SRI International

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

2014 NETL CO_2 Capture Technology Meeting

July 31, 2014 Pittsburgh, PA.

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:
  - October 2009 through September 2014.

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 stripper.
- Specific objectives and project status:
  - Test the concept on a bench scale batch reactor (completed)
  - Determine the preliminary optimum operating conditions (completed)
  - Design and build a small pilot-scale reactor capable of continuous integrated operation (Design completed; Equipment procurement and assembly in progress, Hazop analysis completed).
  - Perform tests to evaluate the process in a coal gasifier environment (in progress)
  - Perform a technical and economic evaluation on the technology (Updates are in progress).

Process Fundamentals

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

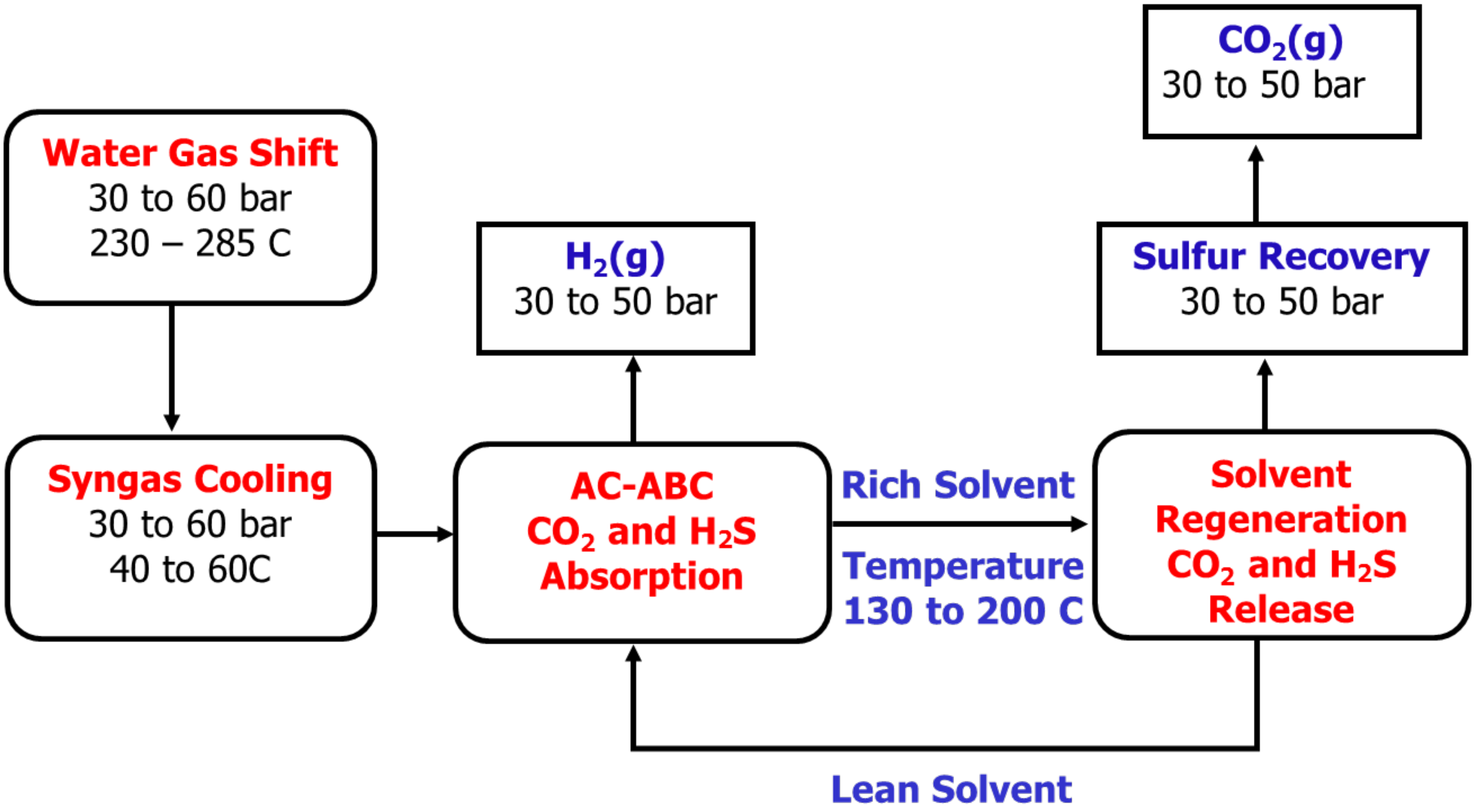
$$NH_4OH + CO_2 \leftrightarrow NH_4HCO_3$$

