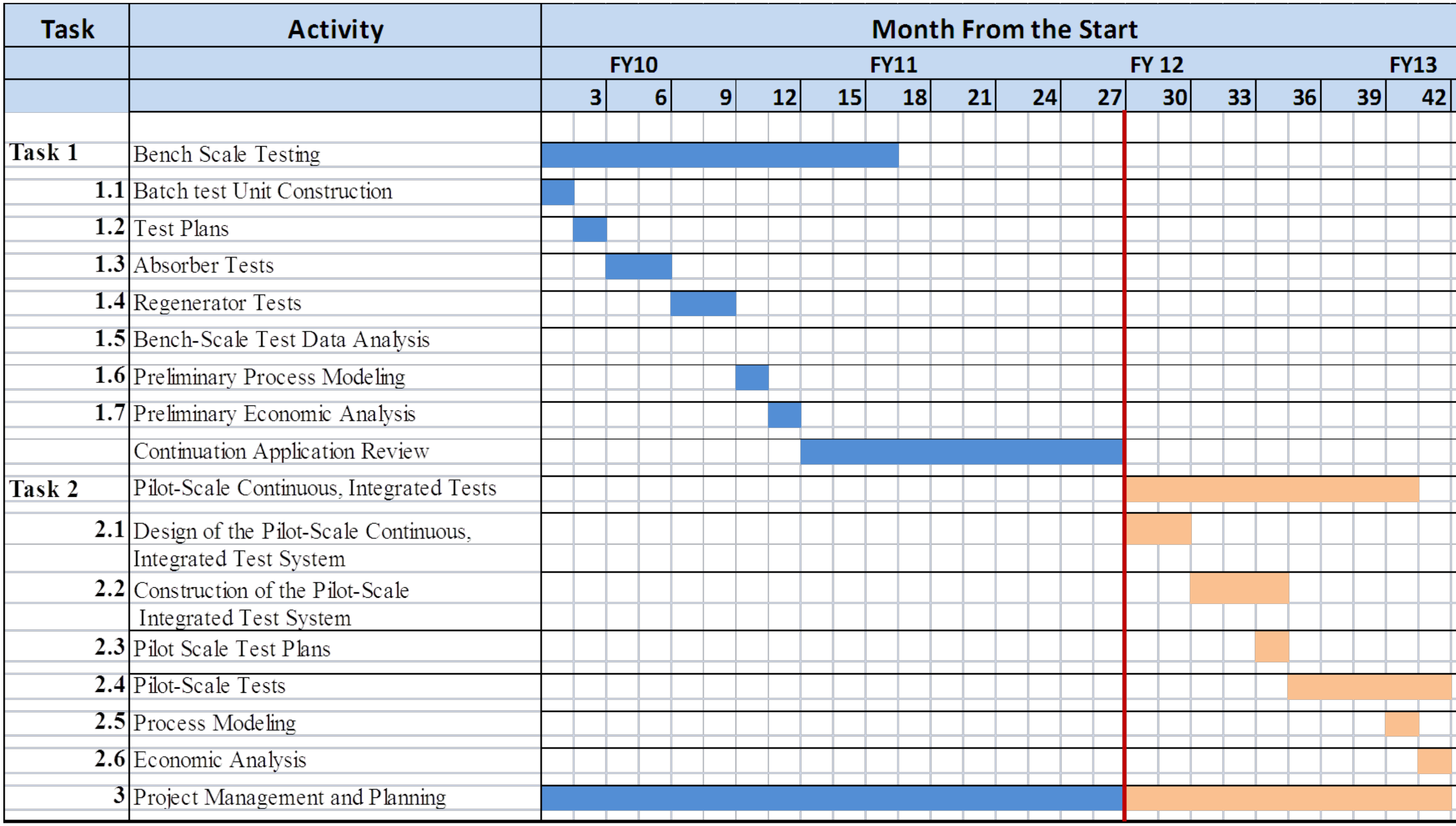
- Results were presented at 2011 NETL Carbon Capture Technology Conference

Task 2: Pilot-Scale Integrated, Continuous Tests

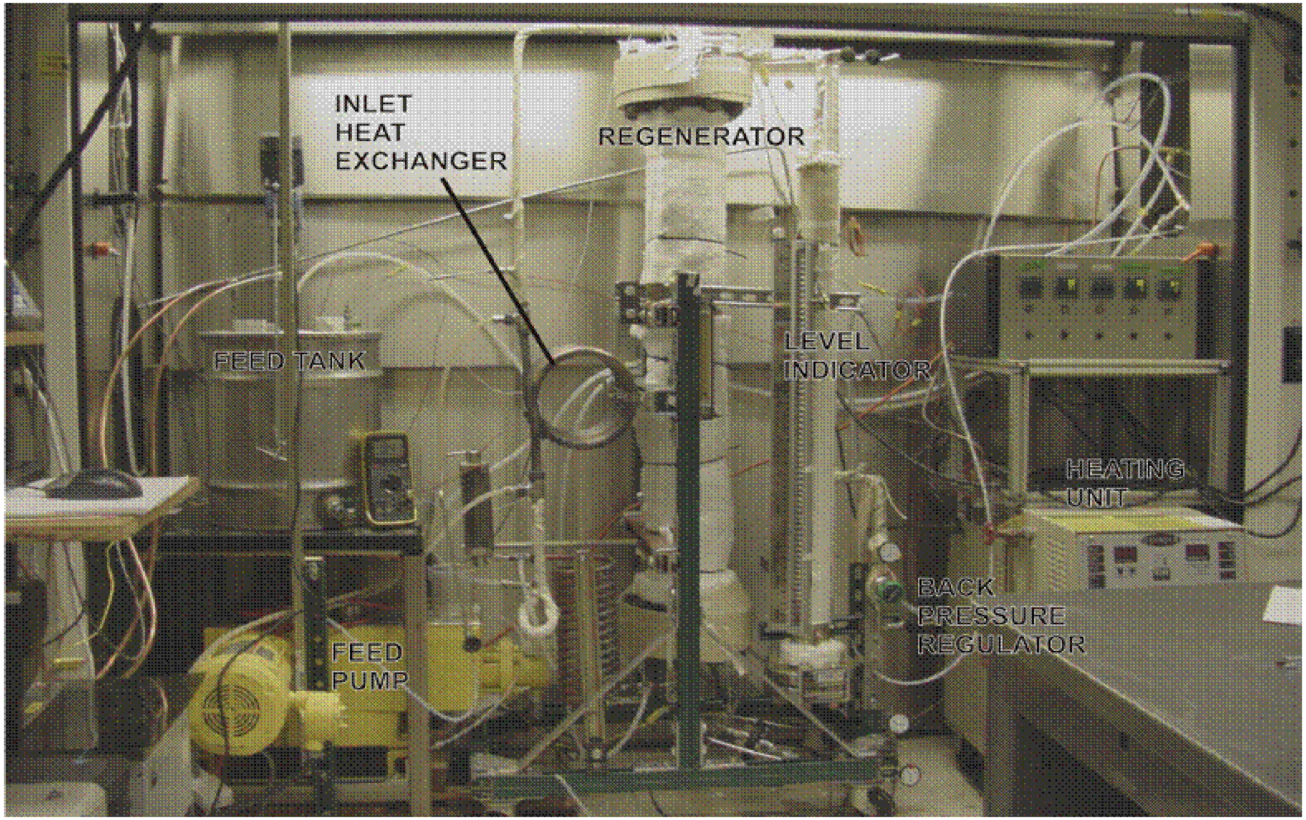
- Focus of the current effort (July 2012 through September 2013)

