Fourth Annual Conference on Carbon Capture & Sequestration

Developing Potential Paths Forward Based on the Knowledge, Science and Experience to Date

Capture and Separation – Oxyfuel Combustion

The Potential for Clean Energy Production using Oxy-Fuel Combustion and Integrated Pollutant Removal

Ochs, Oryshchyn, Weber, Summers

May 2-5, 2005, Hilton Alexandria Mark Center, Alexandria Virginia

Abstract

Effective remediation of flue gas produced by an oxy-fuel coal combustion process has been proven at bench scale in the course of cooperative research between USDOE's Albany Research Center (ARC) and Jupiter Oxygen Corporation. All combustion gas pollutants were captured, including CO_2 which was compressed to a liquefied state suitable for sequestration. Current laboratory-scale research and the future of combined oxy-fuel/IPR systems are discussed.

Albany Research Center
Office of Fossil Energy, U.S. Dept of Energy

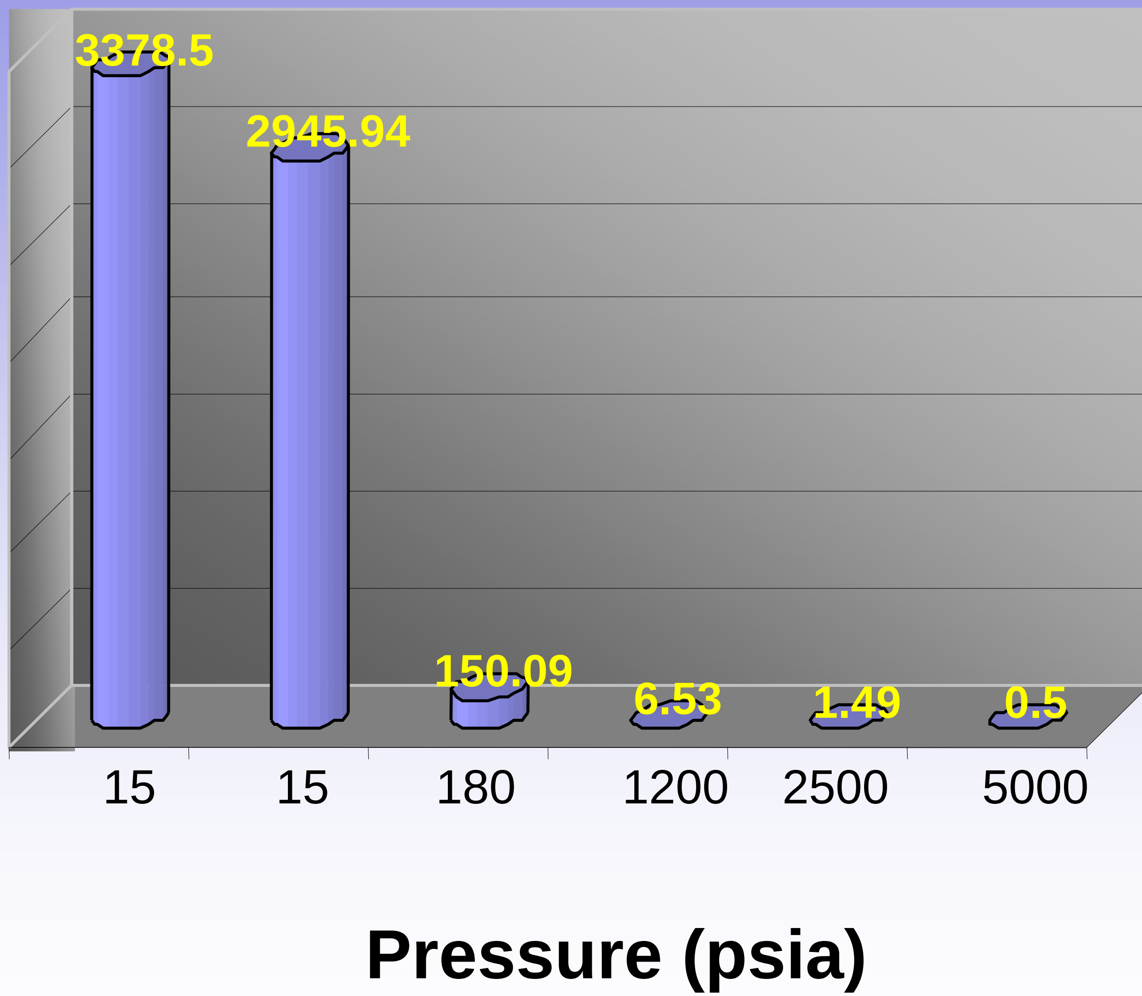
Background

- Project evolved from CO_2 sequestration research started in 2000
  - What can be done with available technology?
- Based on performance improvement principles used in a power plant performance improvement program in Indonesia