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

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

- 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



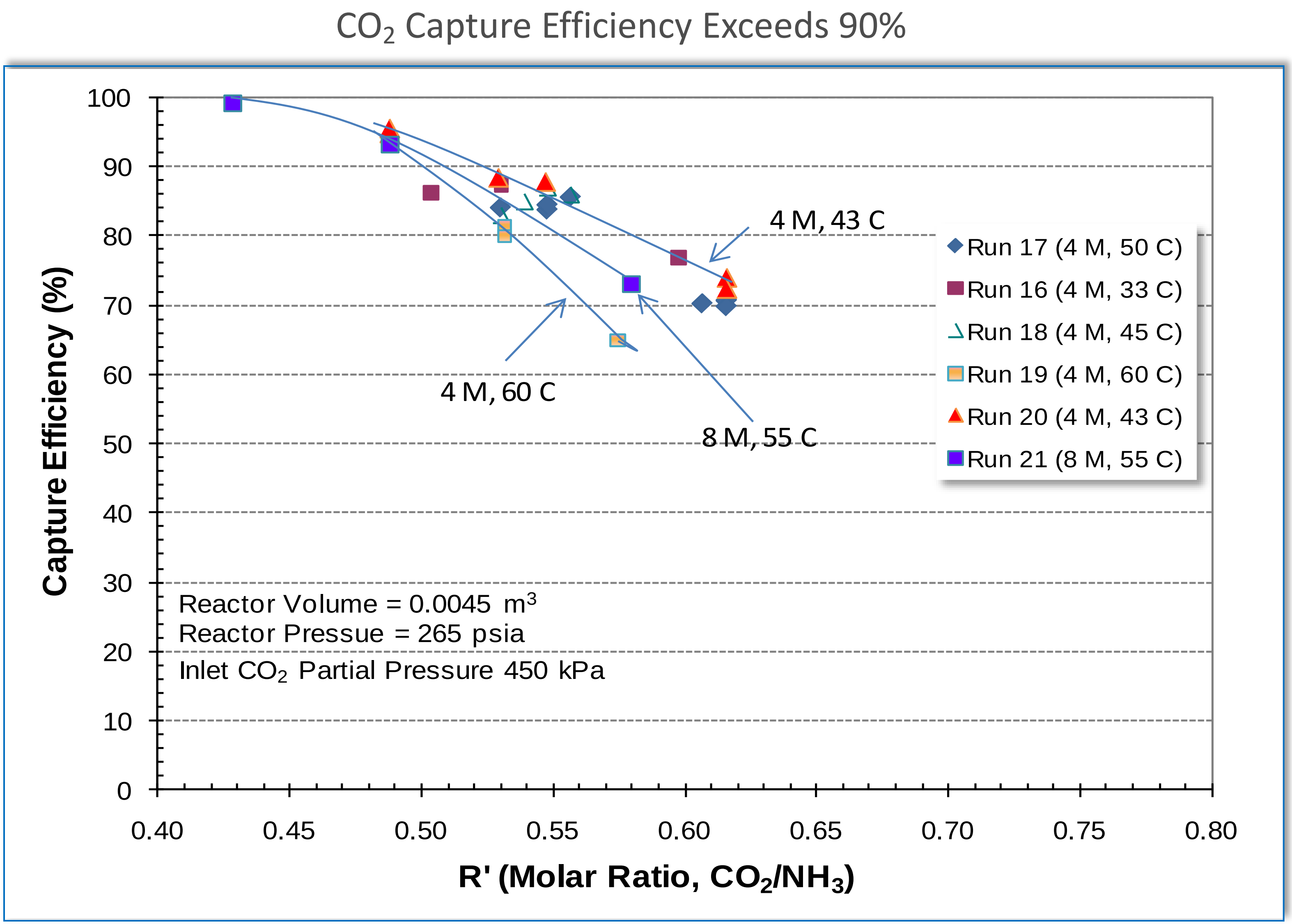
Process Highlights

- Concentrated ammoniated solution is used to capture both CO_2 and H_2S from syngas at high pressure.
- Absorber operation at 40^o-60^o C temperature; No refrigeration is needed.
- CO_2 is released at high pressures (30 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 using a high pressure Claus process, invented by Bechtel, to form elemental sulfur.
  - CO_2 is retained at high pressures.