Task 3: Project Management

Project Schedule



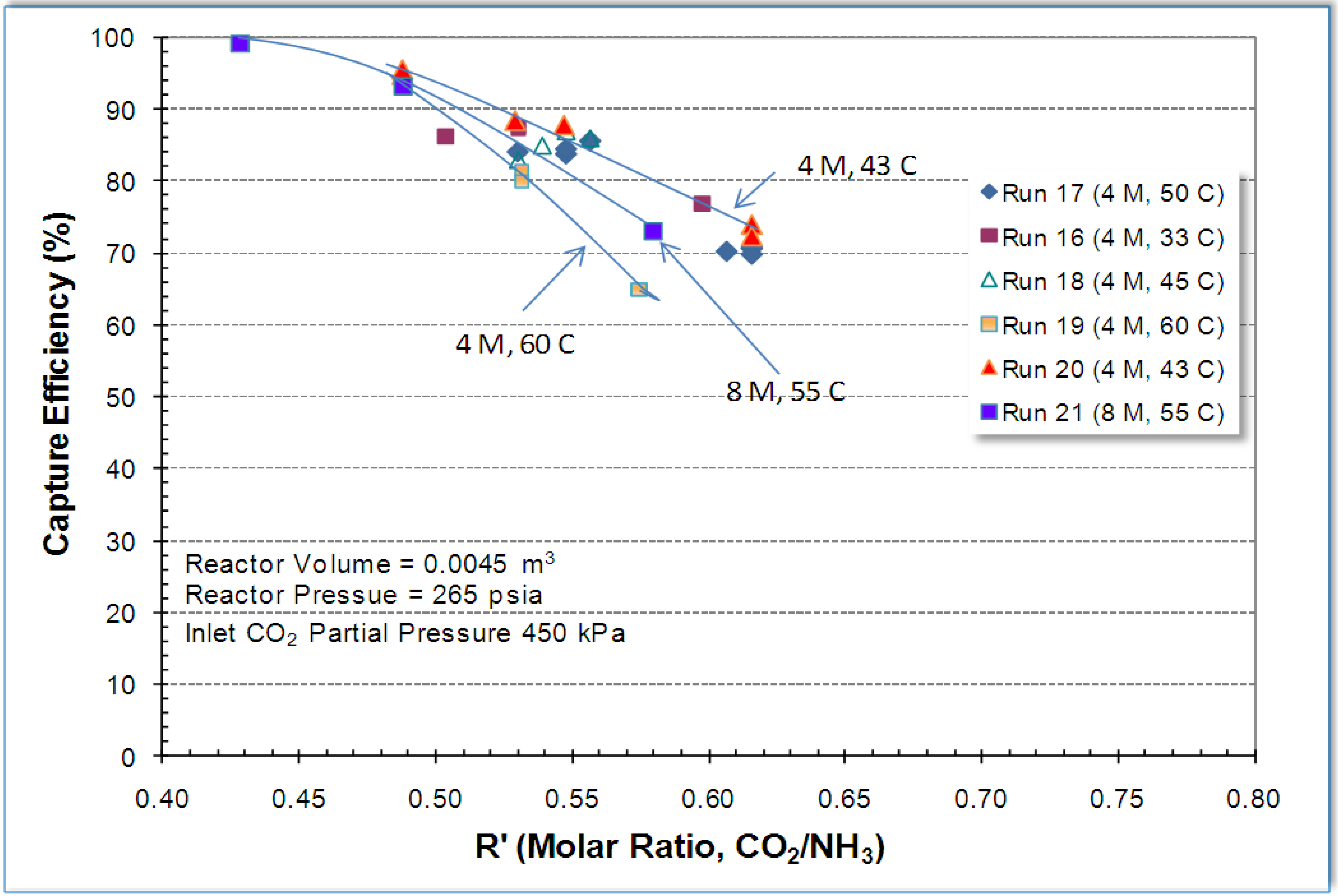
Bench-Scale Regenerator Testing



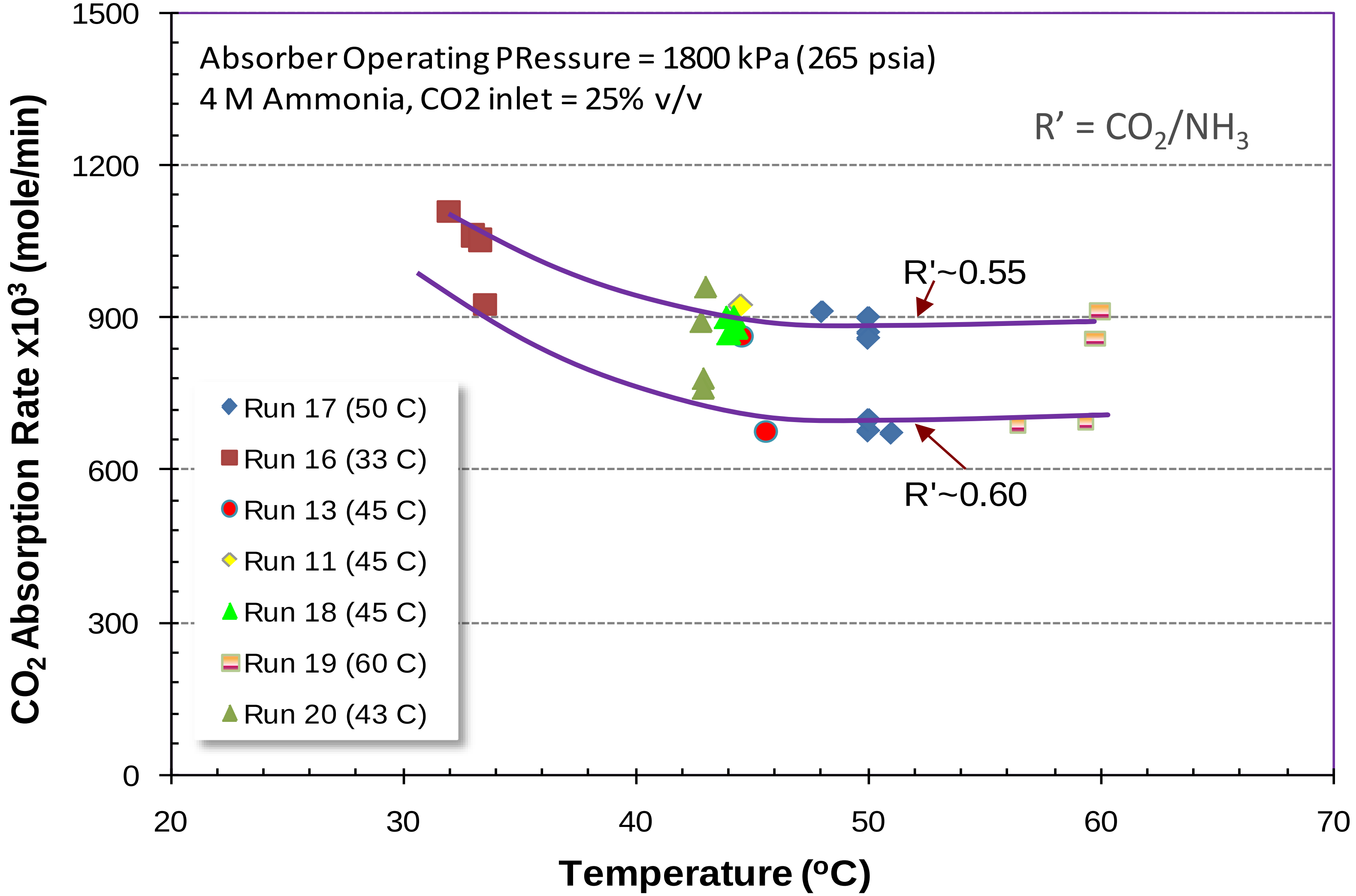
T: 100 - 170 C
P: 10-40 bar
Feed CO_2 Loading: 10-20 wt%

