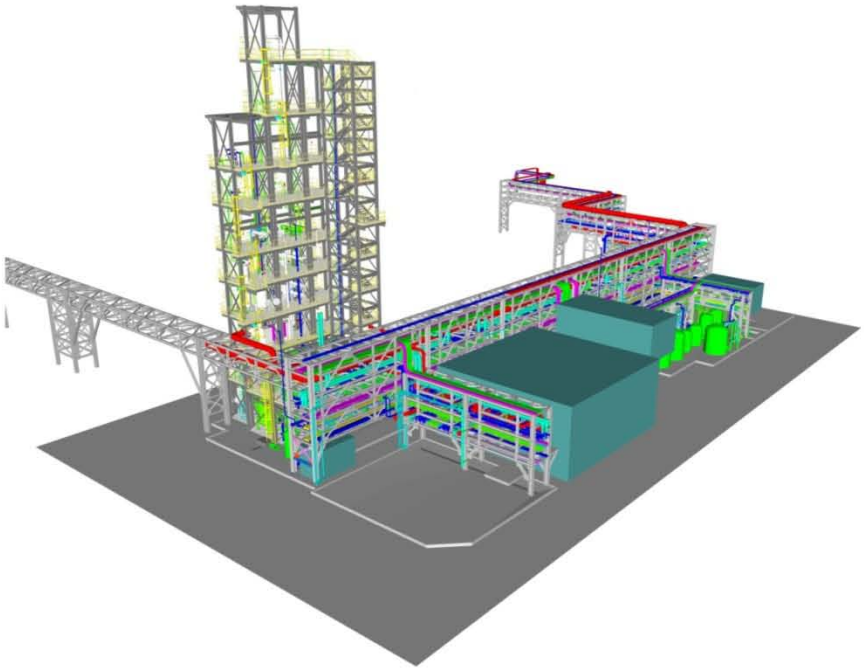
U.S. Department of Energy

National Carbon Capture Center

at the Power Systems Development Facility



Post-Combustion Carbon Capture

National Carbon Capture Center

Post-combustion

- Build test infrastructure at Plant Gaston
- Partner with solvent and process developers for evaluation
- Move technology forward to demonstration phase

Pre-combustion

- Utilize and expand existing syngas infrastructure
- Provide test site for syngas CO_2 capture technology evaluation
- Use data in engineering of full-scale systems

Oxy-combustion

- Scoping / screening studies of new pressurized oxy-combustion process.

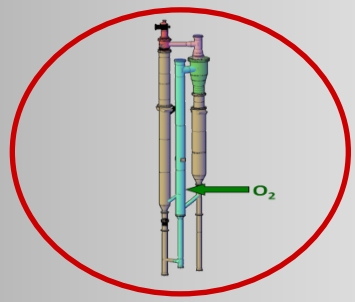
Cooperative Agreement DE-NT0000749 signed in September 2008.

Goals of the NCCC

- Offer a unique flexible testing facility where processes can be tested on coal derived gas at various scales
- Serve as a technology development facilitator by providing facilities for technology scale-up
- Solicit and incorporate activities and projects from a wide variety of participants and partners. Find "Best-in-class" Technology.
- Deliver innovation through a cross-cutting, collaborative project that provides an accelerated pathway to cost-effective CO_2 capture technology for coal fueled power production

