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

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Project Overview

- Project Participants:
  - SRI International.
  - Bechtel Hydrocarbon Treatment Solutions, Inc.
  - EIG, Inc.
  - National Carbon Capture Center
  - U.S. DOE (National Energy Technology Laboratory)
- Funding:
  - U.S. Department of Energy: $5,828,047
  - Cost Share (SRI and BHTS): $1,662,648
  - Total: $7,490,695
- Performance Dates:
  - October 2009 through September 2016

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 (completed)
  - Perform tests to evaluate the process in a coal gasifier environment (completed)
  - 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 :

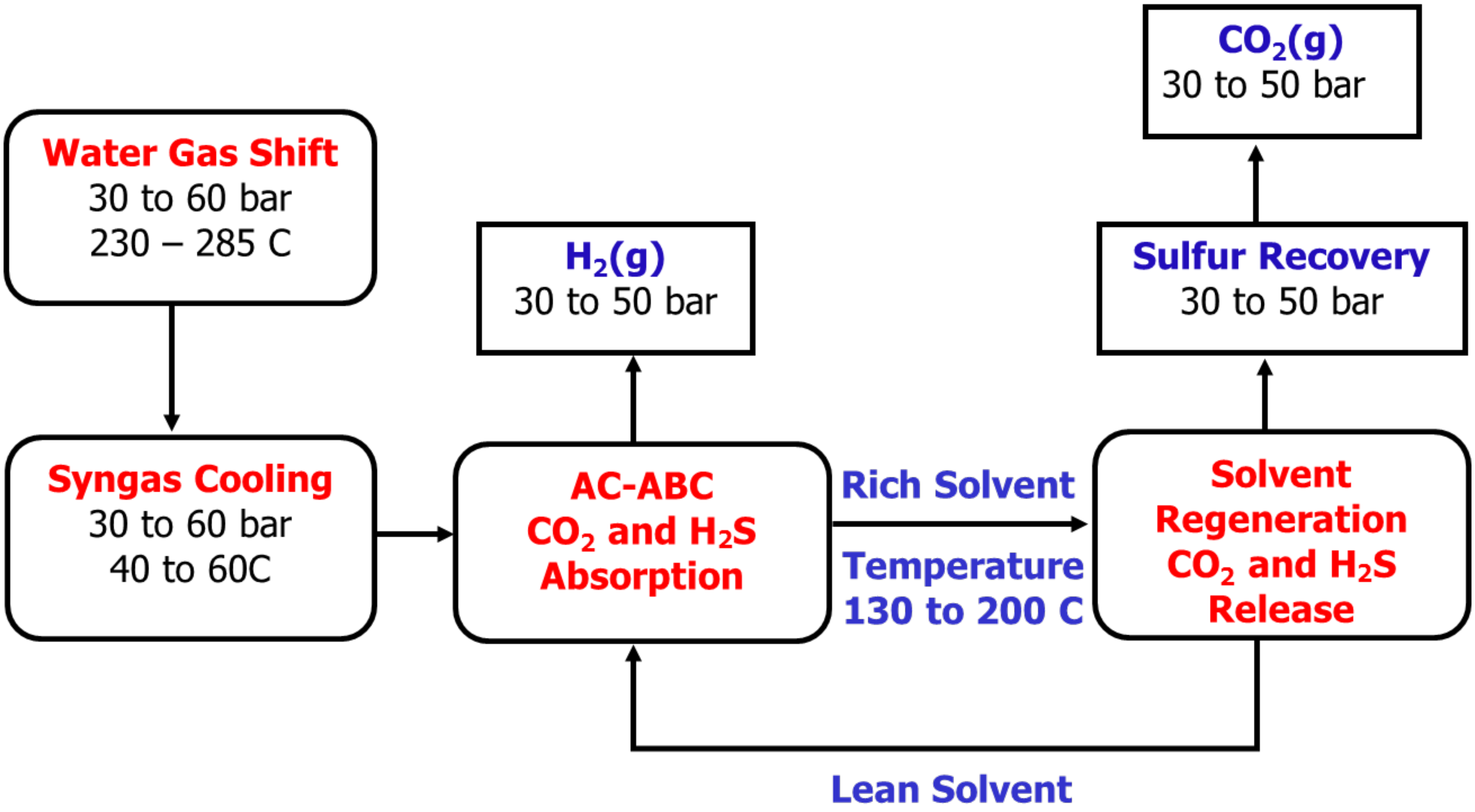
$$NH_4OH + CO_2 \leftrightarrow NH_4HCO_3$$

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

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

- 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



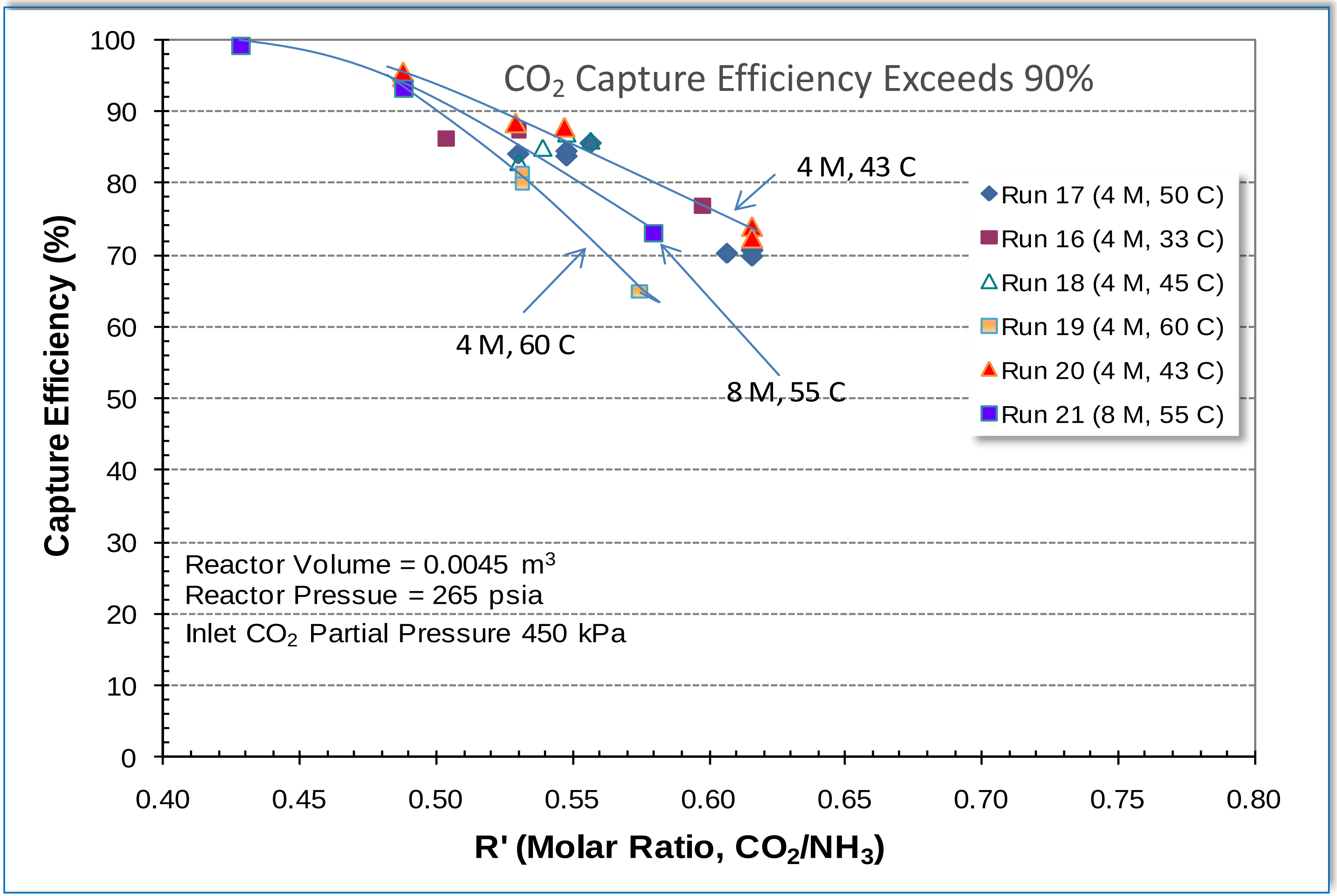
Process Highlights

- 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 pressure (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 wt. %.
- 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.