CO_2 Capture Efficiency vs Solution Composition

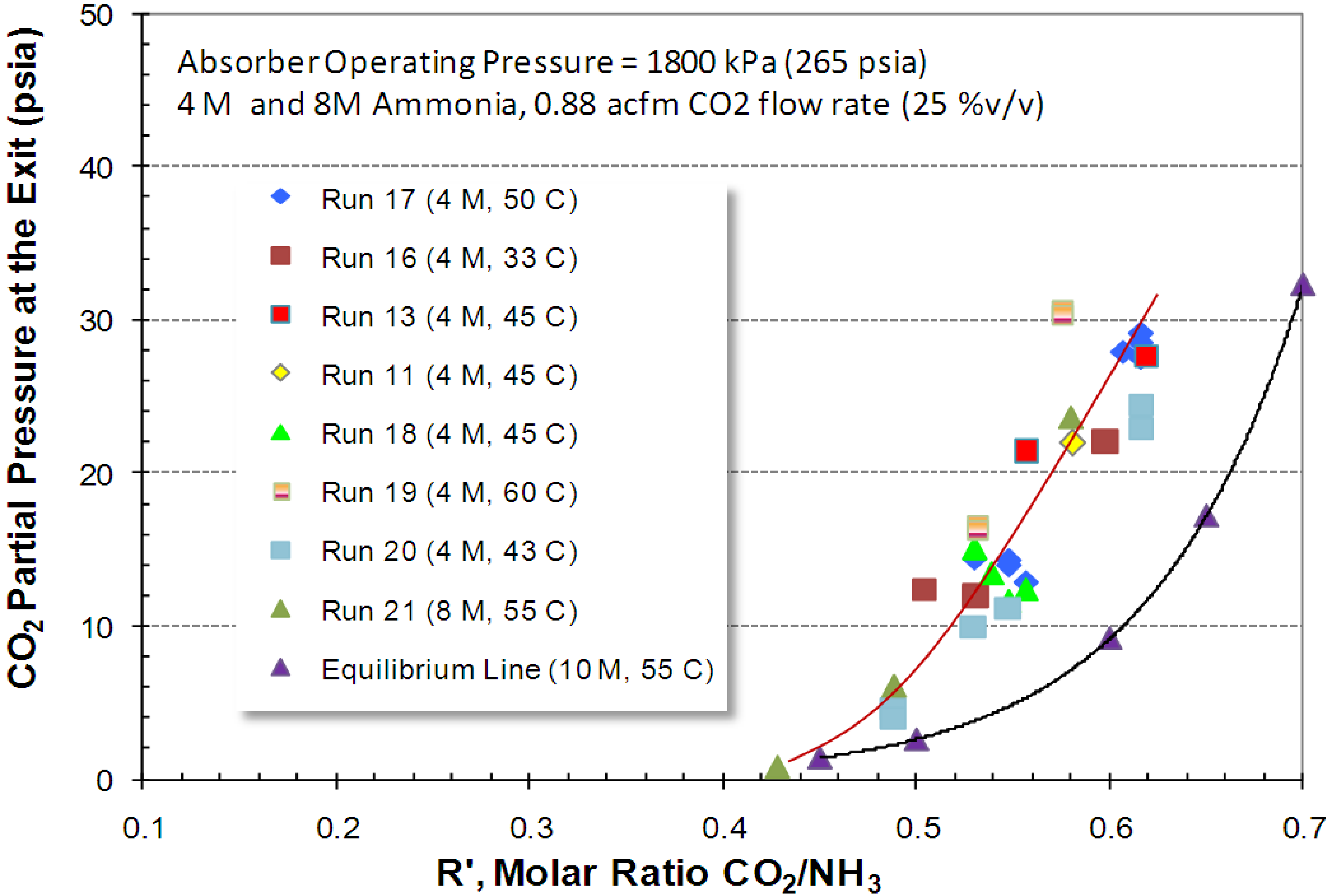
CO_2 Capture Efficiency Exceeds 90%



No Significant Decrease in the Rate of Absorption at Elevated Temperatures