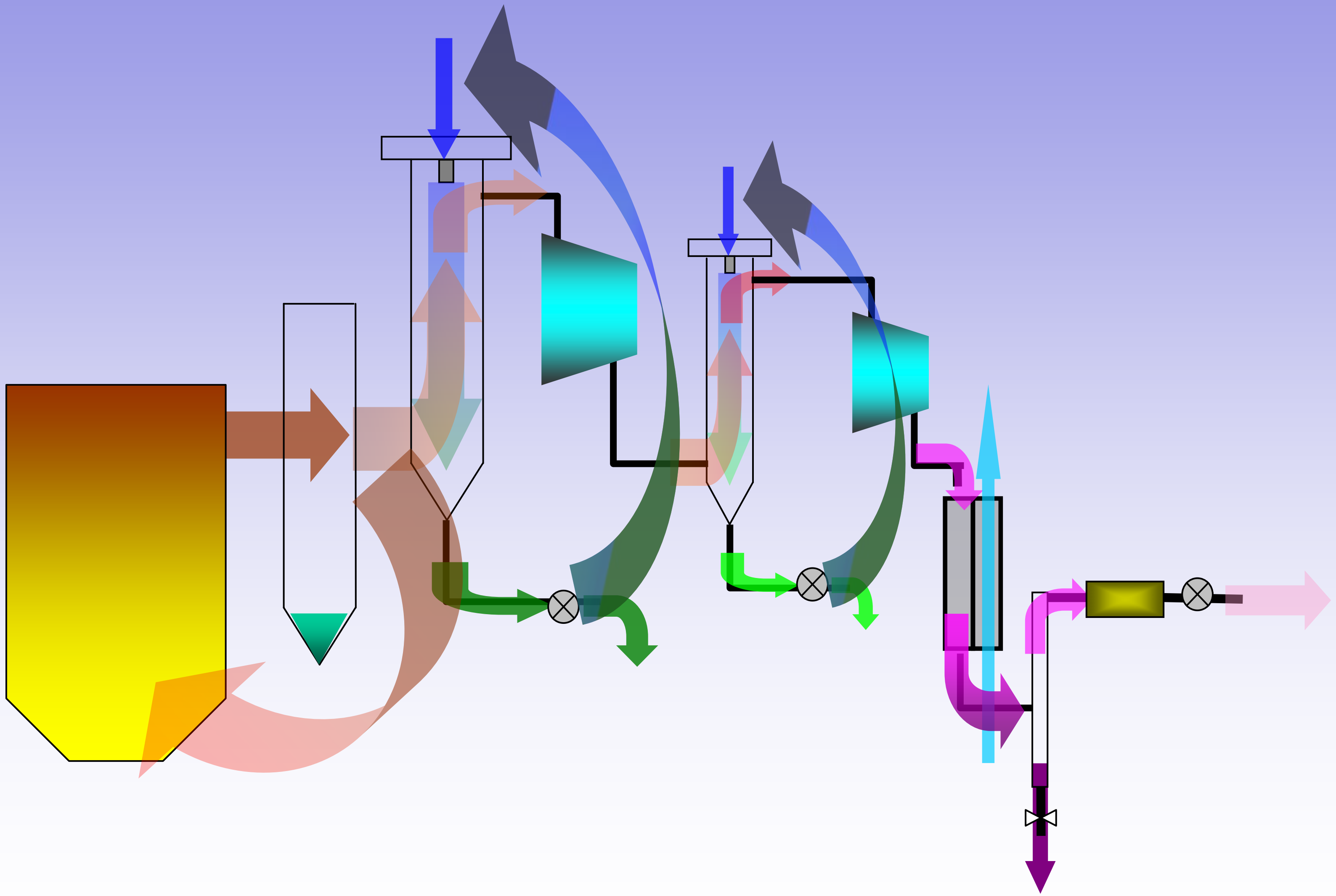
IPR Goals

- Remove all pollutants from a fossil fuel flue-gas stream.
- Produce liquid CO_2 suitable for sequestration
- Power generation thermal efficiency above 33%
- Incur minimal additional cost
- Use off-the-shelf technologies