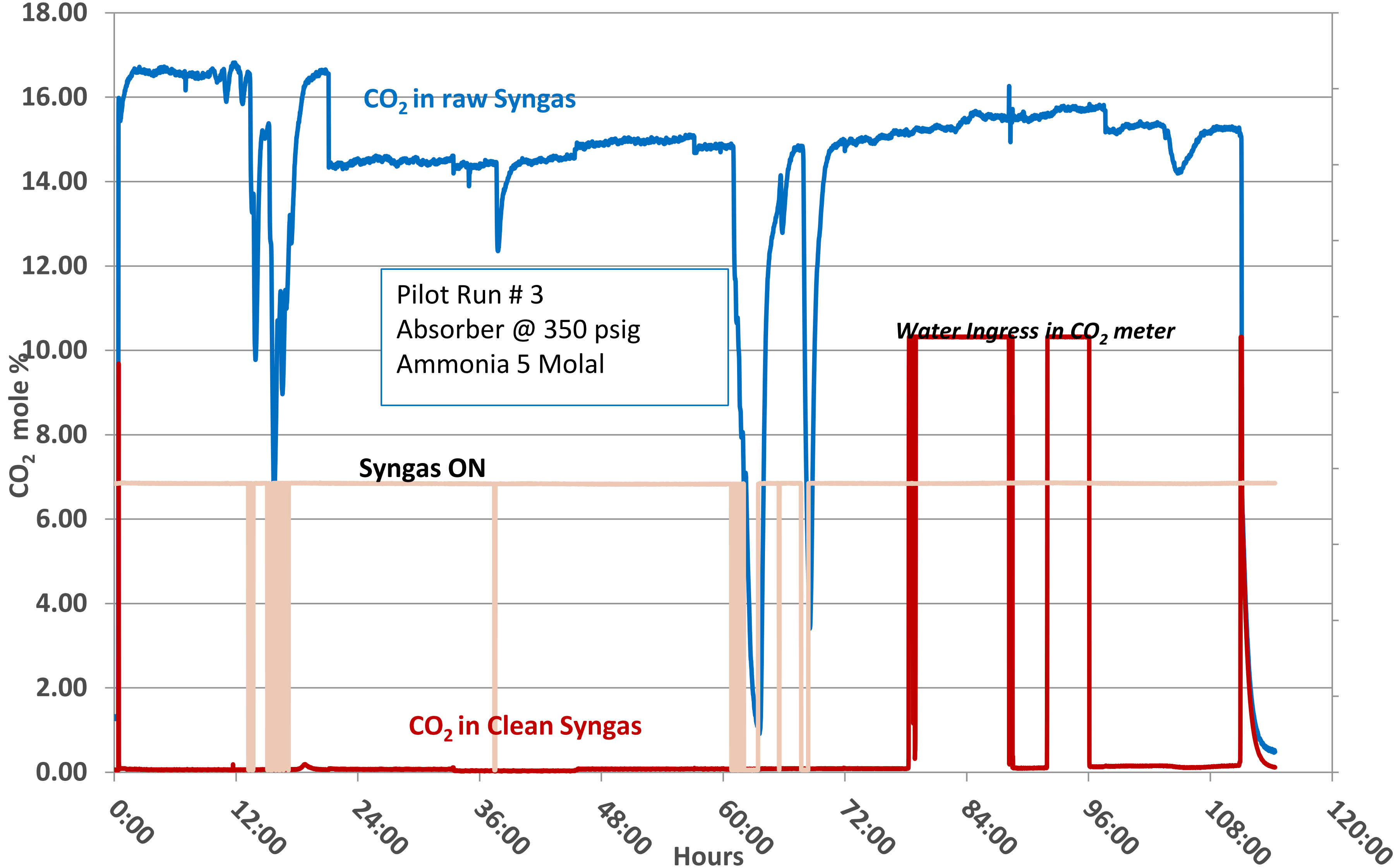
Process Advantages

- 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)
  - <1.5 GJ/Tonne CO2
- Extremely low solubility of H_2, CO and CH_4 in absorber solution: Minimizes loss of fuel species.
- Absorber and regenerator can operate at similar pressure.
  - No need to pump solution across pressure boundaries. Low energy consumption for pumping.

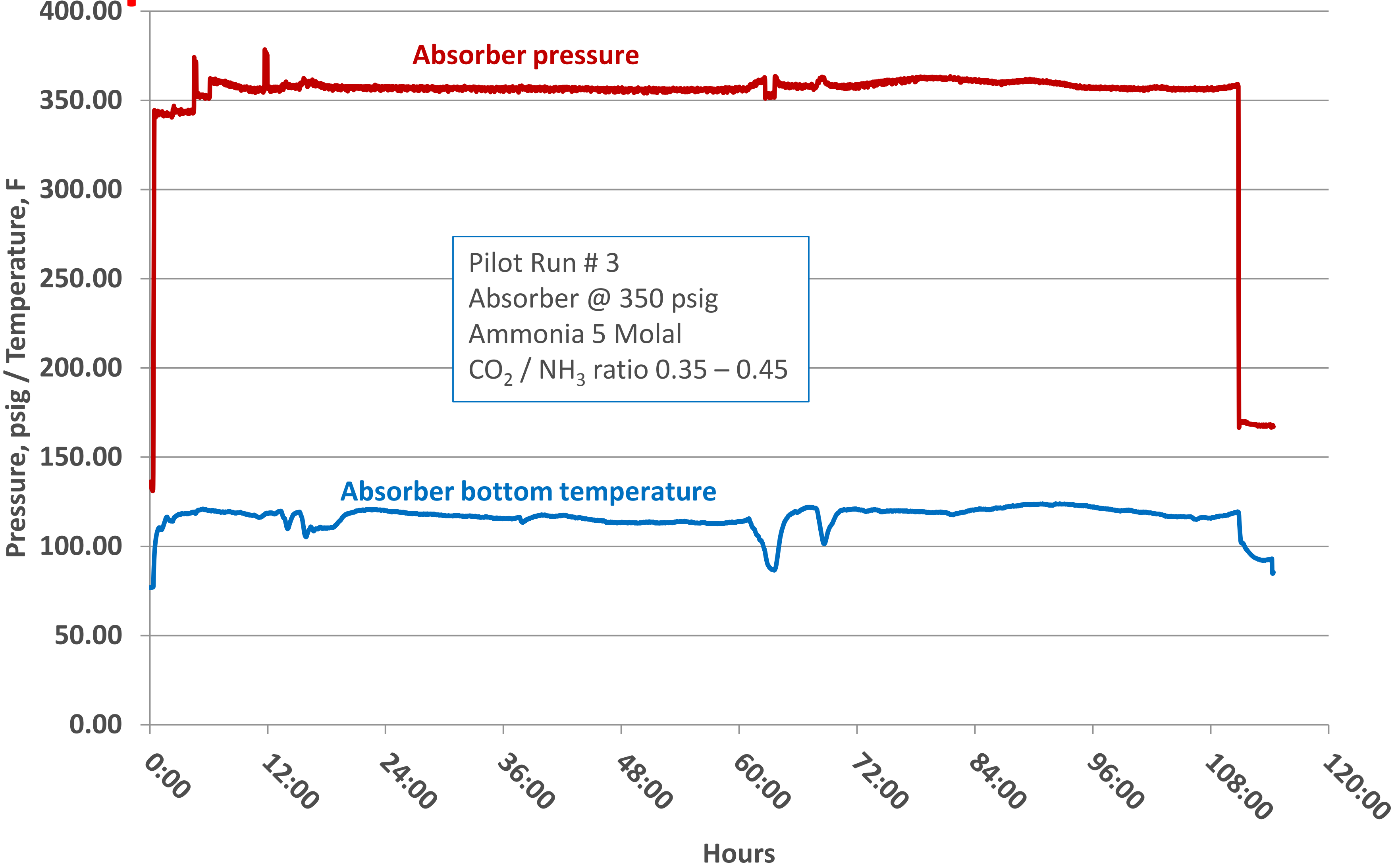
Bench scale data - CO_2 Capture Efficiency vs Solution Composition



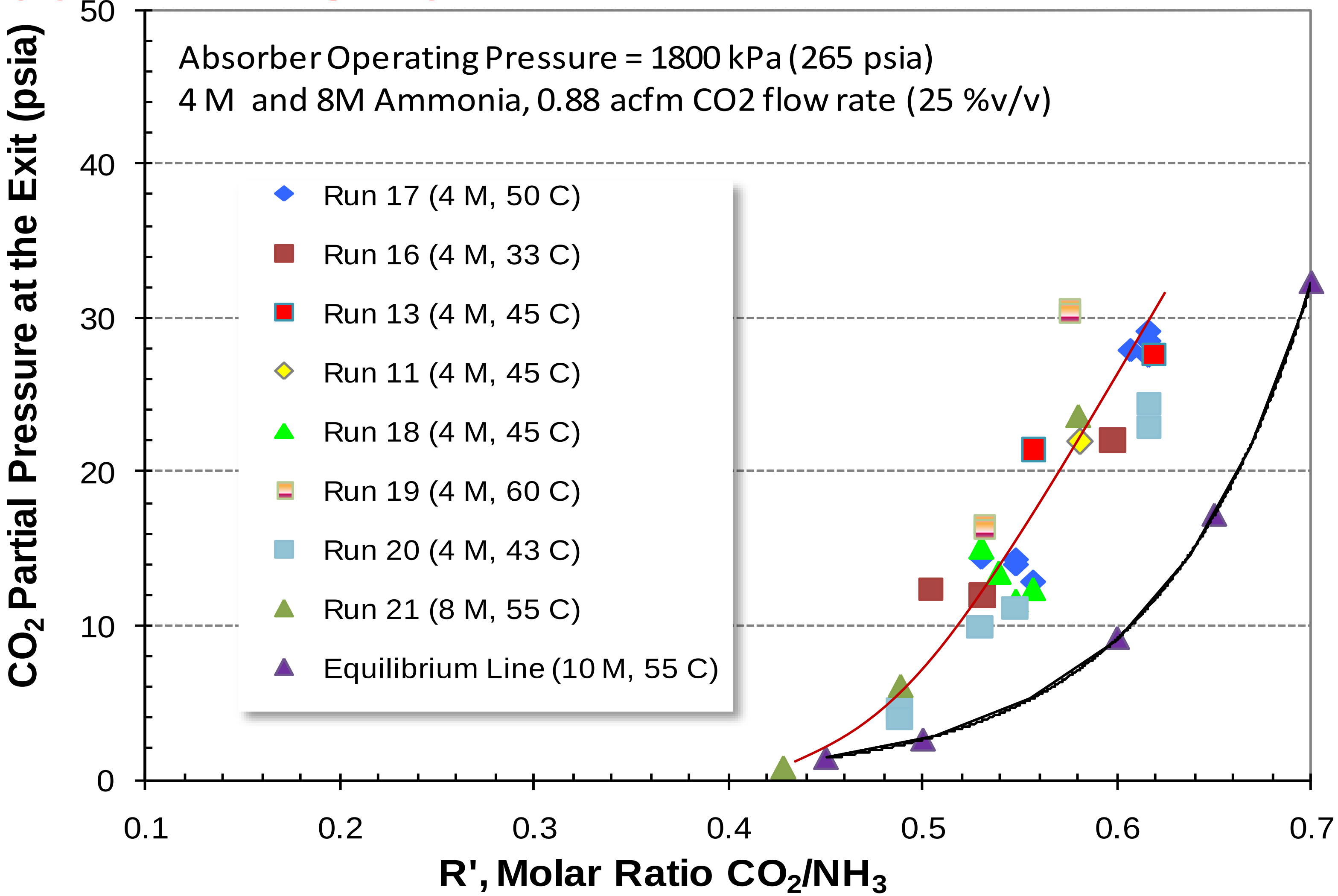
Pilot data - CO_2 Capture Efficiency > 99%