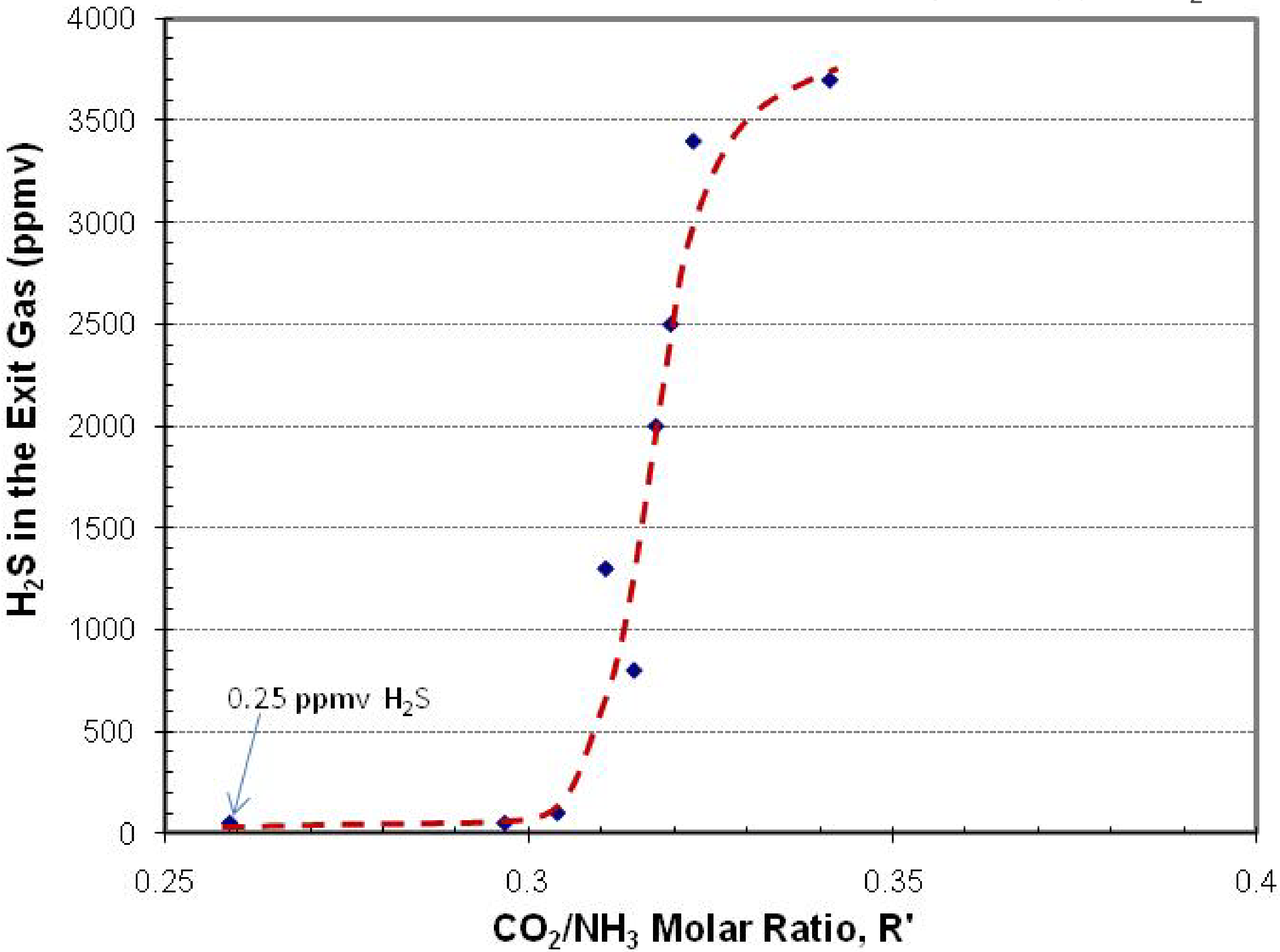


Rapid Rate of Reactions Approaching Equilibrium

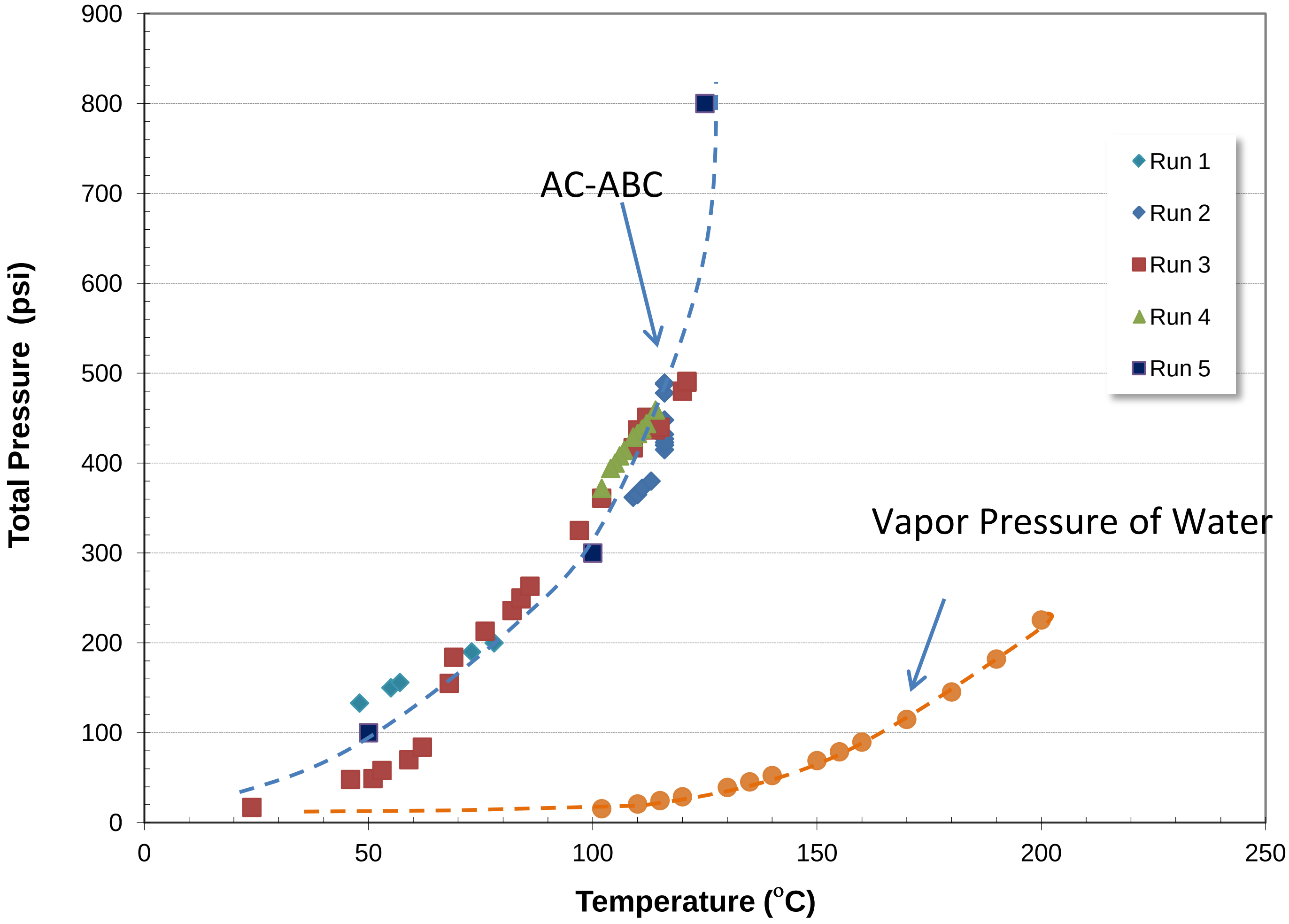


High Efficiency of H_2S Capture

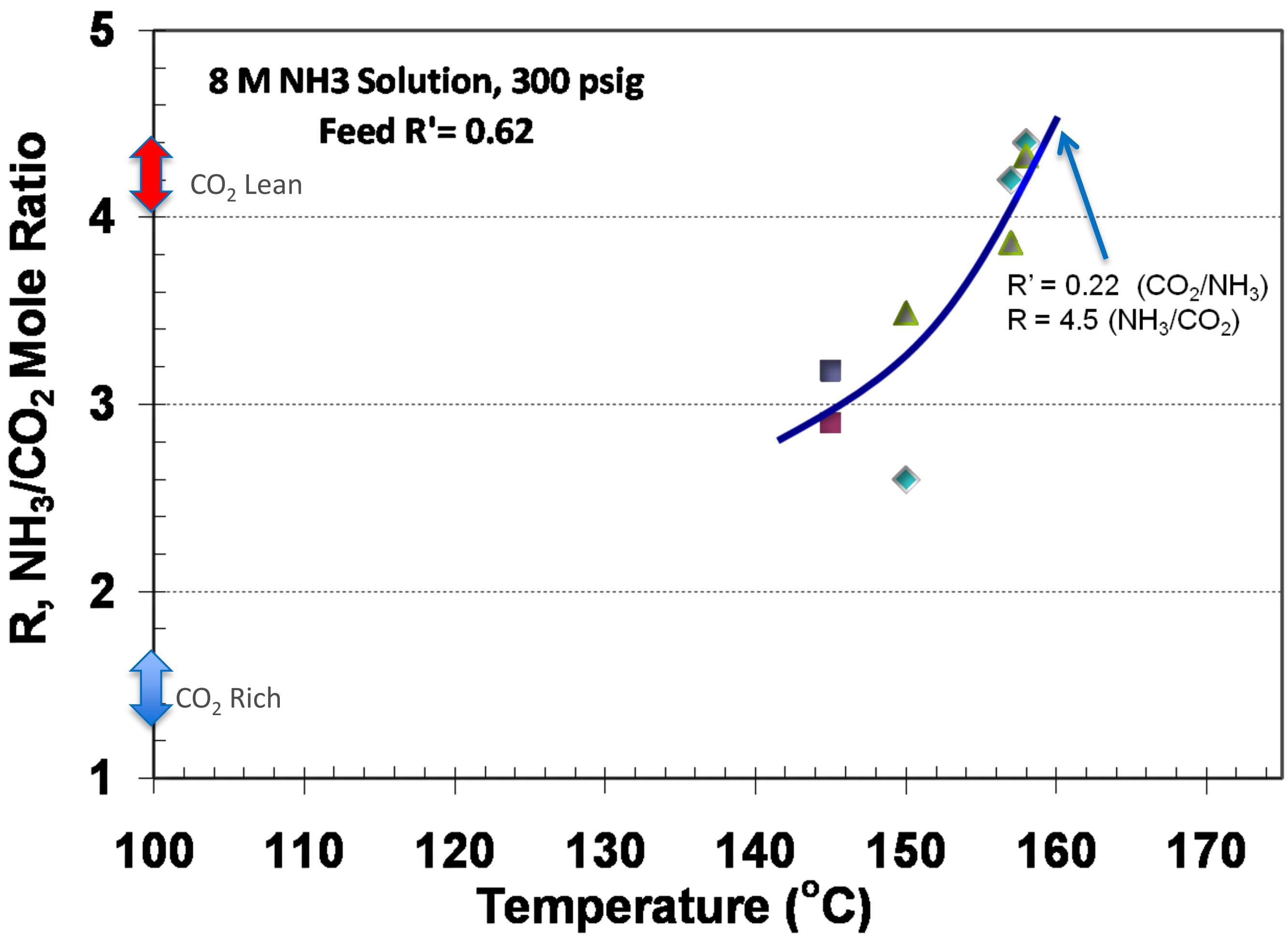