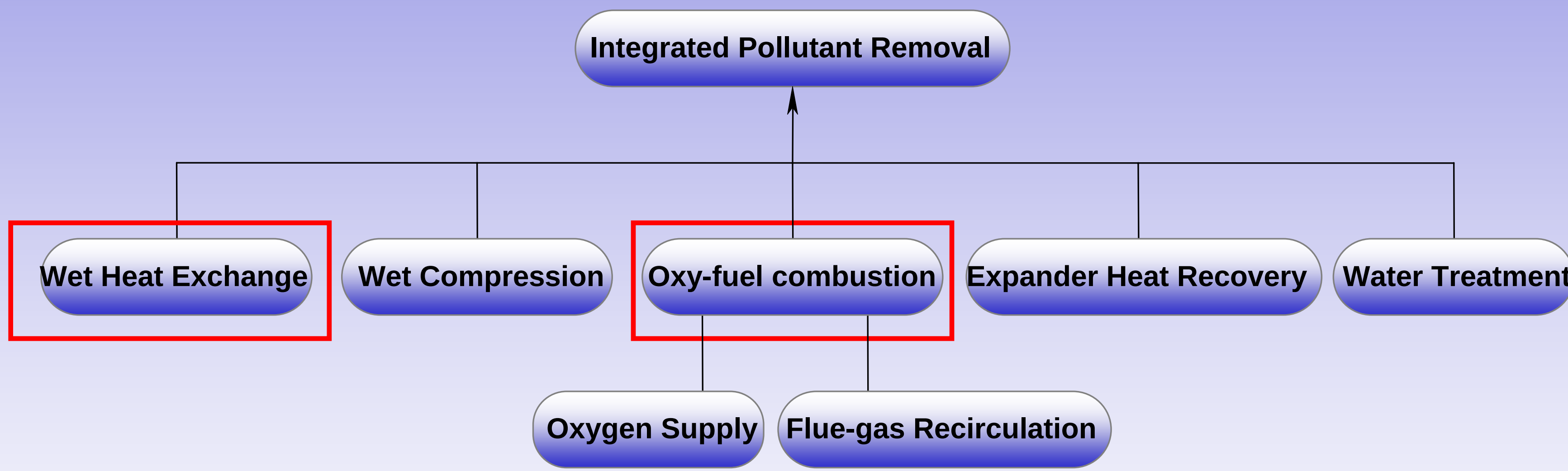
Volumetric Flow Rate (ft^3/s)