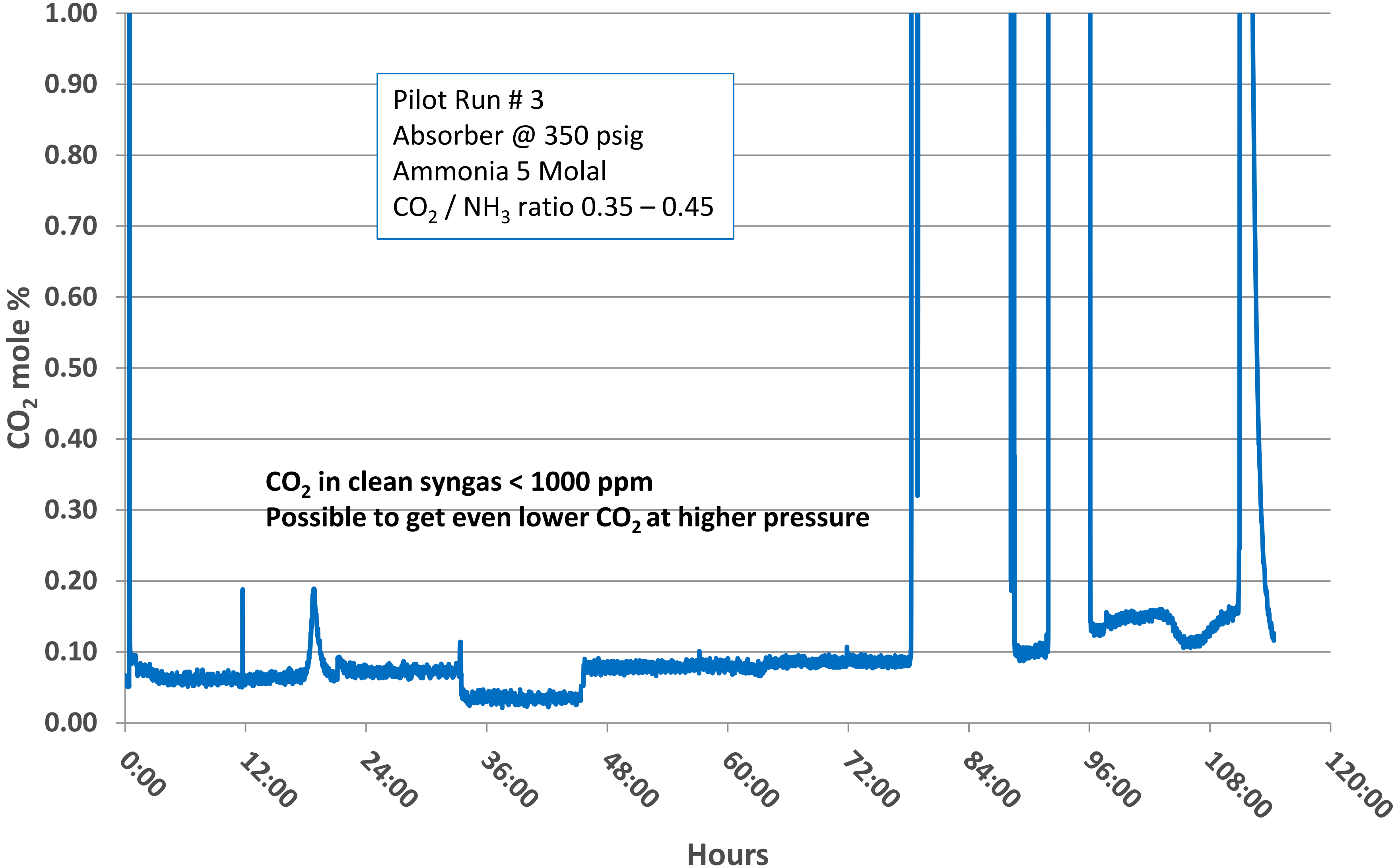
Pilot data – absorption pressure and temperature



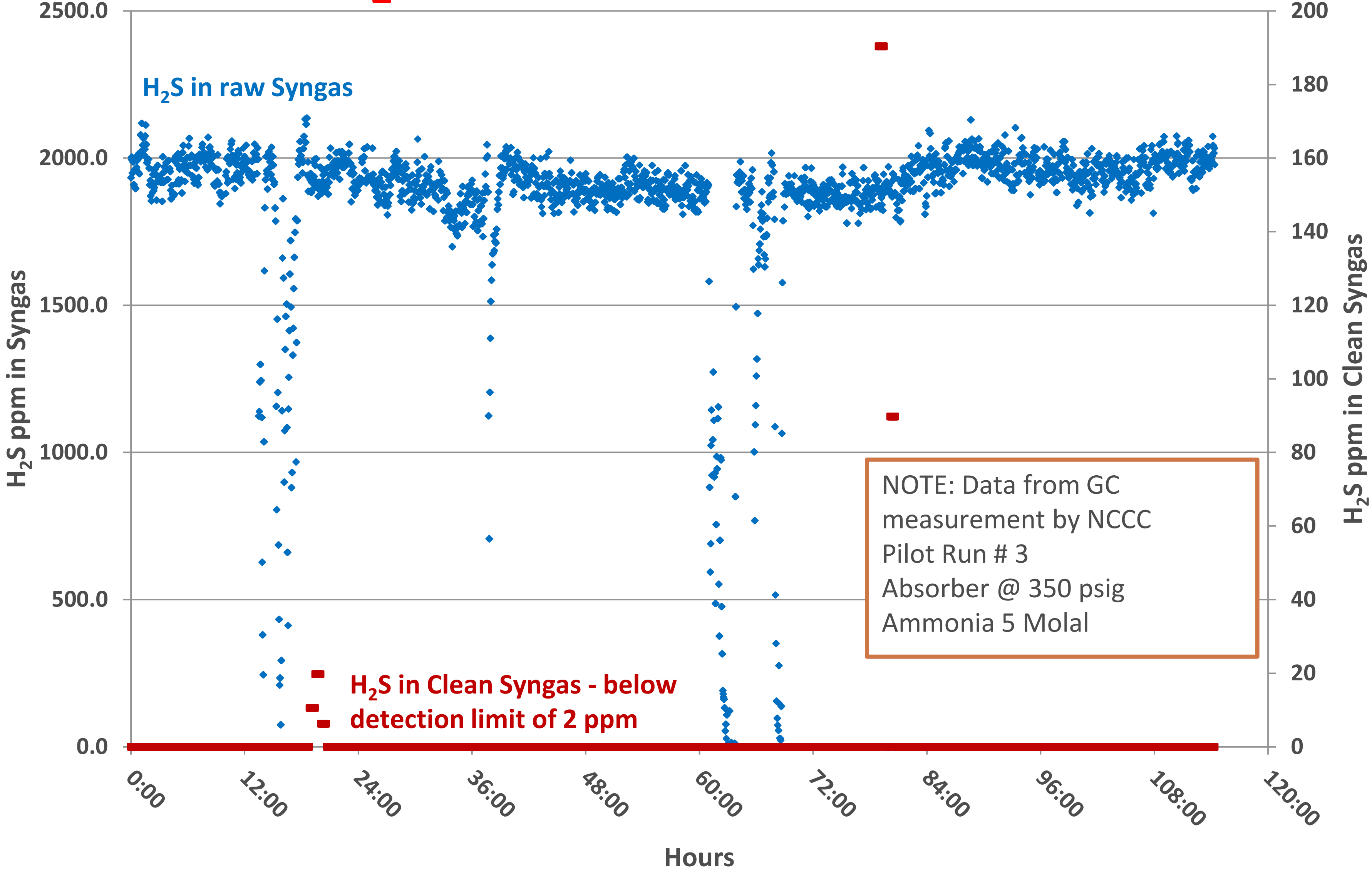
Bench scale data - Rapid Rate of Reaction Approaching Equilibrium