Post-combustion

Pre-combustion



Oxy-combustion

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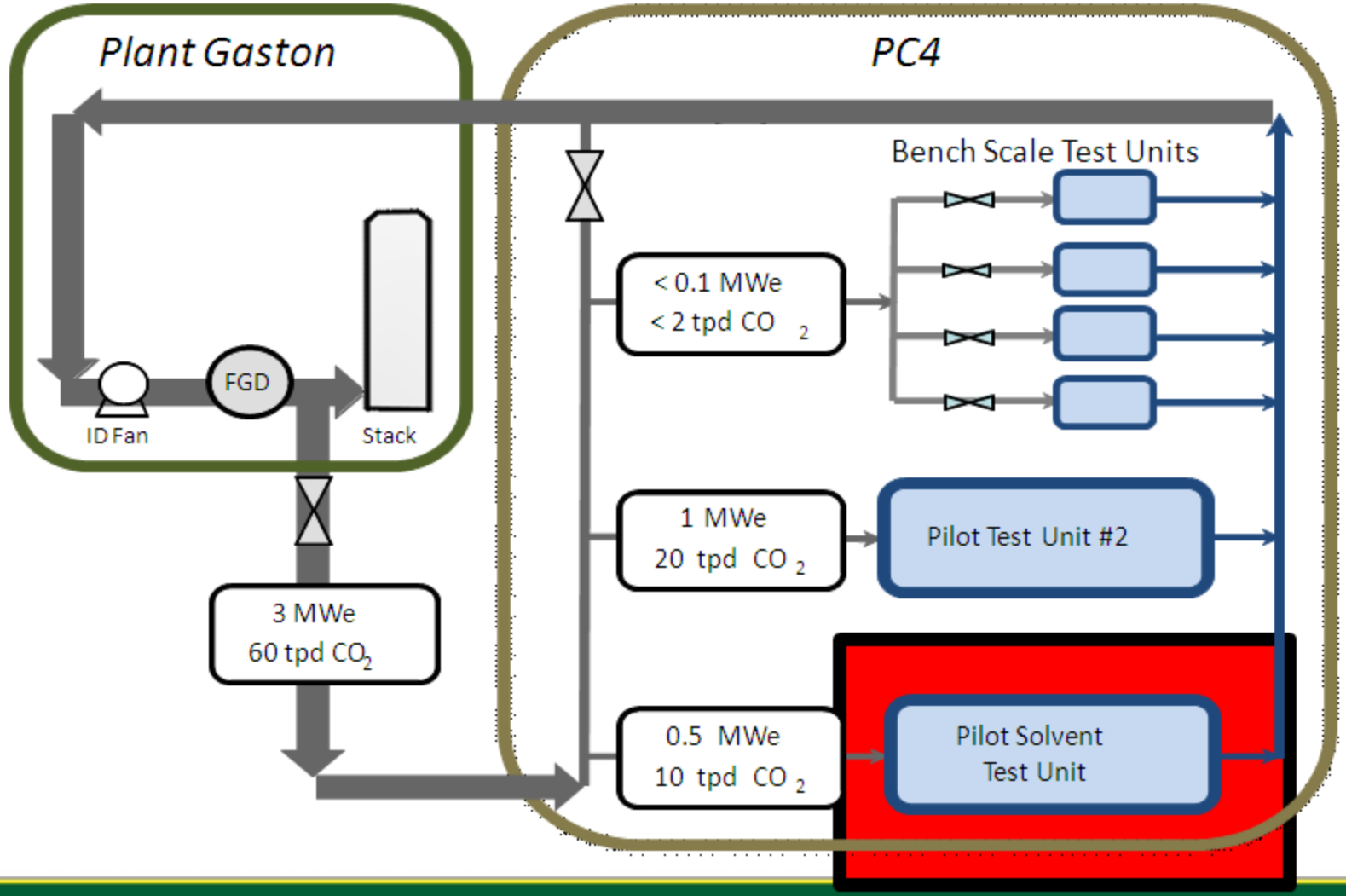
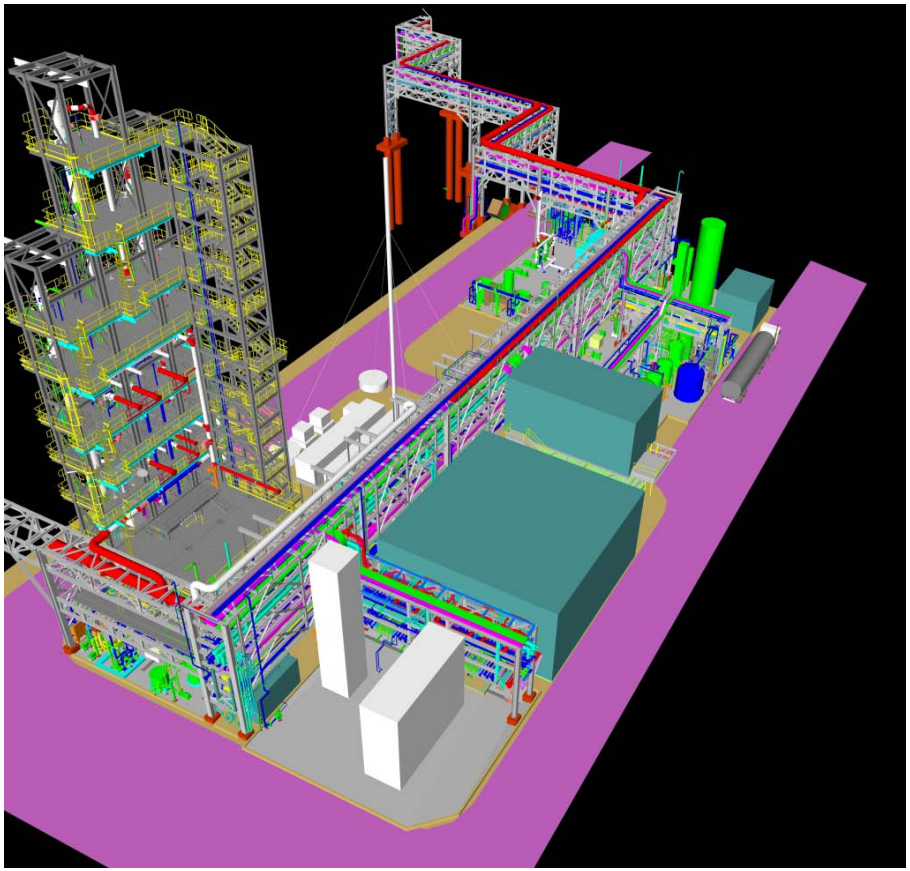
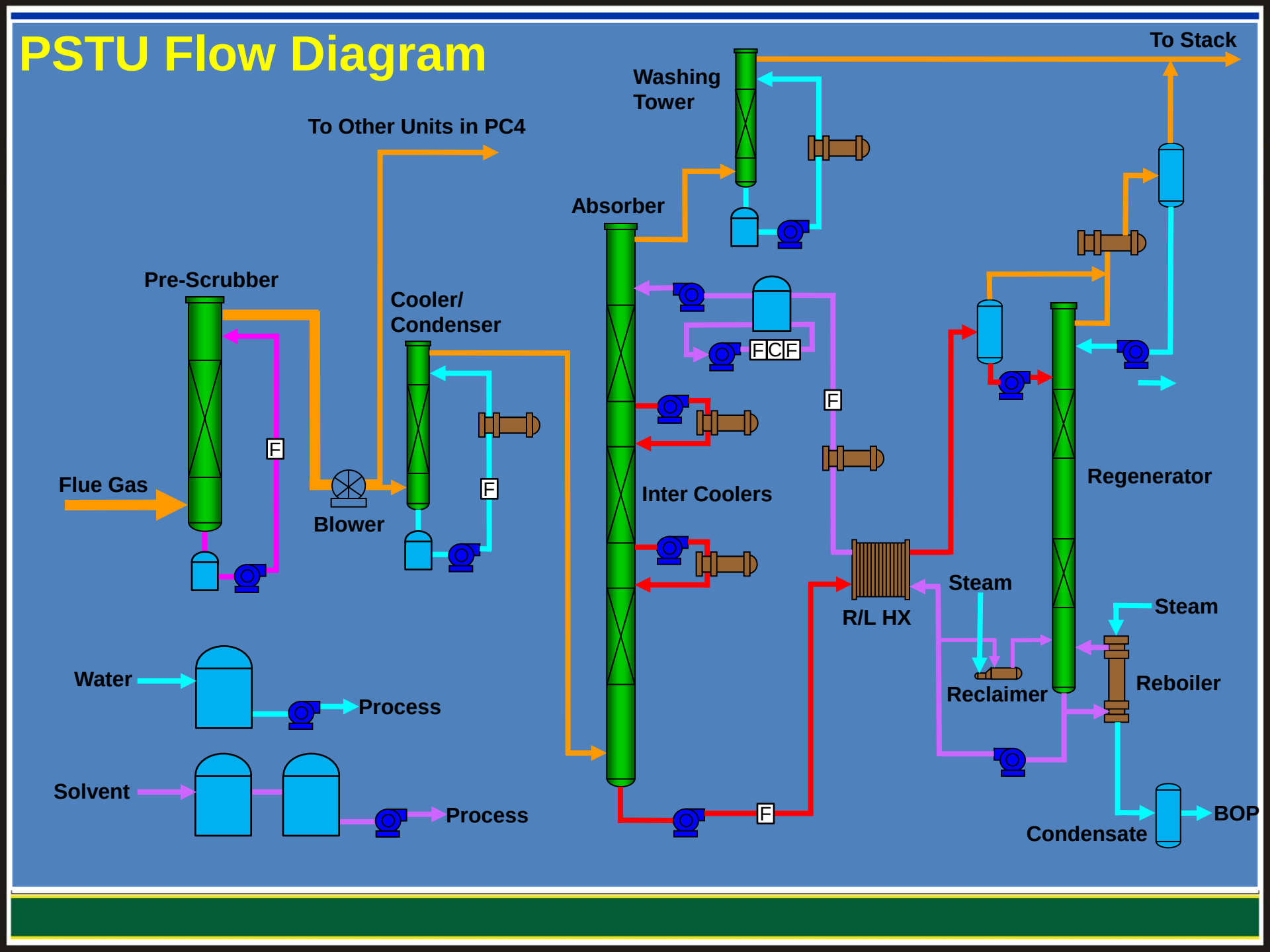
PC4 Test Units