Target < 1 ppmv H_2S



Measured CO_2 Attainable Pressure Function of Temperature



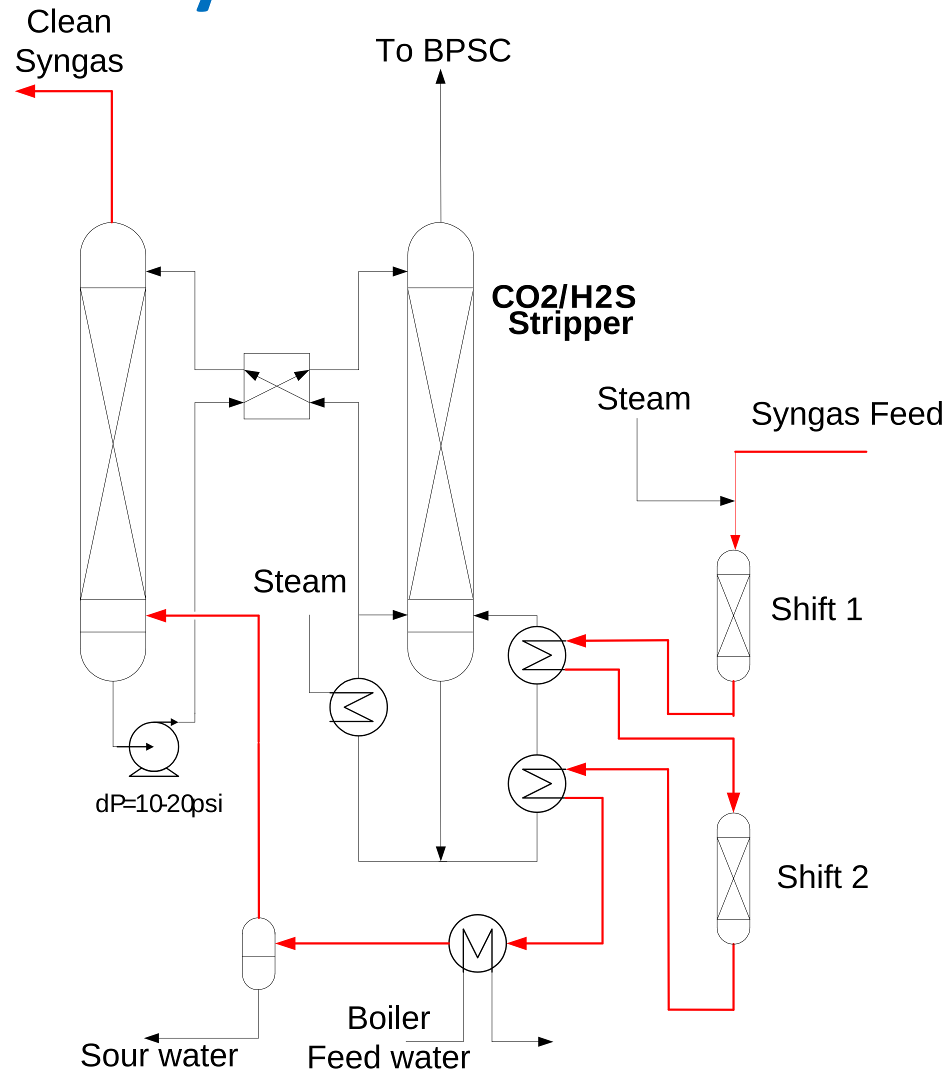
High Levels of Solvent Regeneration at Moderate Temperatures