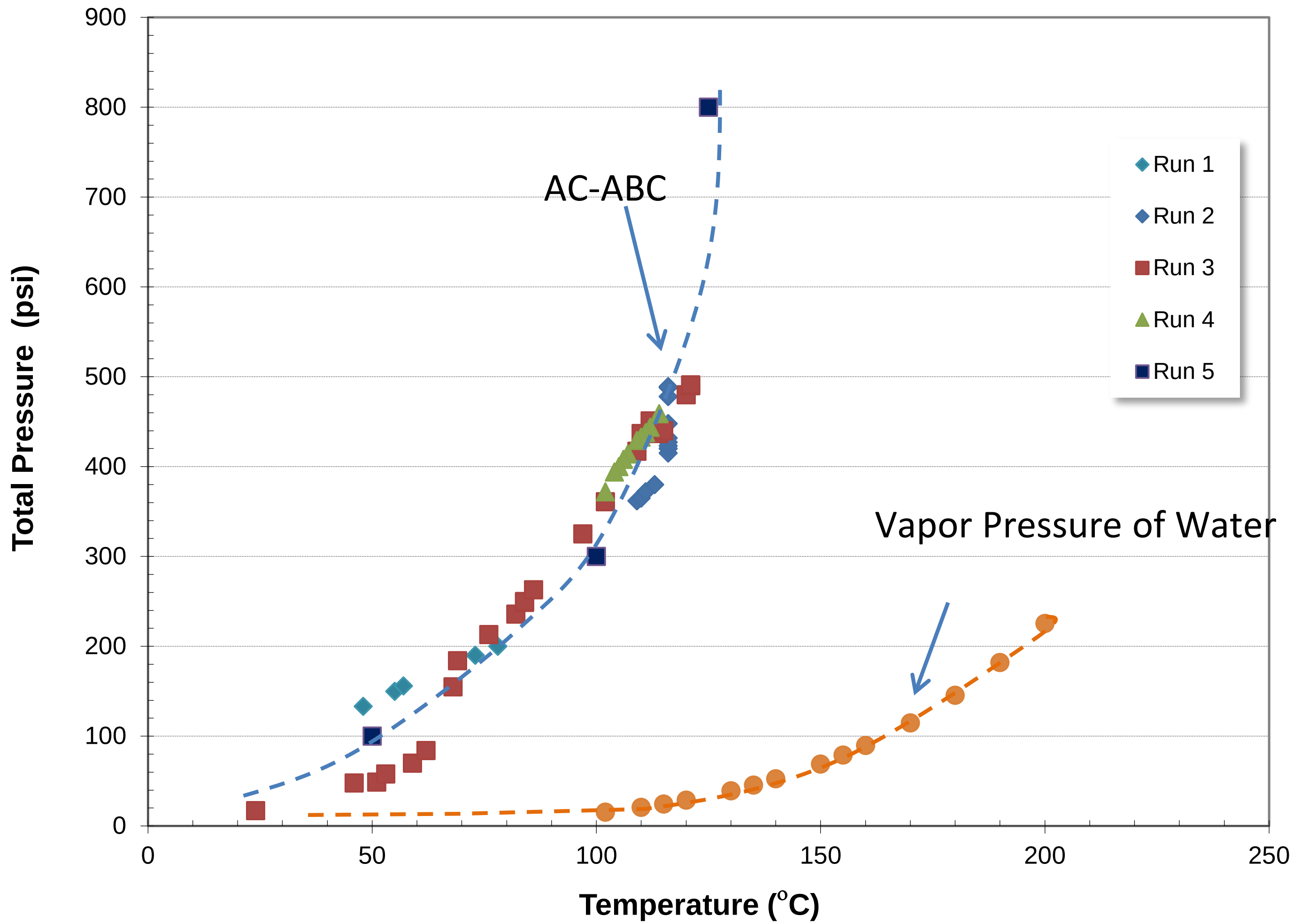
Pilot data - CO_2 in clean syngas



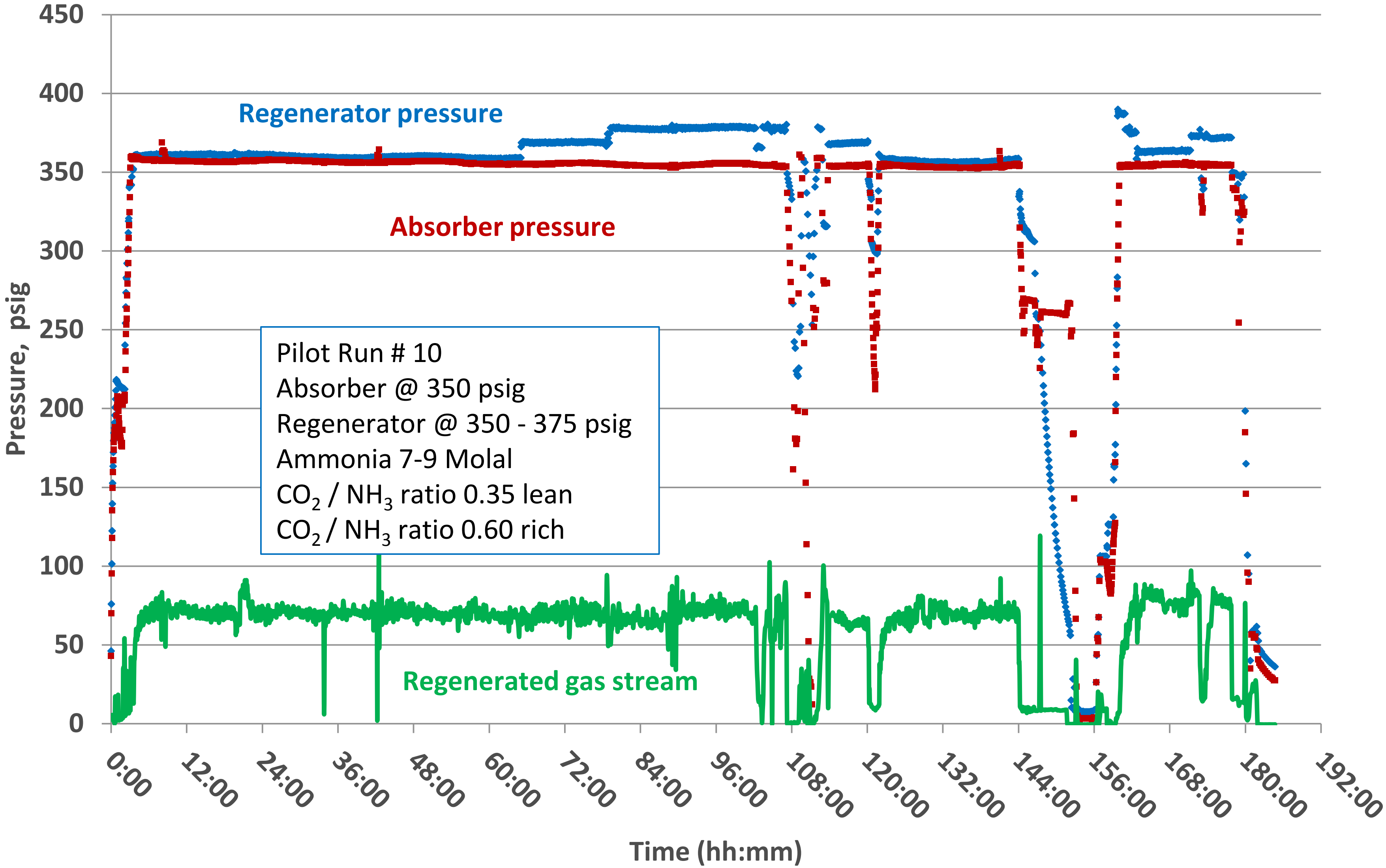
Pilot data - H_2S capture efficiency > 99%



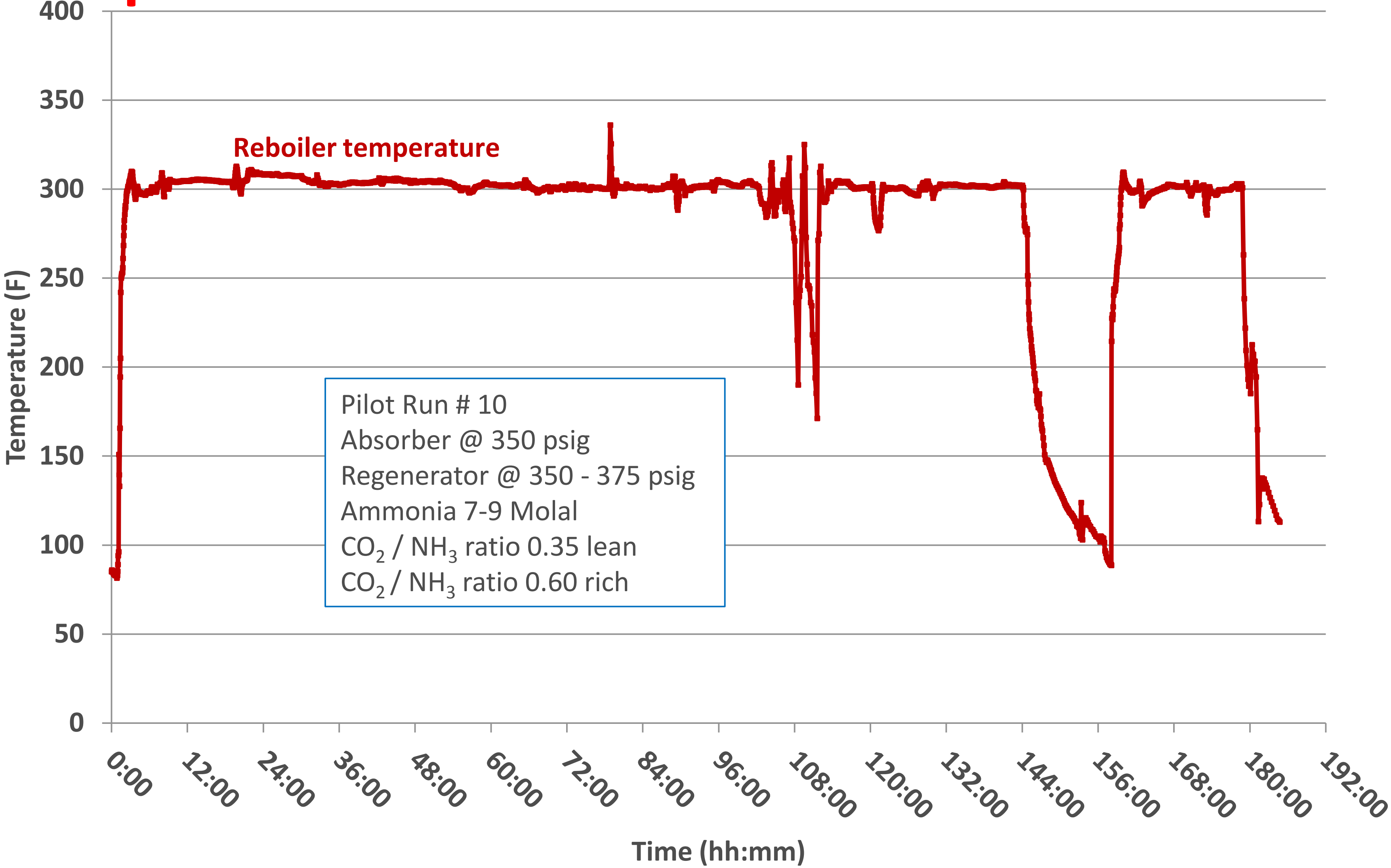
Bench scale data - Measured CO_2 Attainable Pressure Function of Temperature