Overview of IPR



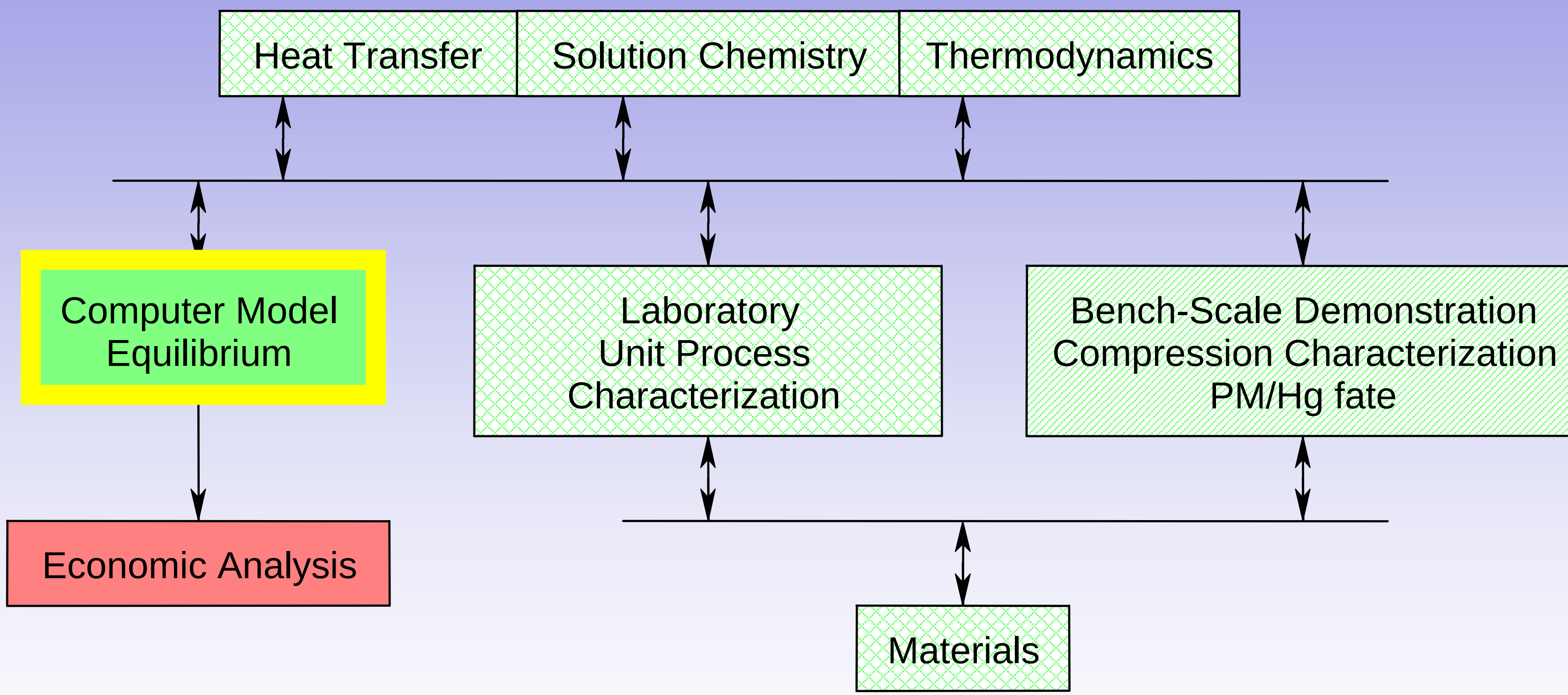
Enabling Technologies



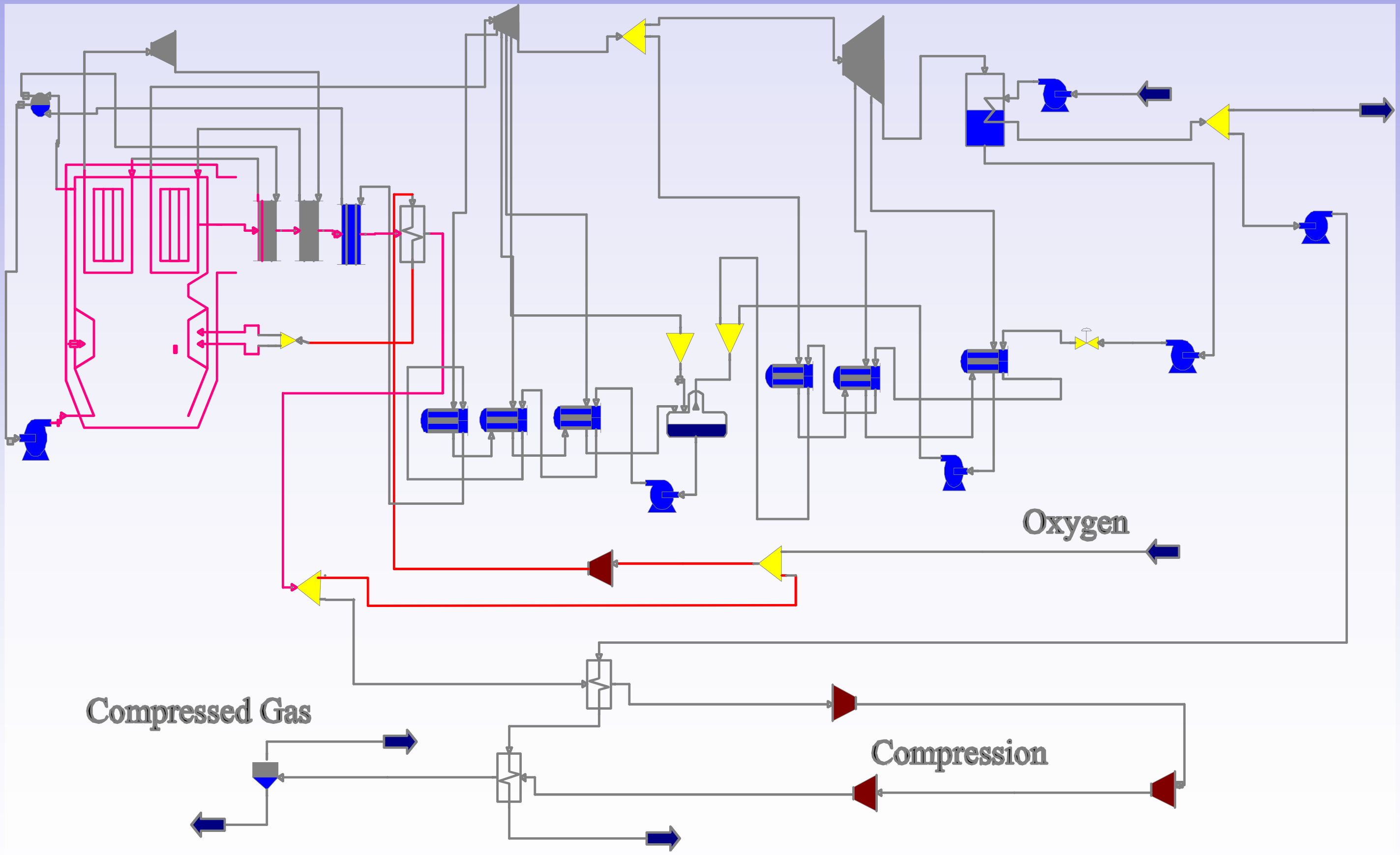
CRaDA with Jupiter Oxygen

(**C**ooperative **R**esearch **a**nd **D**evelopment **A**greement)