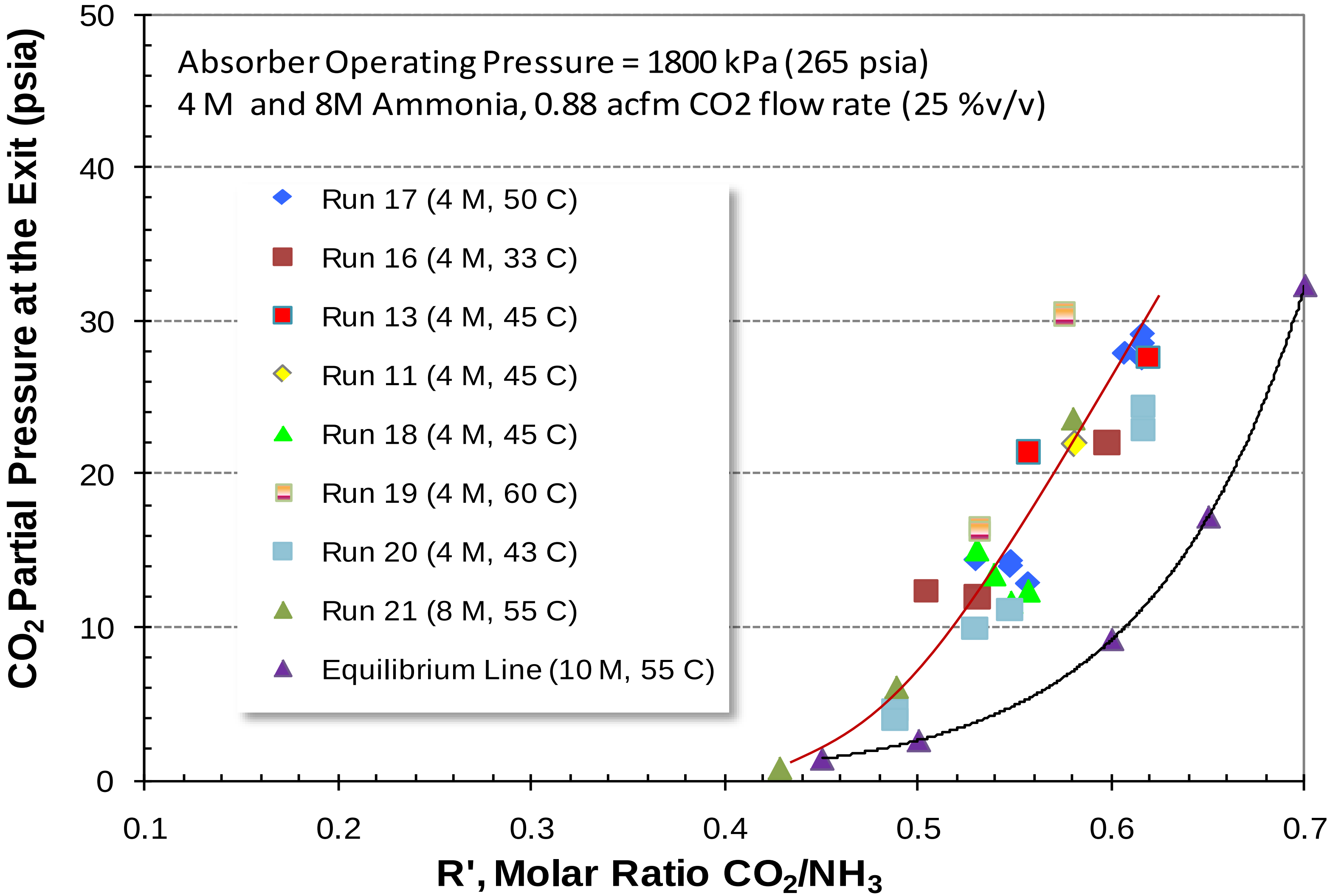
Process Advantages

- 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.