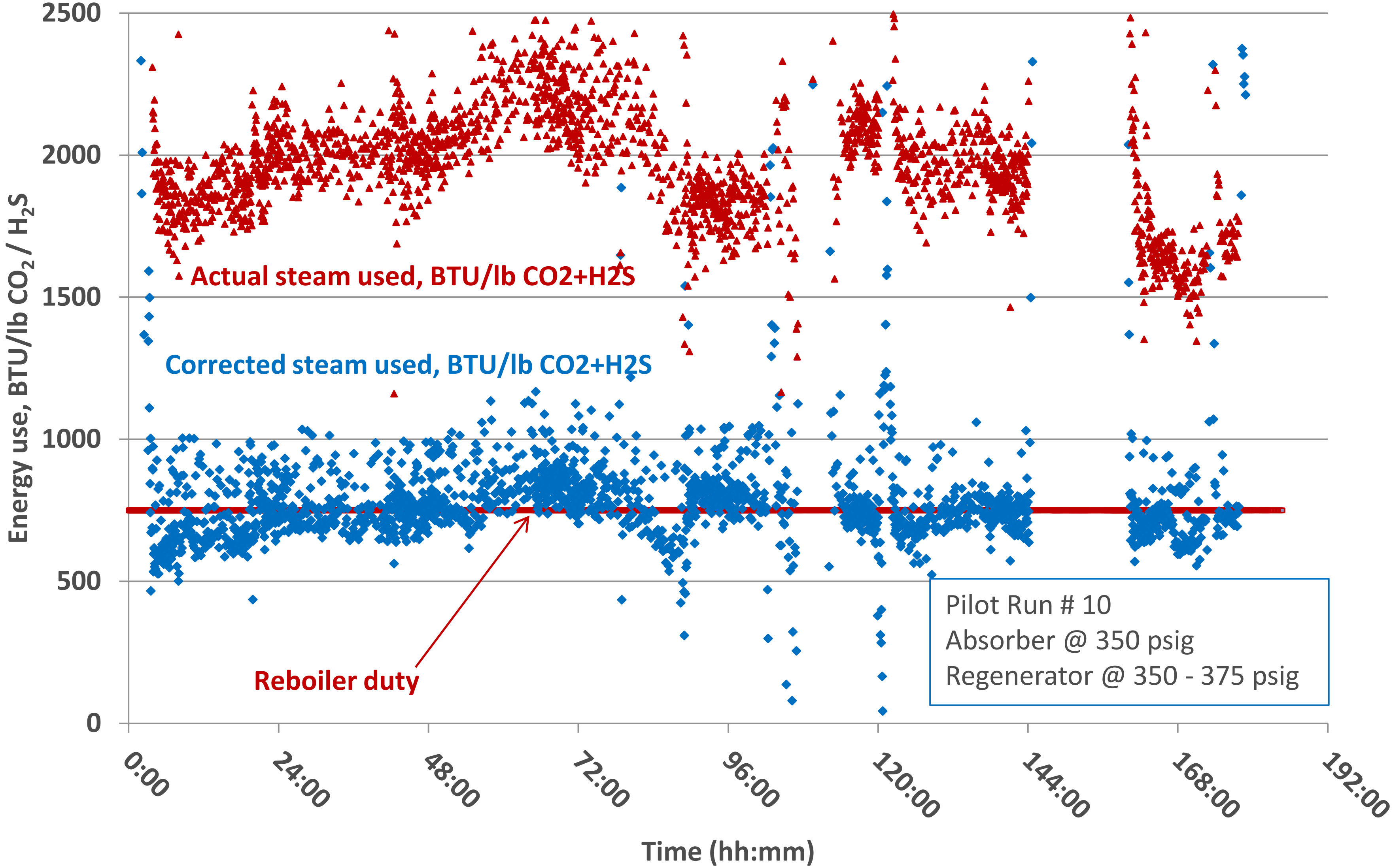
Pilot data – Absorption and Regeneration at high pressure



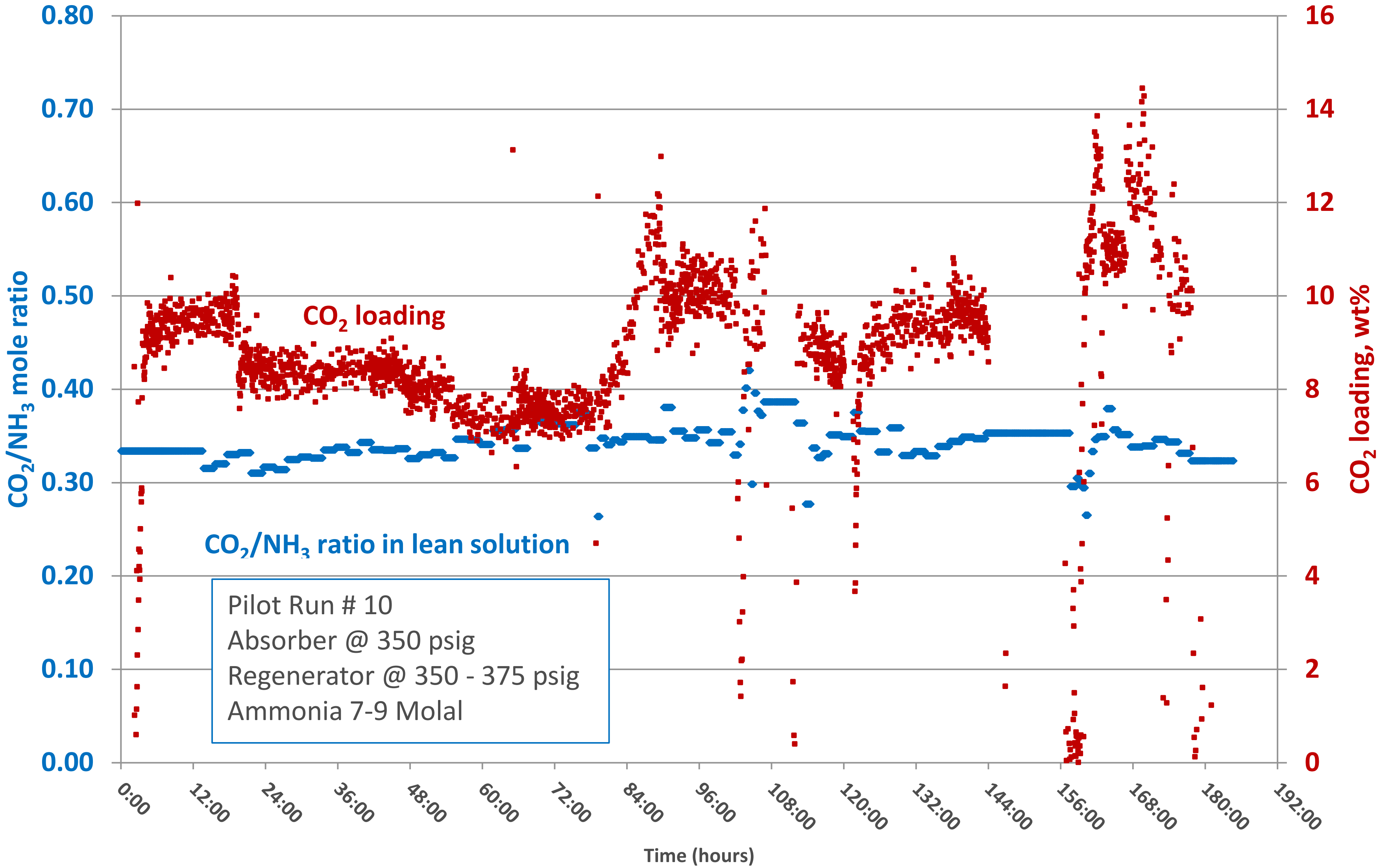
Pilot data – Regeneration at moderate temperature



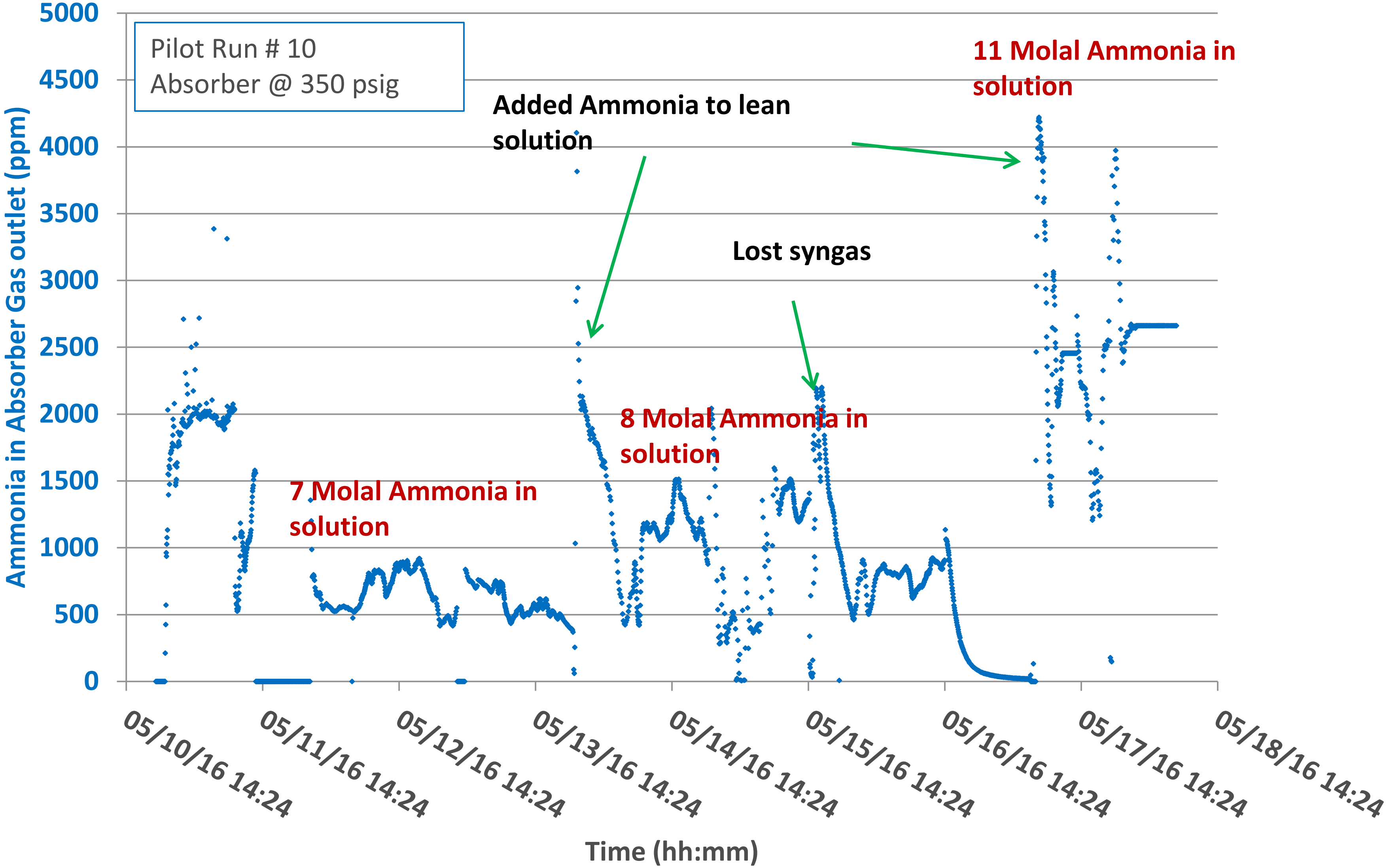
Pilot data - Steam input for regeneration