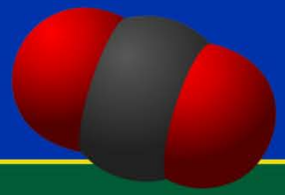



PSTU Flow Diagram
To Stack
Washing Tower
To Other Units in PC4
Absorber
Pre-Scrubber
Cooler/ Condenser
F
C
F
F
Flue Gas
Blower
Inter Coolers
F
Regenerator
R/L HX
Steam
Steam
Reclaimer
Reboiler
Water
Process
Solvent
Process
F
Condensate
BOP

PSTU Baseline Test

- Purpose
  - Hydraulic check
  - Packing clean-out
  - Ambient heat loss estimate
  - Validate analytical methods
  - Instrument calibration
  - Controller tuning
  - Design validation
  - HMB closure

Range of Parameters Tested

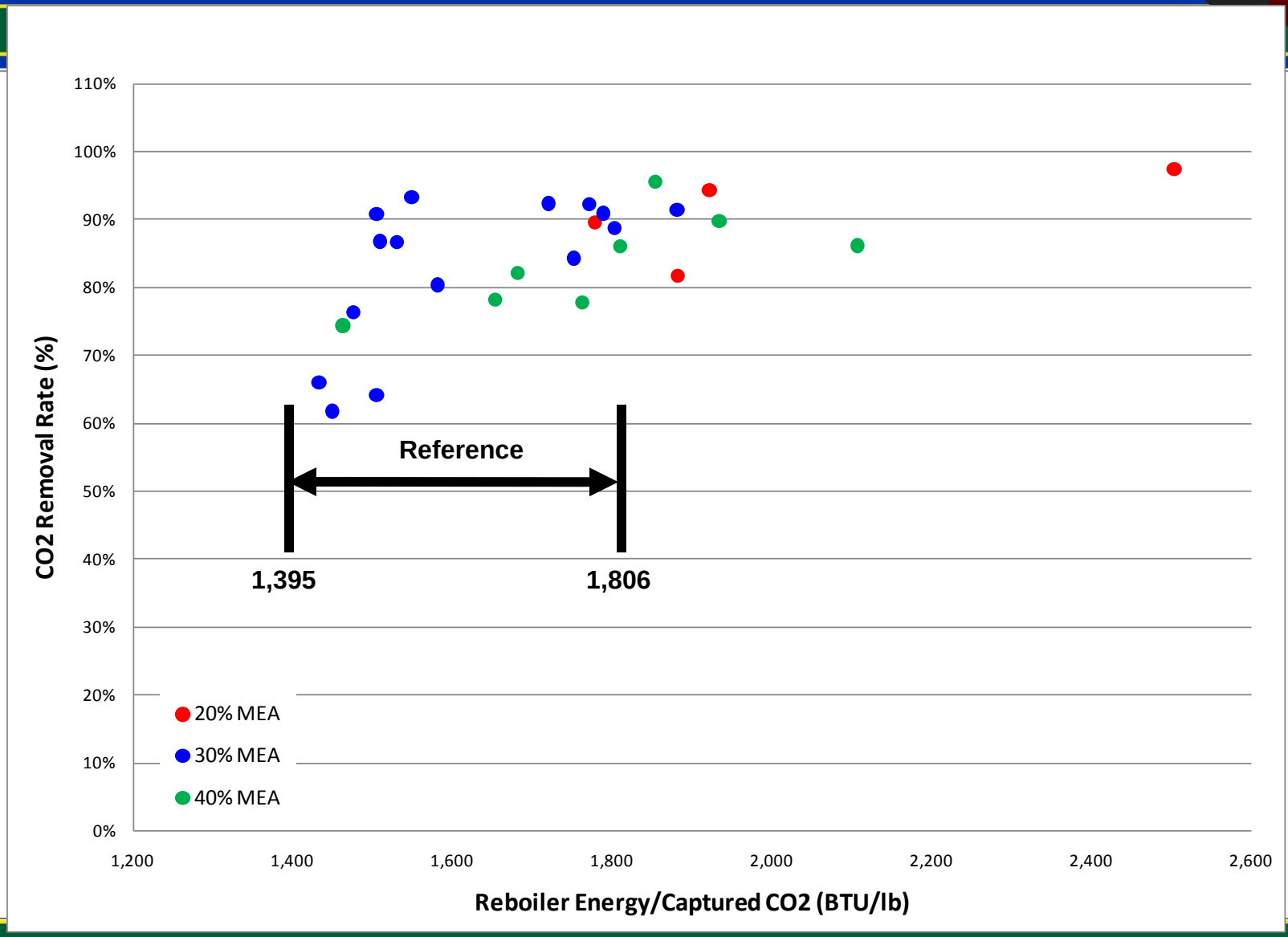


- Total 27 test cases
- 3 to 8 hour mass balance time periods for most cases
- CO_2 removal rate — 62 - 97%
- MEA concentration — 18 – 39wt% (20%, 30%, 40% nominal)
- Flue gas flow rate — 3,100 – 5,000 lb/hr
- Liquid flow rate — 12,500 – 27,500 lb/hr
- L/G ratio (liquid/gas) — 2.8 – 5.5 lb/lb
- Steam flow rate — 680 – 2,460 lb/hr
- S/L ratio (steam/liquid) — 0.04 – 0.12 lb/lb
- Lean CO_2 loading (Absorber inlet) — 0.12 – 0.34 mol/mol
- Rich CO_2 loading (Absorber outlet) — 0.37 – 0.55 mol/mol
- **CO_2 mass balance closure — 92 – 105%**
- Flue gas composition at Absorber inlet (vol%, wet):

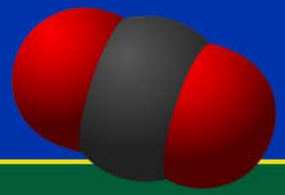
  H_2O = 6.3 – 7.3 O_2 = 4.6 – 7.1 CO_2 = 11.4 – 12.9

  SO_2 < 1 ppmv No CO_2 removed by caustic in Pre-Scrubber

Baseline Test - Reboiler Energy



Baseline Test – MEA Losses



- Preliminary results: analytical procedures still in development.
- Short duration of test did not warrant reclaimer operation
- MEA losses in the gas phase measured < 10 ppm
- One nitrosamine compound (nitrosomorpholine) detected at parts-per-trillion level.
- Other compounds detected at parts-per-billion level:
  - Formaldehyde, Acetaldehyde, Butylaldehyde, Ethylamine, and Dimethylamine.
- All compounds detected well below OSHA Permissible Exposure Limits.
- This type of sampling needs to be done with other solvents and other operating conditions to better understand causes and potential methods of emission control.