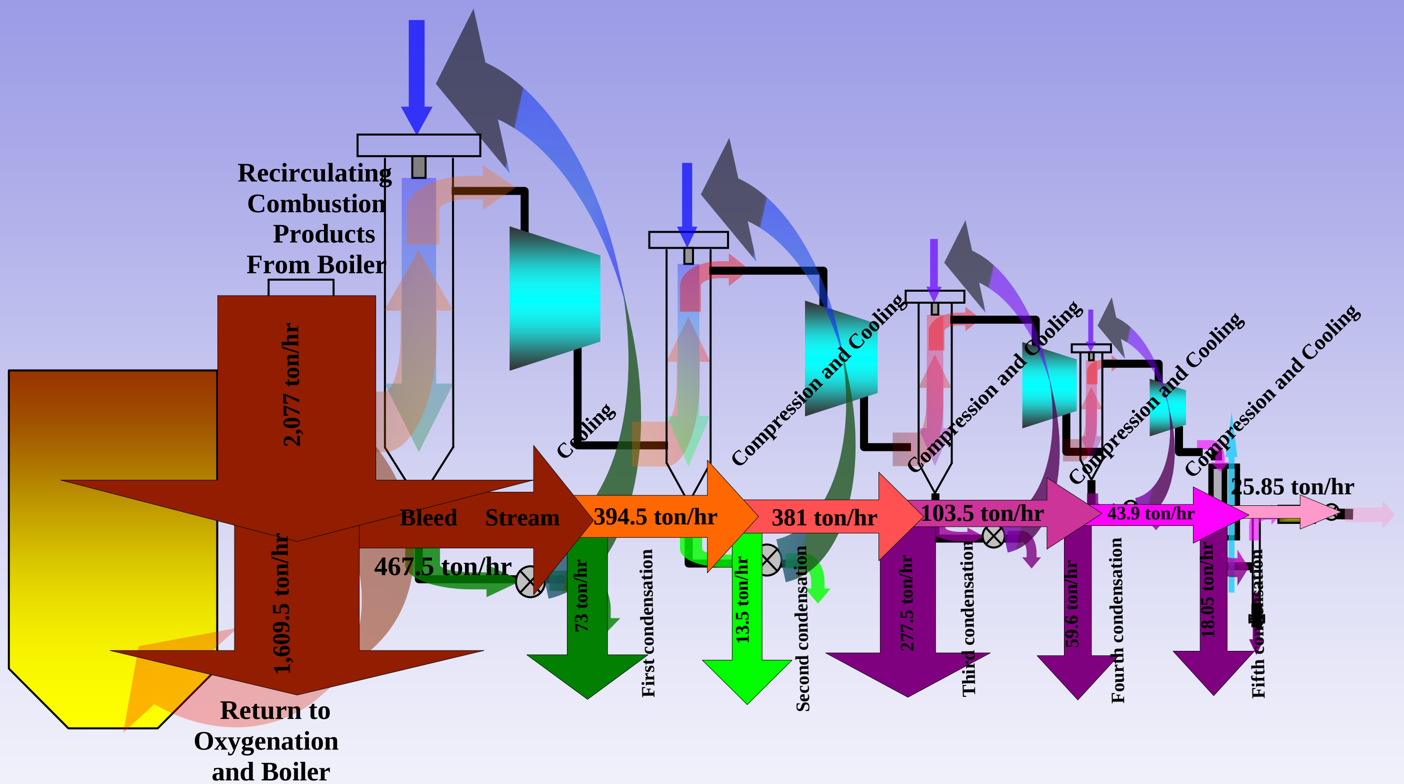
- Proven proprietary oxy-fuel system for aluminum melting
- Experience in oxygen production and burner technology
- Applying oxy-fuel to power generation
- Help fulfilling IPR’s need for oxy-fuel system