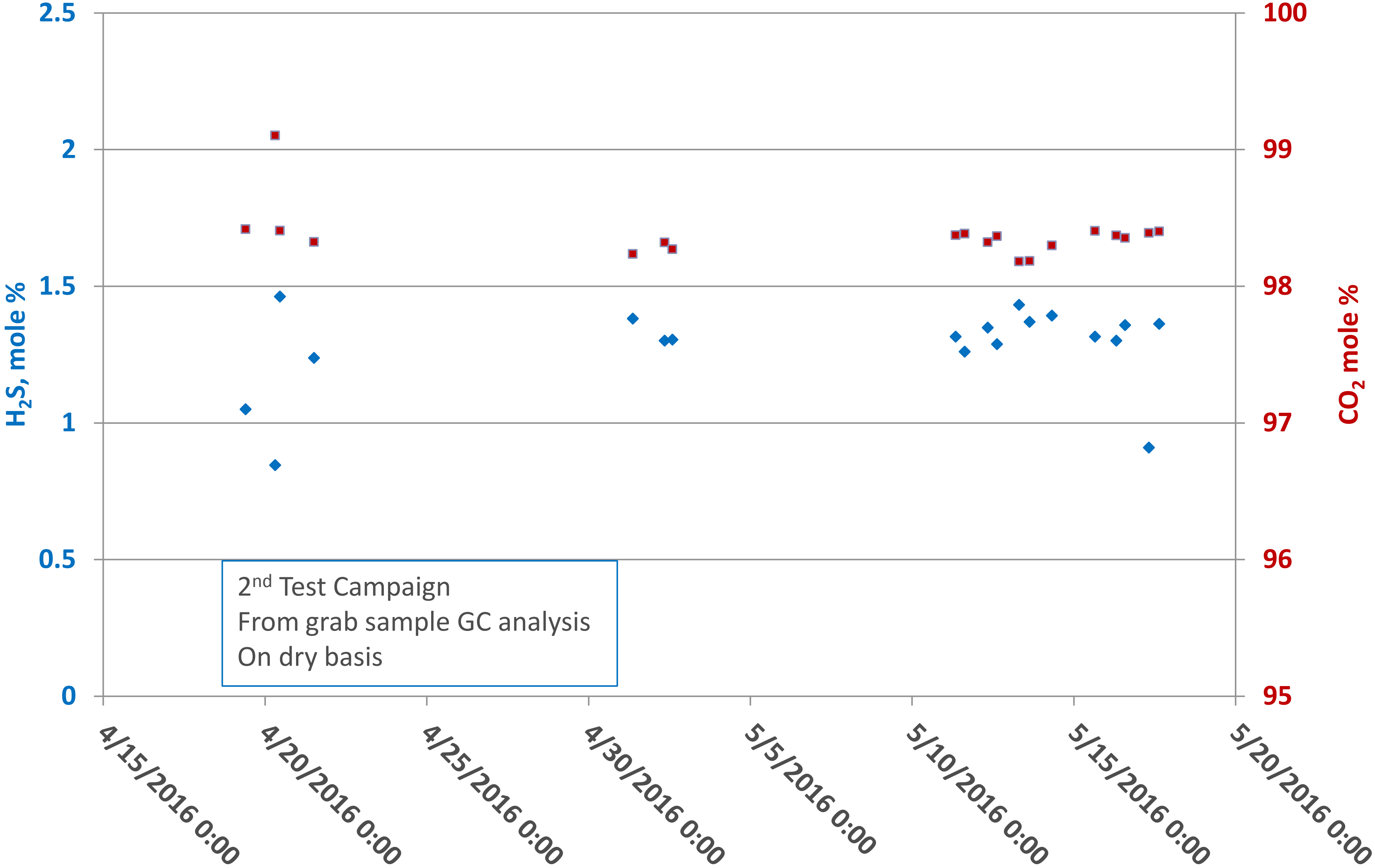
Pilot data – Effective CO_2 loading



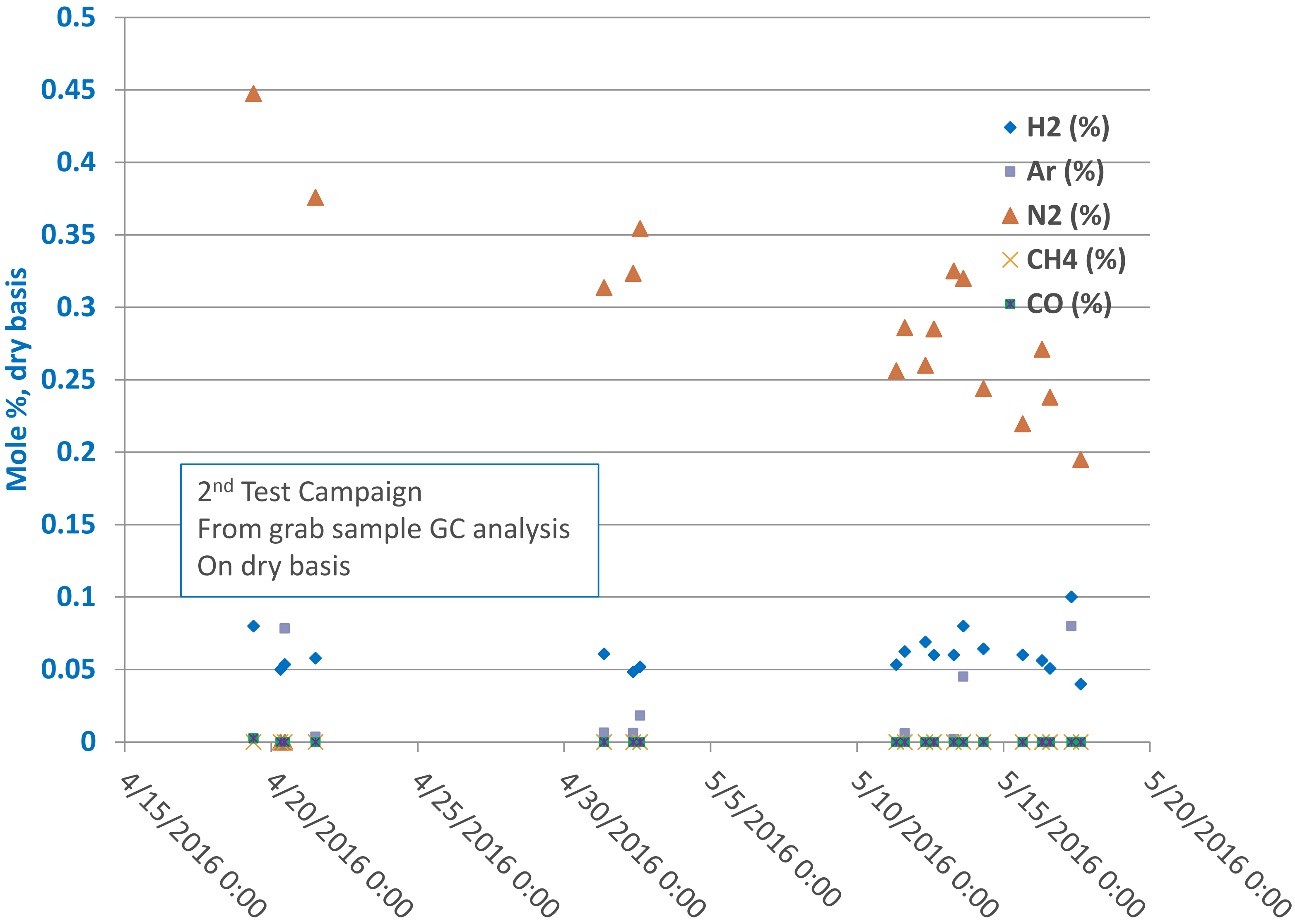
Pilot data - Ammonia emission from absorber