CO_2 Capture Efficiency vs Solution Composition

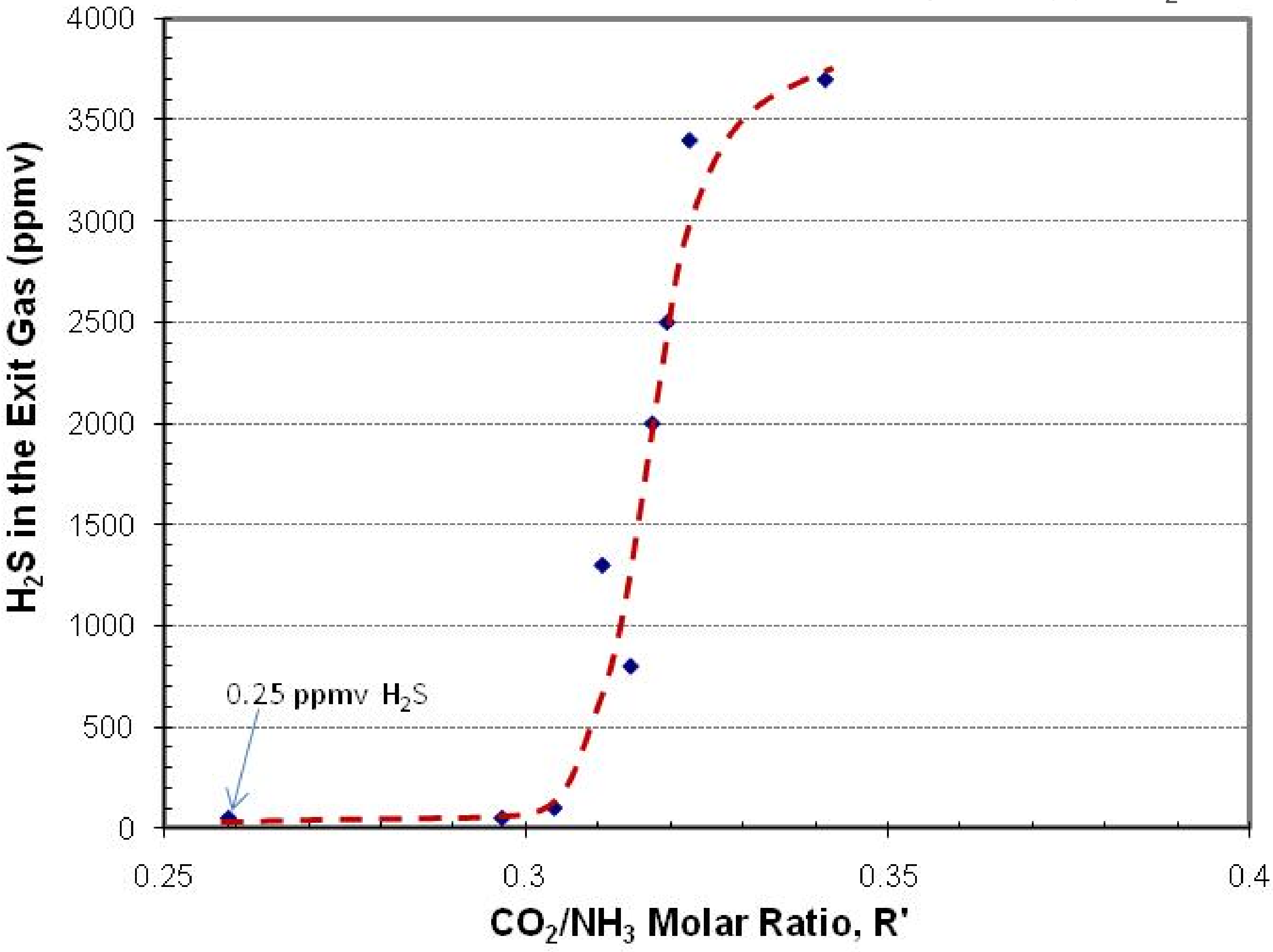


Rapid Rate of Reactions Approaching Equilibrium