Target R Value: >4

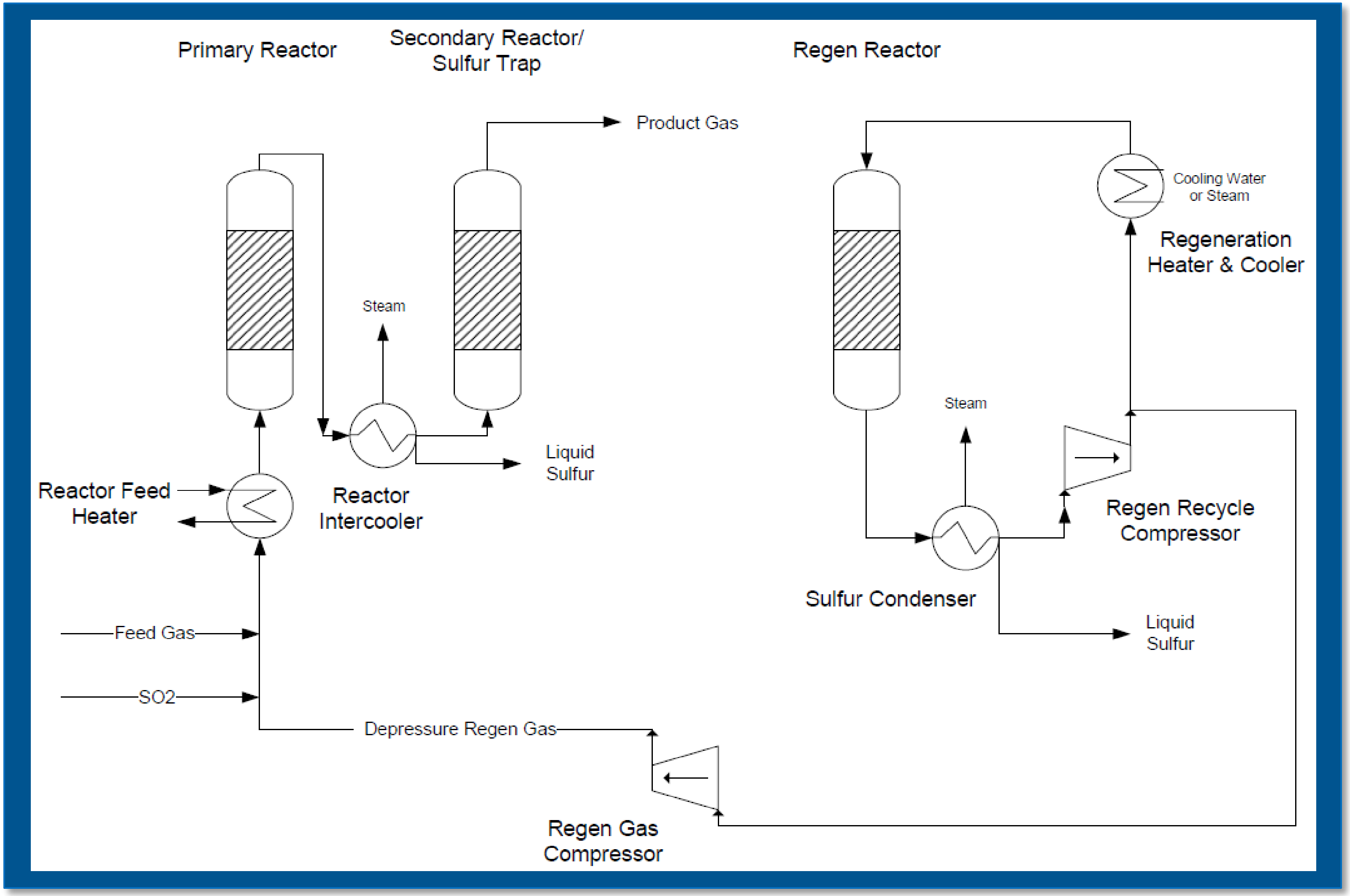
Technical and Economic Analysis

- 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.