Heat Transfer
Solution Chemistry
Thermodynamics
Computer Model
Equilibrium
Laboratory
Unit Process
Characterization
Bench-Scale Demonstration
Compression Characterization
PM/Hg fate
Economic Analysis
Materials

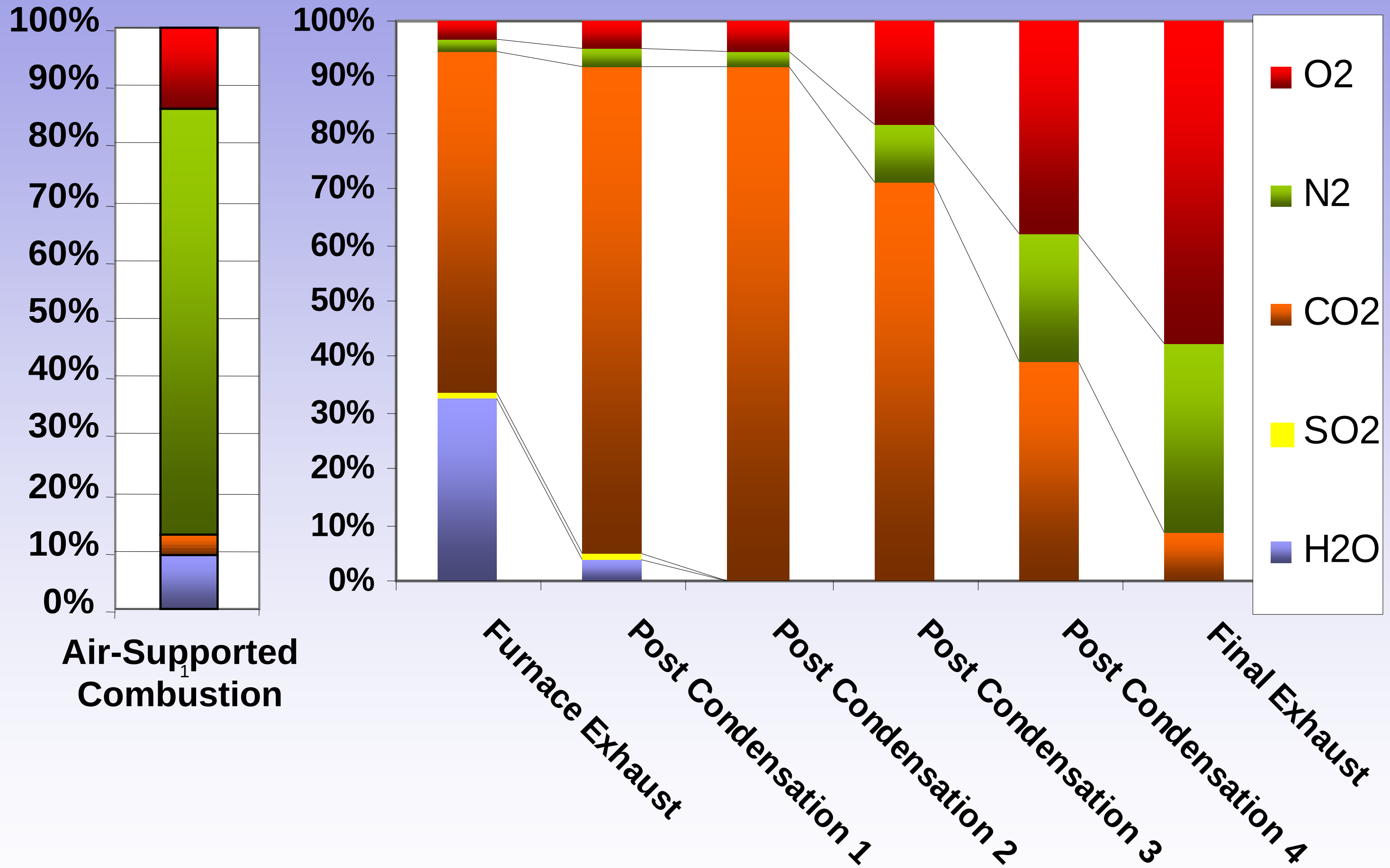
Parametric computer model of wet flue-gas heat exchanger