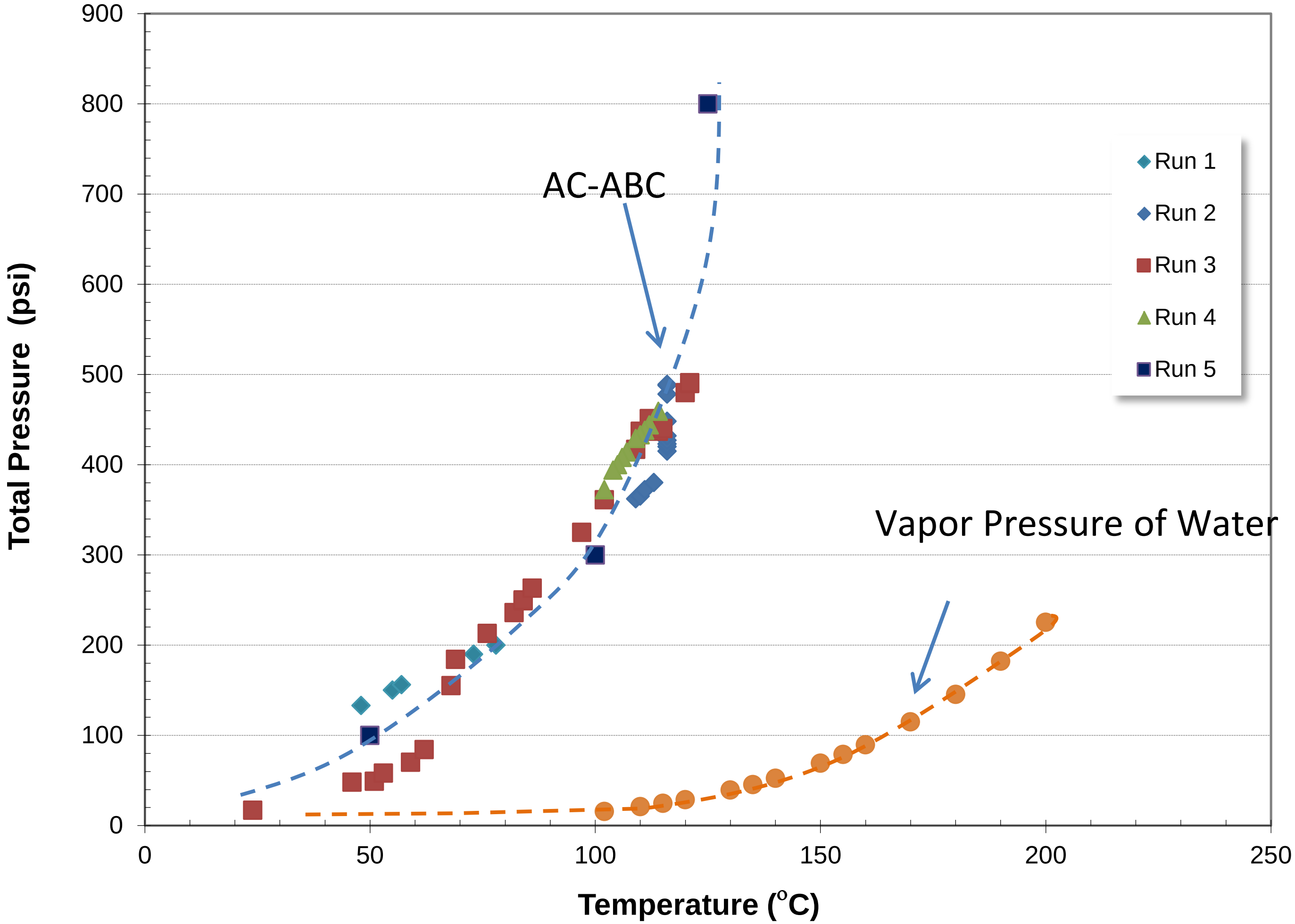


High Efficiency of H_2S Capture

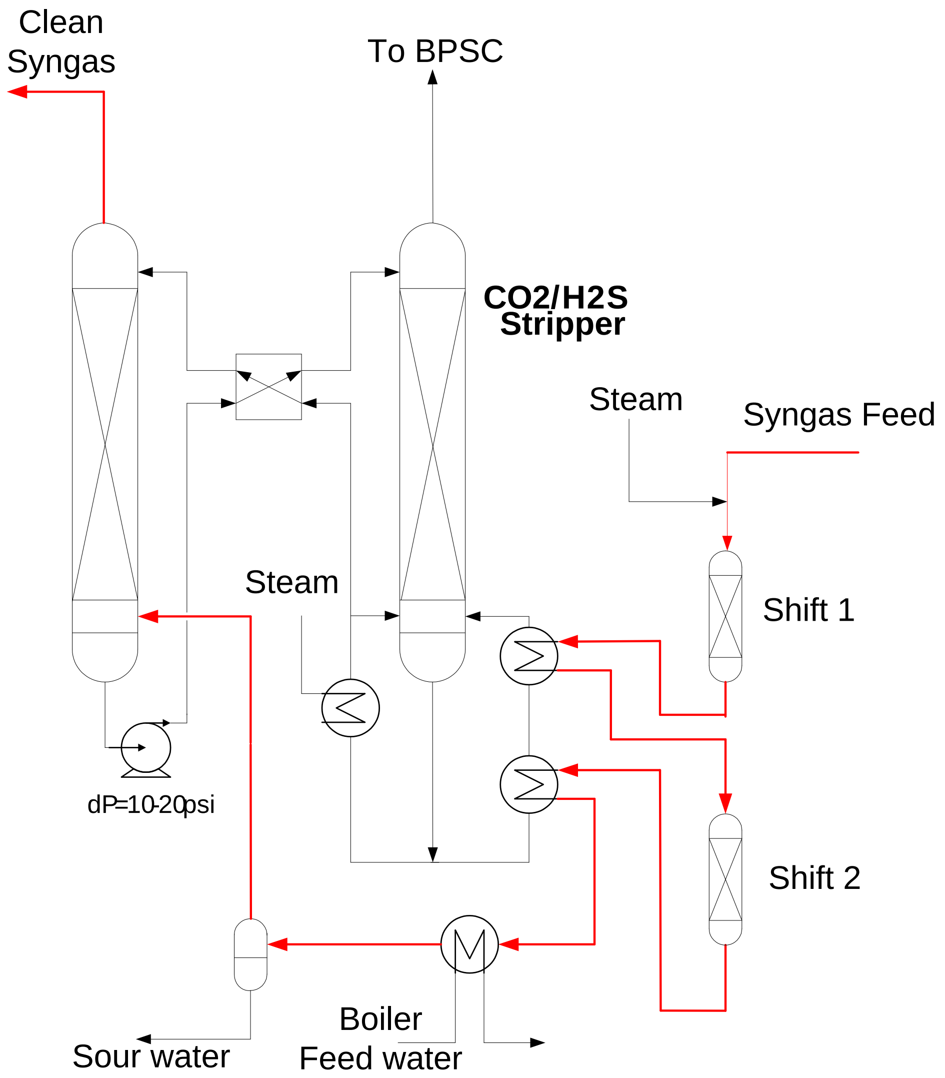