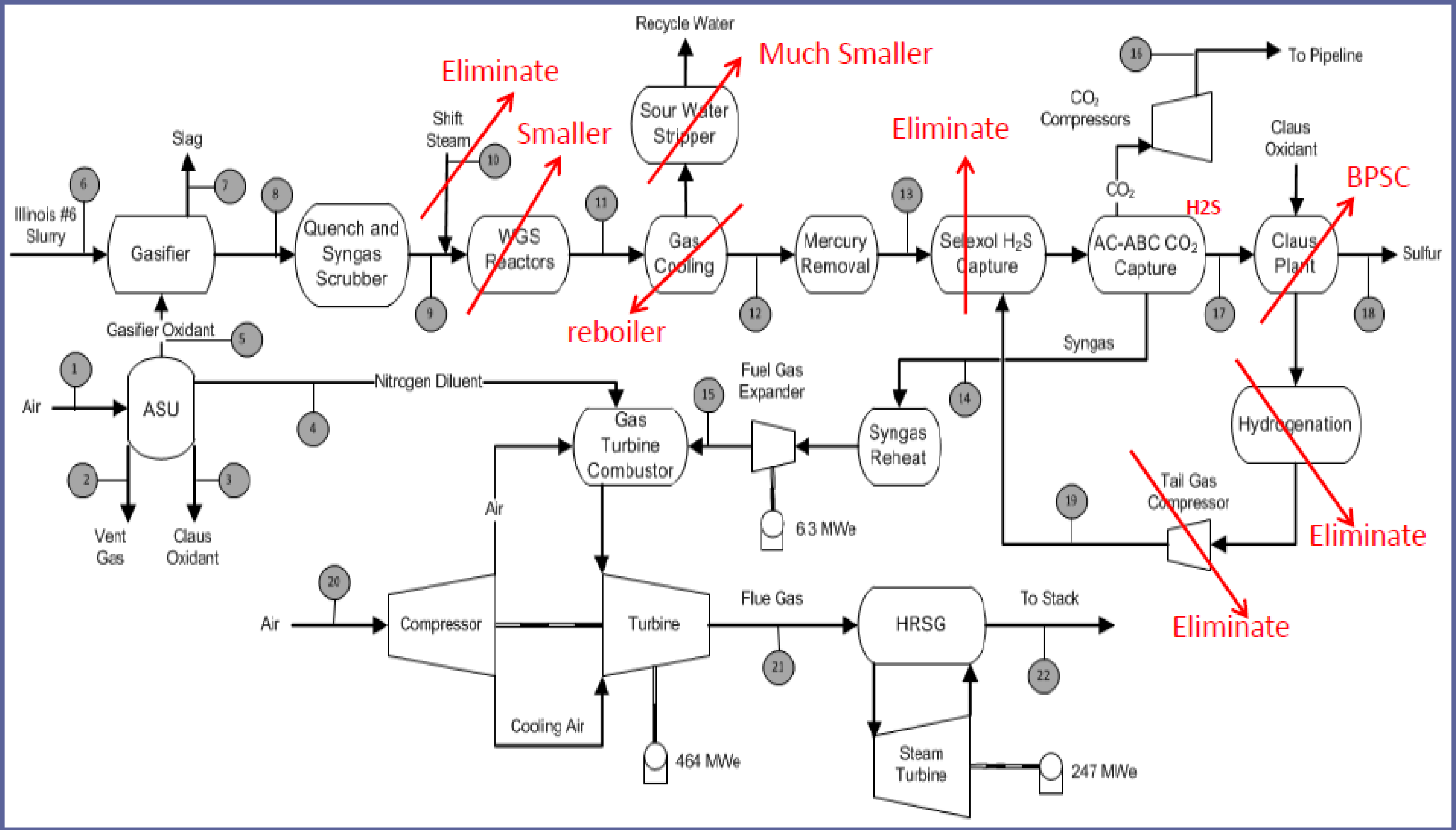


Process Energy Requirements: CO_2 stripping, solution pumping, and CO_2 compression