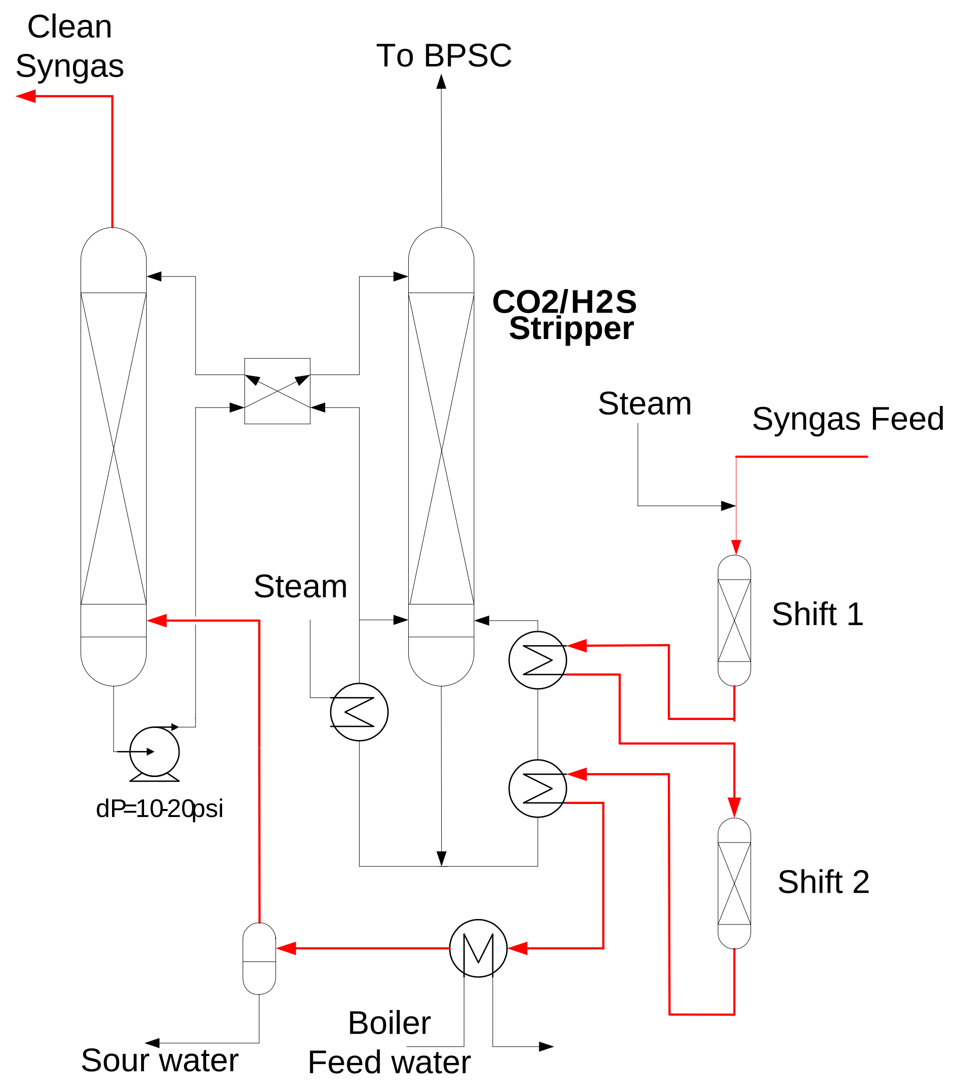
Pilot data – Regenerated gas stream



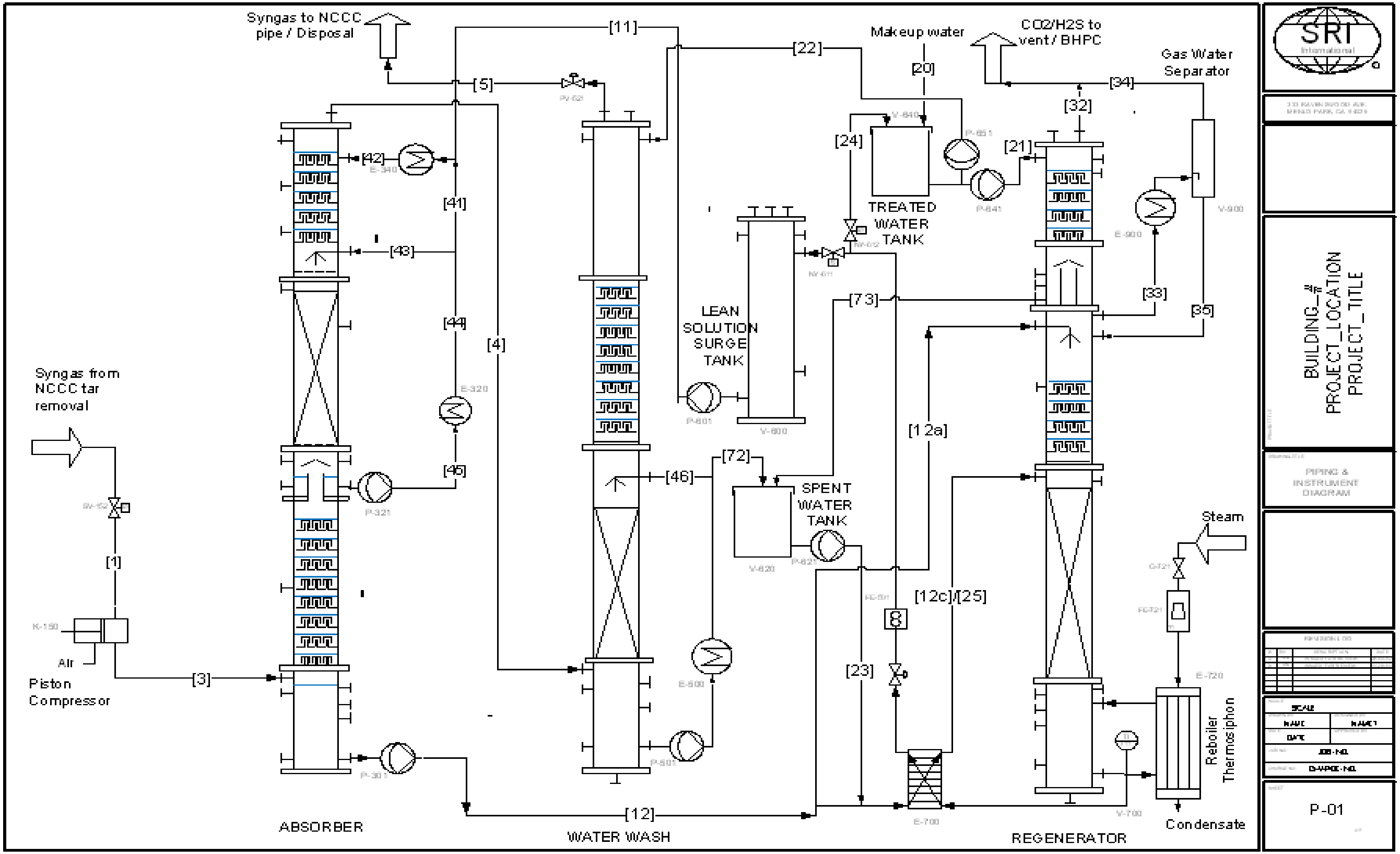
Pilot data – Regenerated gas stream contd.



AC-ABC Process Schematic



PFD for the NCCC Test



AC-ABC / BPSC pilot at NCCC

1st Test Campaign - August/Sept 2015 – 300 hr. operation
2nd Test Campaign April/May 2016 – 400 hr. operation

Syngas Compressor and inlet gas manifold

Analytical equipment cabinet, pressurized

- **CO_2 measurement**
- **Ammonia measurement**

AC-ABC columns and skids

Process columns
- SS 316, 8” dia., 40’ tall

Process skids
- 5’ x 10’ – 2 skids

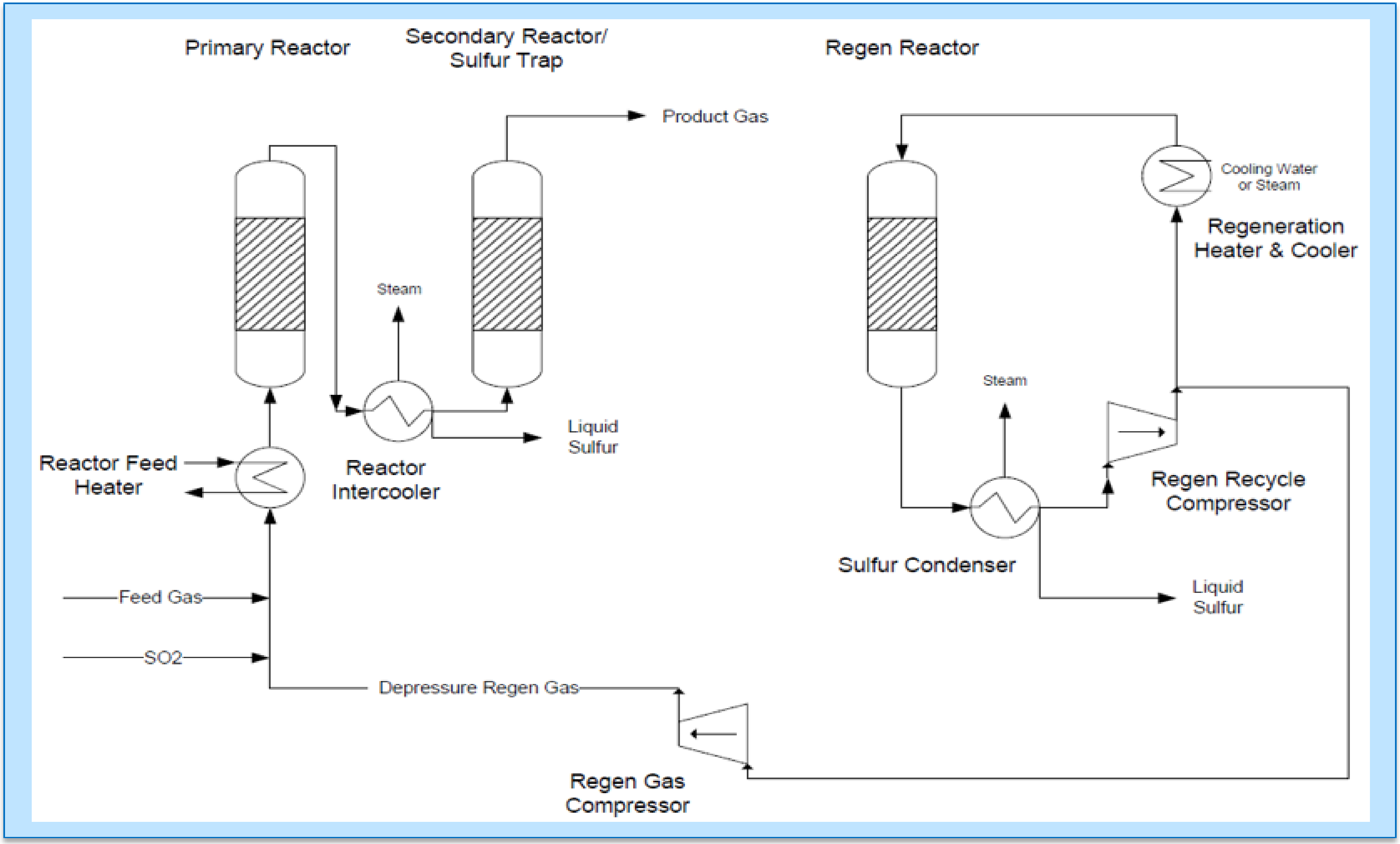
Electrical, control and data acquisition