Target < 1 ppm H_2S



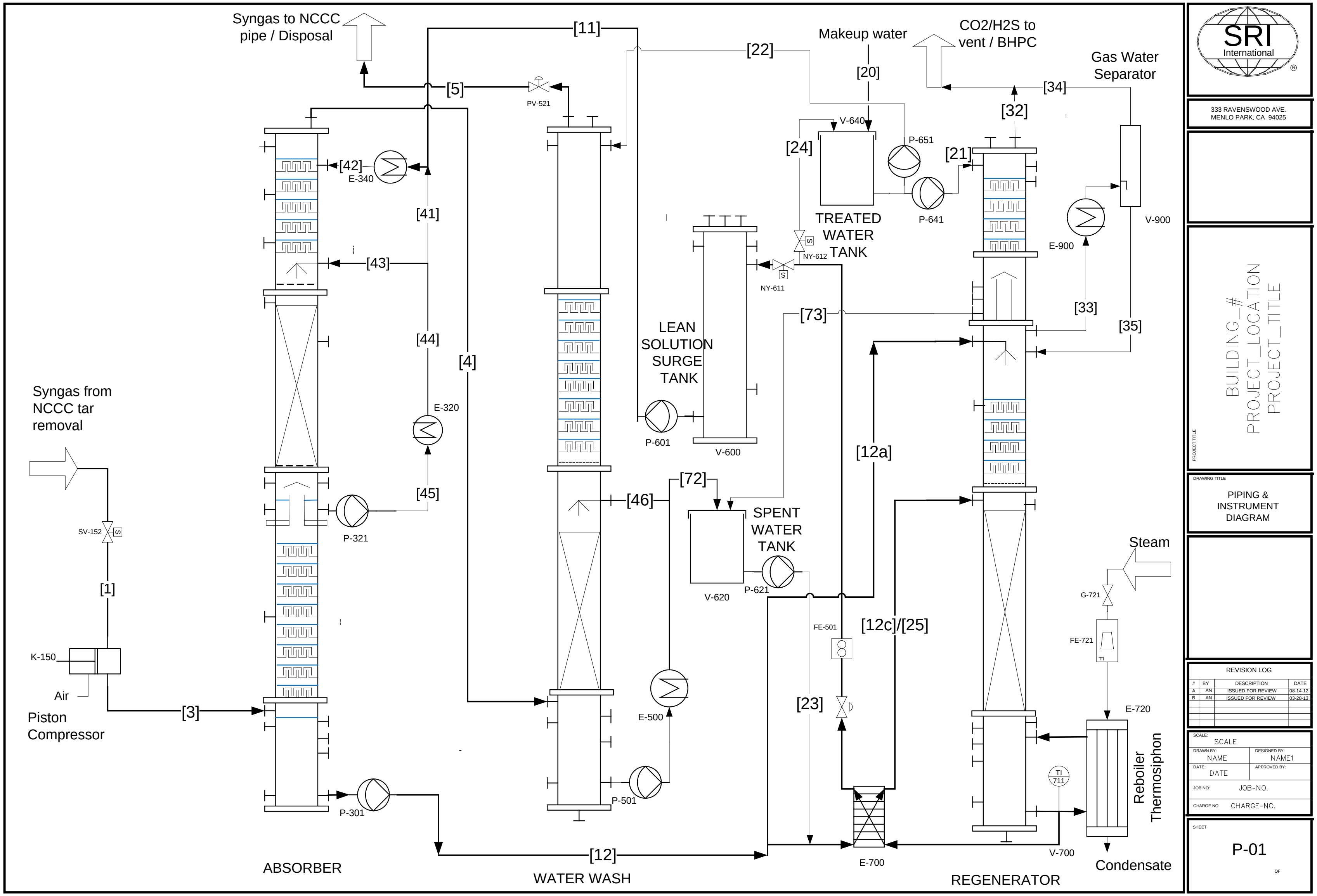
Measured CO_2 Attainable Pressure Function of Temperature