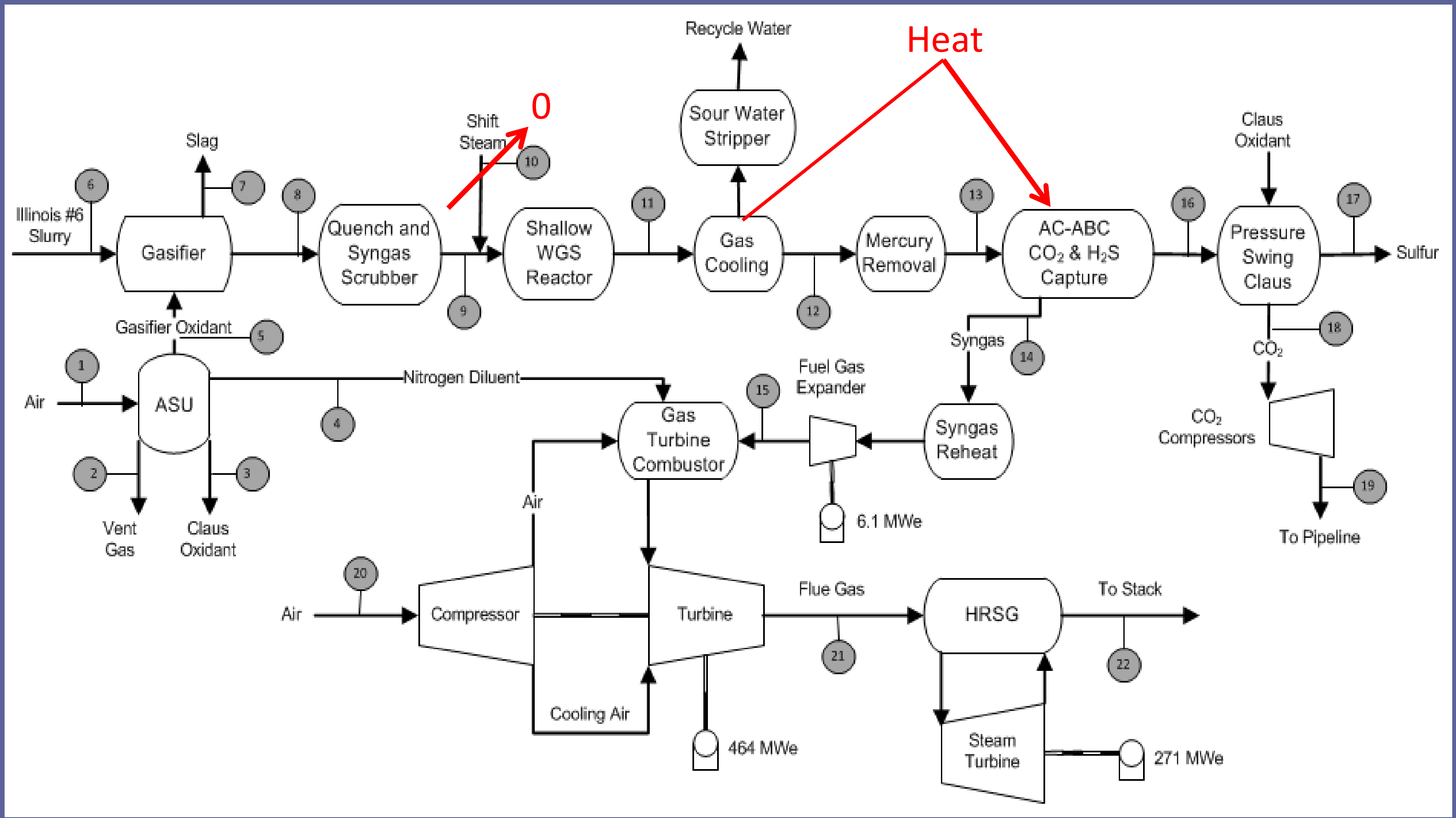
Bechtel High-Pressure Claus Process



AC-ABC and BPSC Process Changes to IGCC Reference Case



IGCC with AC-ABC for CO2/H2S capture with BPSC



DOE Economic Analysis

Presented at 11th Annual Conference on CCUS

Economic Analysis (June 2011$)	IGCC with SRI AC-ABC and BPSC	Reference Case
Total Plant Cost, before Owner's Costs, million	$1,676	$1,785
Total Plant Cost, before Owner's Costs	$2,962/kW	$3,286/kW
Initial Chemical Fill Cost, million	$4.3	$15.9
Annual Fixed O&M Cost, million	$64.5	$68.0
Annual Variable O&M Cost, million	$42.4	$45.9
Total Annual O&M Cost, million	$106.9	$113.9
FY COE* without TS&M**	$108.28	$118.85
FY COE with TS&M	$113.33	$124.04

*FY COE = First Year Cost of Electricity

**TS&M = Transport, Storage, and Monitoring

Plant Performance Summary

DOE Presentation at 11th Annual Conference on CCUS

Plant Performance	Units	IGCC with SRI AC-ABC and BPSC	Reference Case
Gas Turbine Power	MWe	464.0	464.0
Syngas Expander Power	MWe	5.7	6.5
Steam Turbine Power	MWe	246.2	263.5
Auxiliary Load	MWe	150.0	190.8
Net Plant Power	MWe	565.9	543.3
Net Plant Efficiency (HHV)	-	33.7%	32.6%
Net Plant Heat Rate (HHV)	kJ/kWh Btu/kWh	10,679 10,122	11,034 10,458

Anticipated Benefits, if Successful

- We estimate a 22.7 MW improvement in Net Plant Power and a 1.1 percentage point increase in Net Plant Efficiency (HHV basis) than a reference plant (GE gasifier with Selexol AGR and conventional Claus).
- The capital cost is ~6% less expensive than the reference plant on an absolute basis.
- The COE is 9% lower for the SRI AC-ABC and BPSC plant relative to the reference case.
- The process configuration is economically viable per this analysis.
- The project will be tested in this Budget Period in an operating gasifier environment that will lead to further system improvements.

Acknowledgement

- SRI International
  - Gopala Krishnan – Associate Director (MRL) and Principal Investigator
  - Indira Jayaweera, Jordi Perez, Anoop Nagar, Daniel Steel and Esperanza Alavarez
  - Angel Sanjurjo – Materials Research Laboratory Director and Project Supervisor
- EIG: Eli Gal
- Bechtel Hydrocarbon Treatment Solutions:
  - Lee Schmoe and Martin Taylor
- National Carbon Capture Center: Frank Morton and Tony Wu
- DOE-NETL
  - Elaine Everett, Megan Napoli, Susan Maley, Jenny Tennent, James Black, Peter Kabateck

Thank You

Headquarters: Silicon Valley

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

Princeton, New Jersey

SRI International Sarnoff
201 Washington Road
Princeton, NJ 08540
609.734.2553

Additional U.S. and international locations

www.sri.com