Baseline Test - Lessons Learned

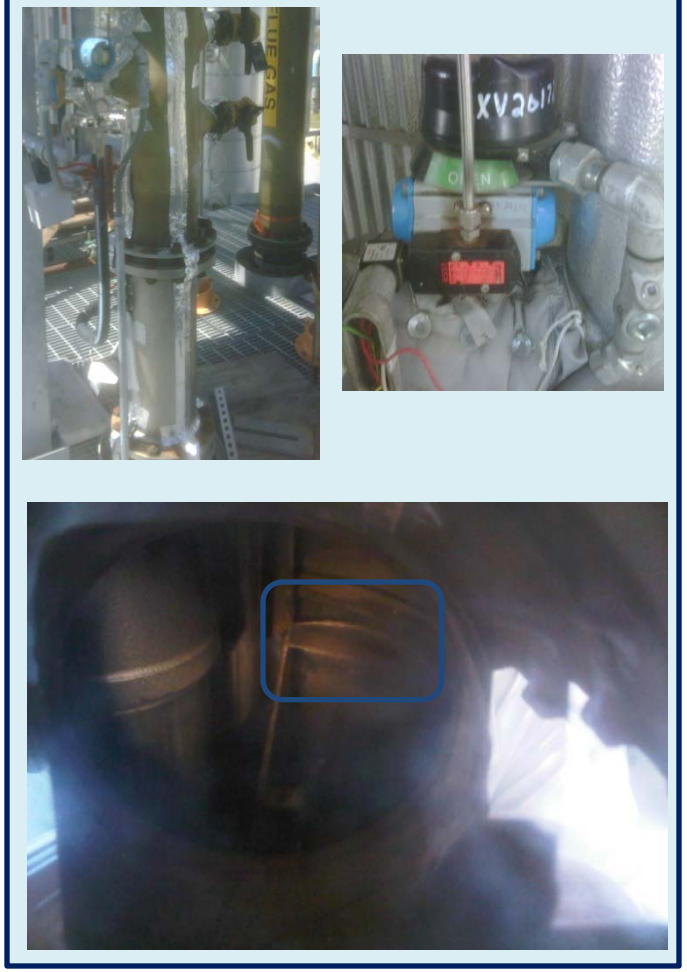
Operations

- System cleanup – solvent filtration
  - Three days to clean-up particulate from piping
- Water balance
  - Requires close monitoring, controls installed to automate water transfers
- Power plant interaction
  - Utility supplies, boiler operations
- SO_2 removal in pre-scrubber below 1 ppm with negligible CO_2 removal
- Regenerator condenser overhead controls a challenge
  - May modify condenser level control
- MEA losses from wash tower

Baseline Test - Lessons Learned

Equipment

- Gas flow transmitters
  - Impulse line modification
- Differential pressure measurement on packing bed
- Storage of equipment before run
  - Solenoid valves had to be overhauled
- Pump seal design
  - Threaded connections prone to leak
  - Filtration too close to system filtration
- Plate frame design
  - No low point drain
- Liquid distribution in absorber
  - Suspicious temperature profile
- Insulation and heat tracing capability
  - Stable temperatures ~110 F during shutdowns

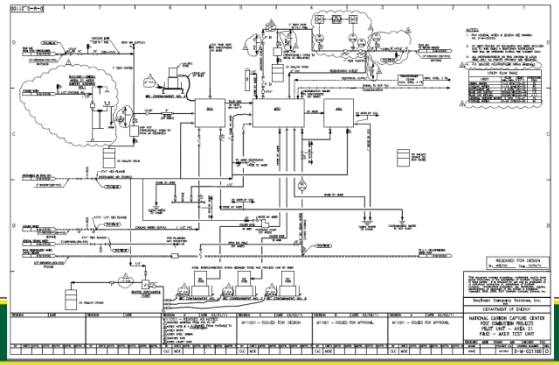


PSTU Outage Work

- Modifications for B&W Solvent
  - Instrumentation and piping changes
- Plate/Frame heat exchanger drain
- Absorber and regenerator packing change-out
  - From 304SS to 316SS per original spec
- Electrical upgrades
- MTR connections
- Second instrument air compressor
- FTIR probe upgrades
- Instrument improvements

Aker Mobile Test Unit

- Solvent-based mobile test unit in 2nd bay
- Previously tested at power plant in Scotland
- 0.25 MWe capacity
- At PC4, first 24-hour operation
- Testing underway



MTR Membrane Technology

- Membrane Technology & Research (MTR) CO_2 membrane skid
- 50 kW/1 tpd CO_2 Capacity
- Previous testing at 3 sites
- Provides data for larger scale test unit

MTR

PC4 Test Plan

2011Testing

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PSTU	Commissioning		Baseline Test						B&W Solvent			
2nd Bay					Aker MTU							
Bench 1									MTR Membrane			
Bench 2									Codexis*			
Bench 3												
Bench 4												
BOP						2nd Air compressor and Electrical Upgrades						

**Negotiating Codexis Contract*

Potential Technology Developers for 2012 and 2013

Solvent Developers

B&W power generation group

CHIYODA CORPORATION

HITACHI Inspire the Next

ION ENGINEERING

3H

Process Development

Aker CleanCarbon

Advanced Membranes

MTR

AIR LIQUIDE

Enzymes

CODEXIS

AKERMIN