Process controllers

Data acquisition system

Pump speed controllers

Bechtel Pressure Swing Claus (BPSC) Process

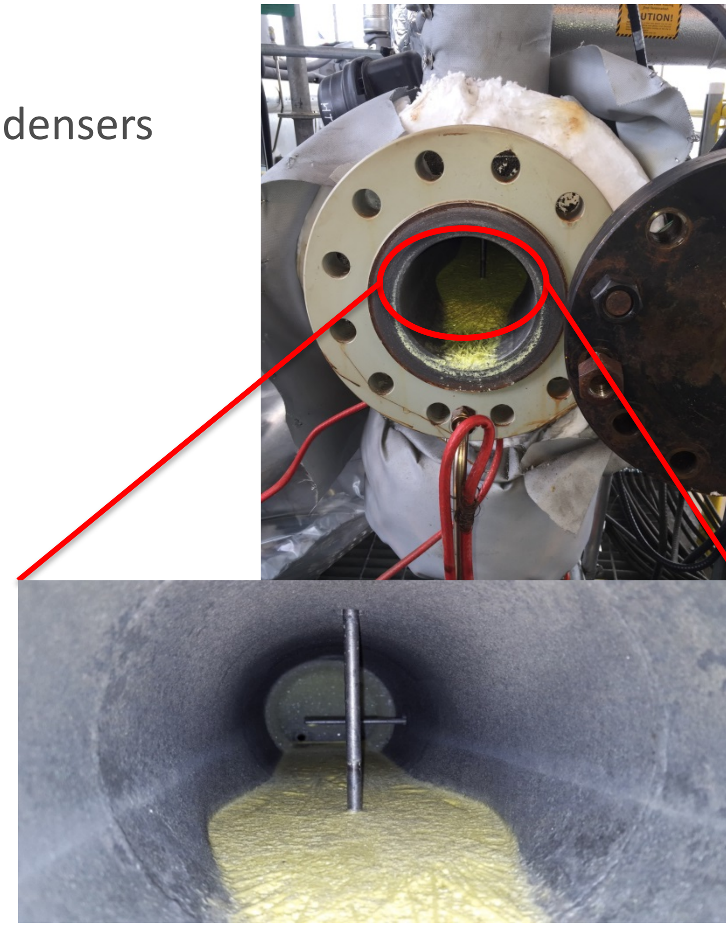


BPSC Process Skid -Columns and sulfur condenser

Catalytic reactors, 4” dia., 10’ tall

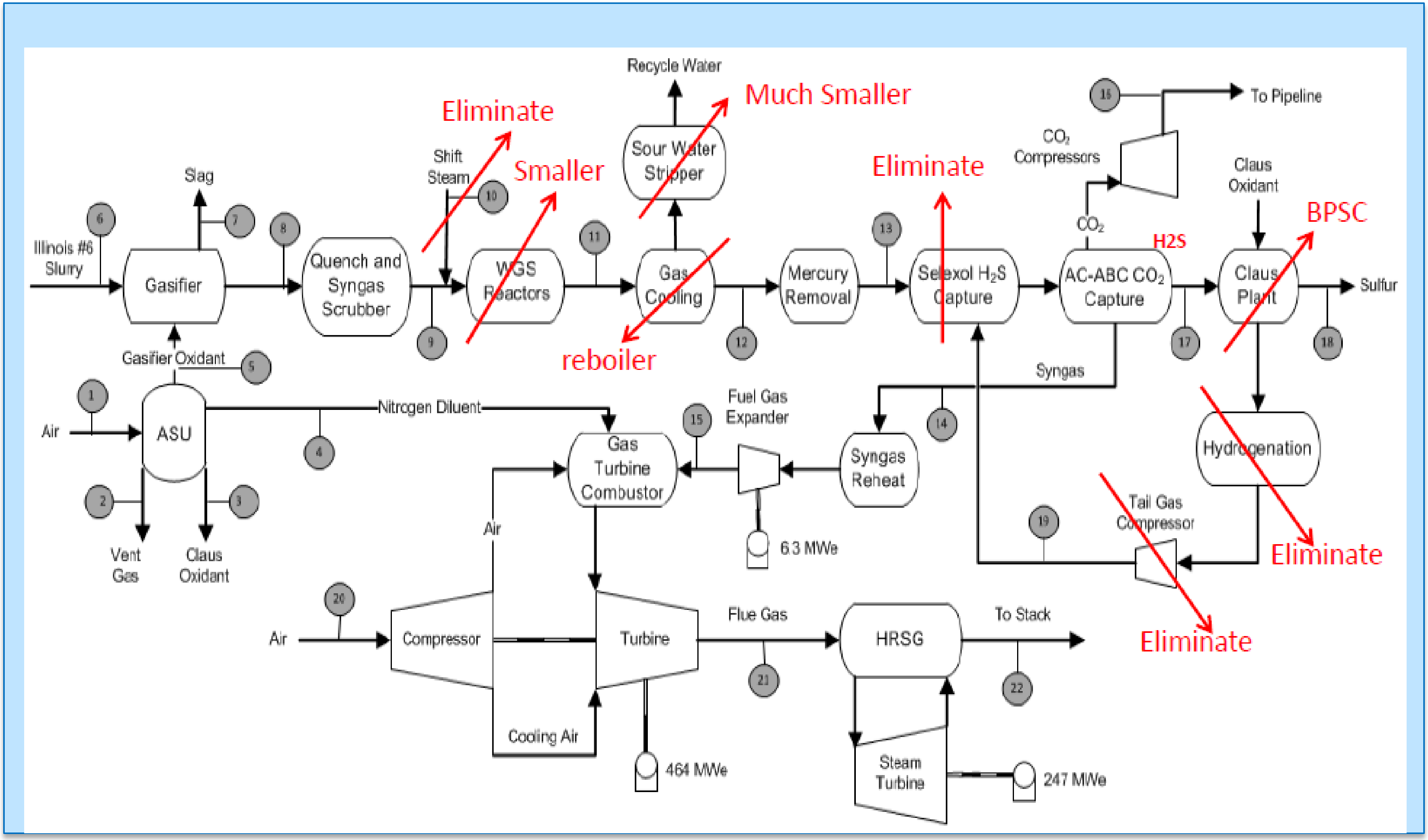
Condensers

2 Skids – 5’ x 10’ and 10’ x 14’



Elemental sulfur

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 IGCC with CO_2 capture B5B#
Gas Turbine Power	MWe	464.0	464.0
Syngas Expander Power	MWe	6.3	6.5
Steam Turbine Power	MWe	243.8	263.5
Auxiliary Load	MWe	162.5	190.8
Net Plant Power	MWe	551.6	543.3
Net Plant Efficiency (HHV)	-	33.1%	32.6%
Net Plant Heat Rate (HHV)	kJ/kWh Btu/kWh	10,166 9,636	11,034 10,458

Cost and Performance Baseline for Fossil Energy Plants, Vol 1b, July 31, 2015, Table ES-2

Economic Analysis

Economic Analysis (base 2011$)	IGCC with SRI AC-ABC and BPSC	Reference Case IGCC with CO_2 capture B5B#
Total Plant Cost, before Owner's Costs, million	$1,648	$1,840
Total Plant Cost, before Owner's Costs	$2,988/kW	$3,387/kW
Initial Chemical Fill Cost, million	$4.90	$16.50
Annual Fixed O&M Cost, million	$69.40	$69.40
Annual Variable O&M Cost, million	$41.20	$46.60
Total Annual O&M Cost, million	$110.60	$116.00
FY COE* without TS&M**	$124.46	$135.56
FY COE with TS&M	$133.66	$144.76
COE (% increase from base case IGCC, no CO_2 capture)	30.3 %	41.2 %

*FY COE = First Year Cost of Electricity

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

Cost and Performance Baseline for Fossil Energy Plants, Vol 1b, July 31, 2015, Table ES-4

Anticipated Benefits

- We estimate a 8.3 MW improvement in Net Plant Power and a 0.5 % point increase in Net Plant Efficiency (HHV basis) than a reference plant (GE gasifier with Selexol AGR and conventional Claus).
- Capital cost is ~10 % less than the reference IGCC plant with CO_2 capture.
- The COE is 7.5 % lower for the SRI AC-ABC/BPSC plant relative to the reference IGCC case with CO_2 capture.
- The process configuration is economically viable per this analysis.

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  - Steve Mascaro

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