AC-ABC Process Schematic



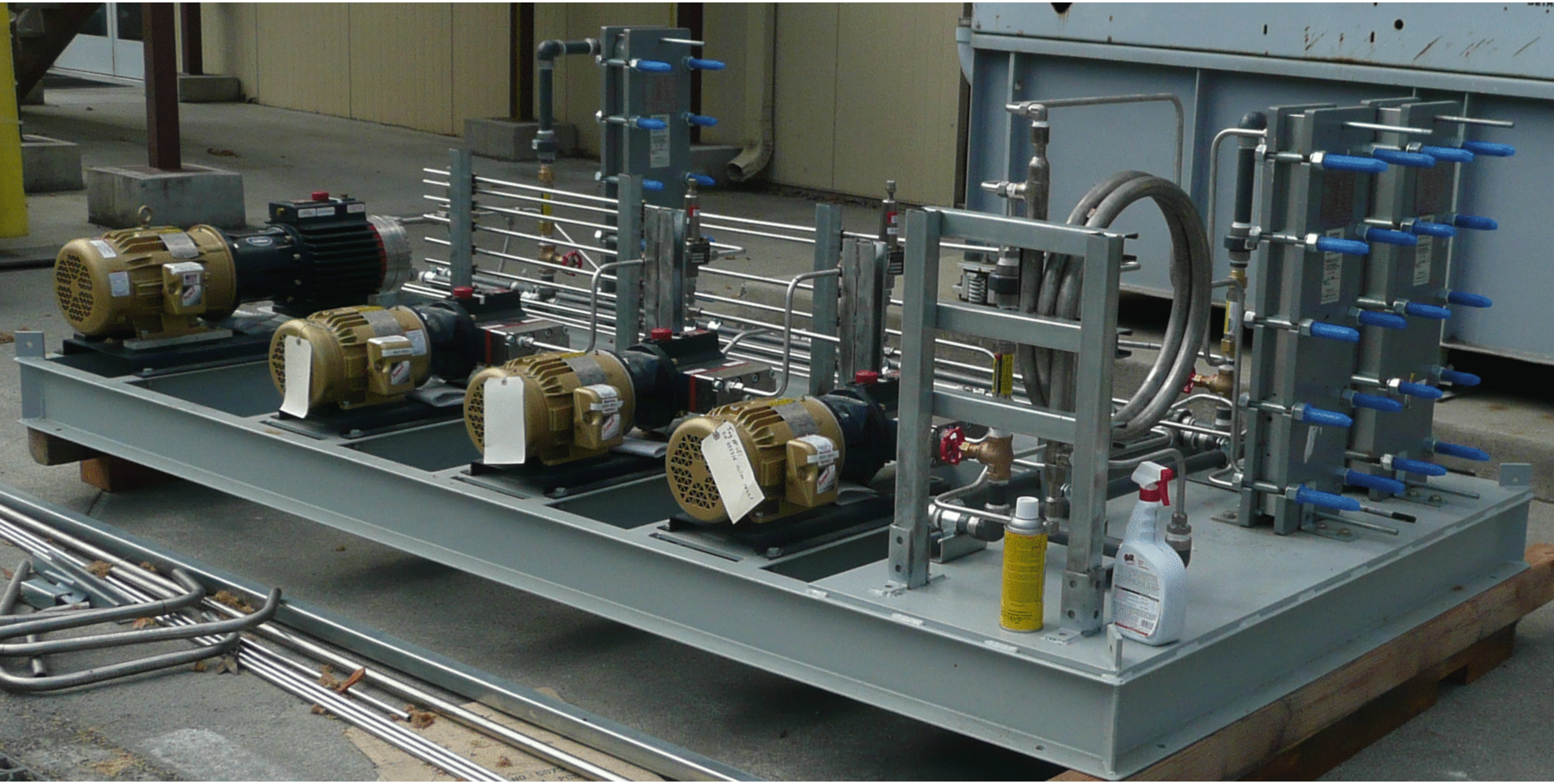
P & ID for the NCCC Test



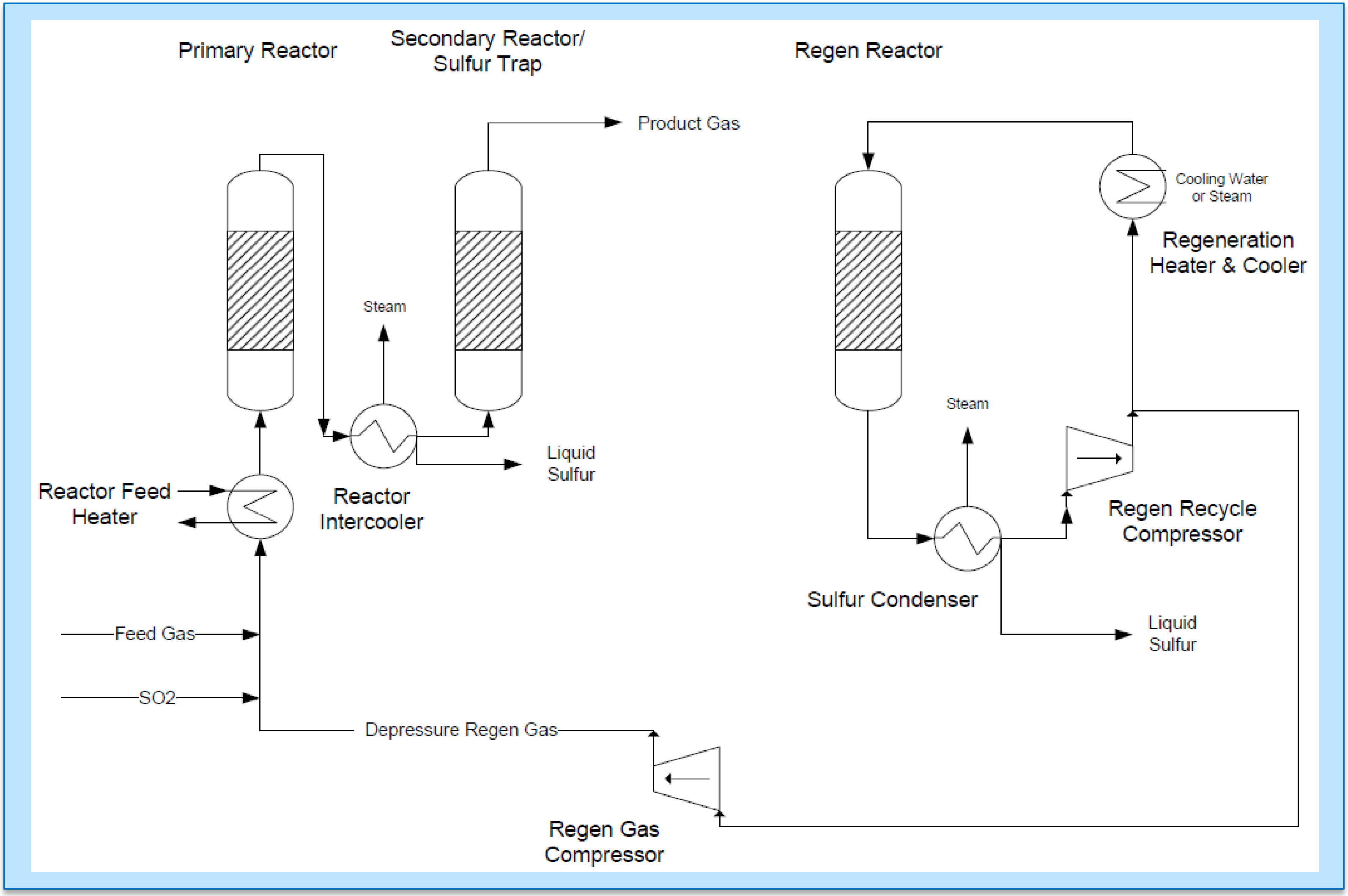
Absorber, Stripper, Water Wash Columns

Syngas Compressor

Heat Exchangers and Circulating Pumps

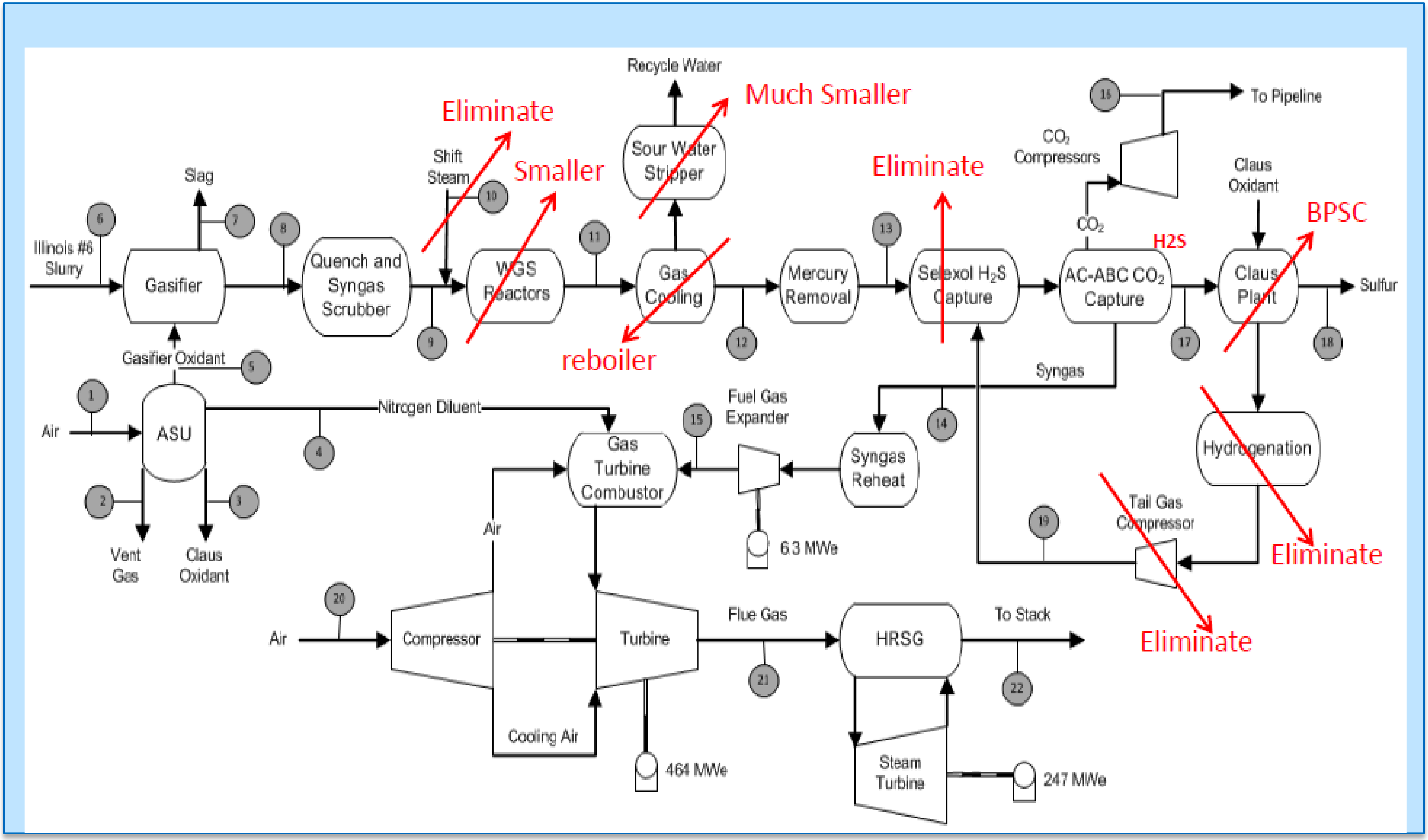


Bechtel Pressure Swing Claus (BPSC) Process



BPSC Process Skid (Columns and sulfur condenser

AC-ABC and BPSC Process Changes to IGCC Reference Case



Plant Performance Summary

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

Economic Analysis

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

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).
- Capital cost is ~6% less expensive than the reference plant on an absolute basis and 9% less on a normalized 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 process will be tested in this Budget Period at the National Carbon Capture Center.

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