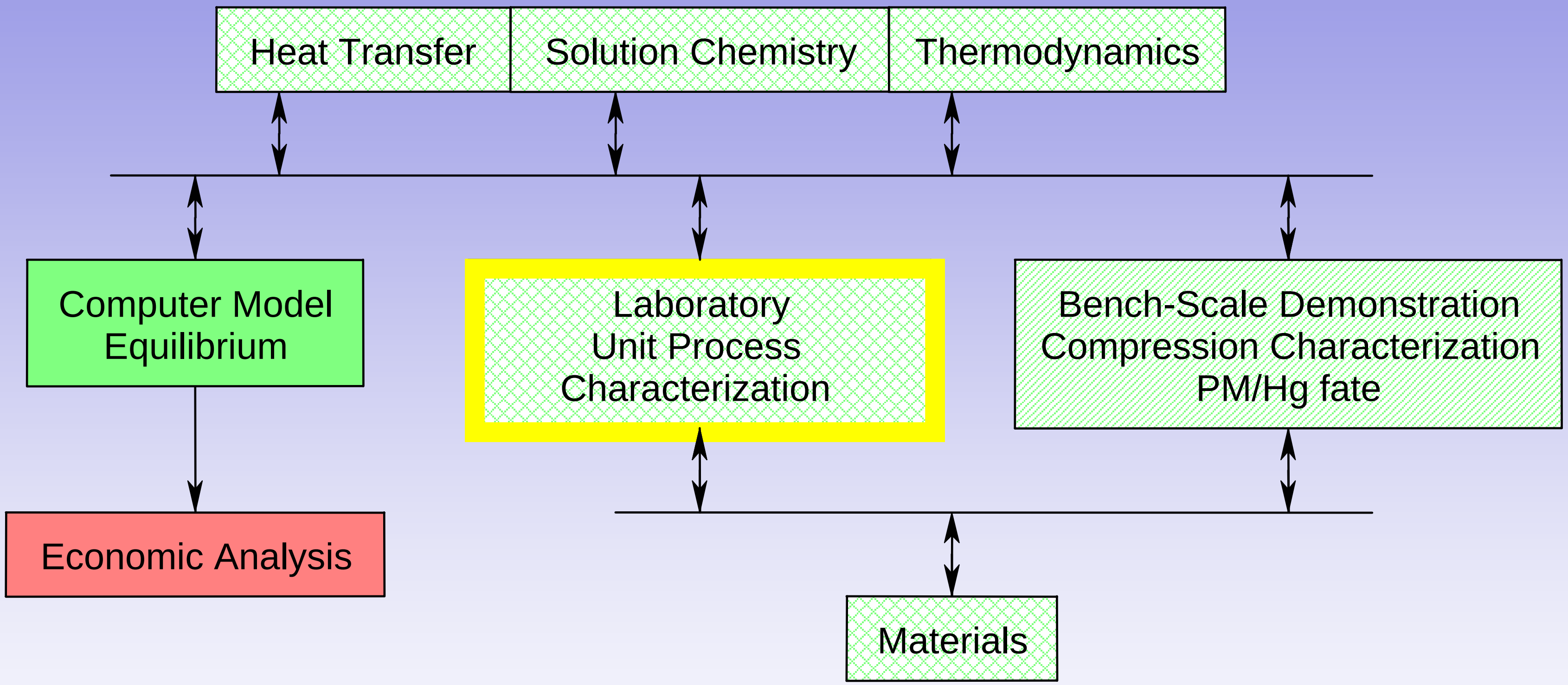


Compression/Extraction



Progressive Composition of Exhaust

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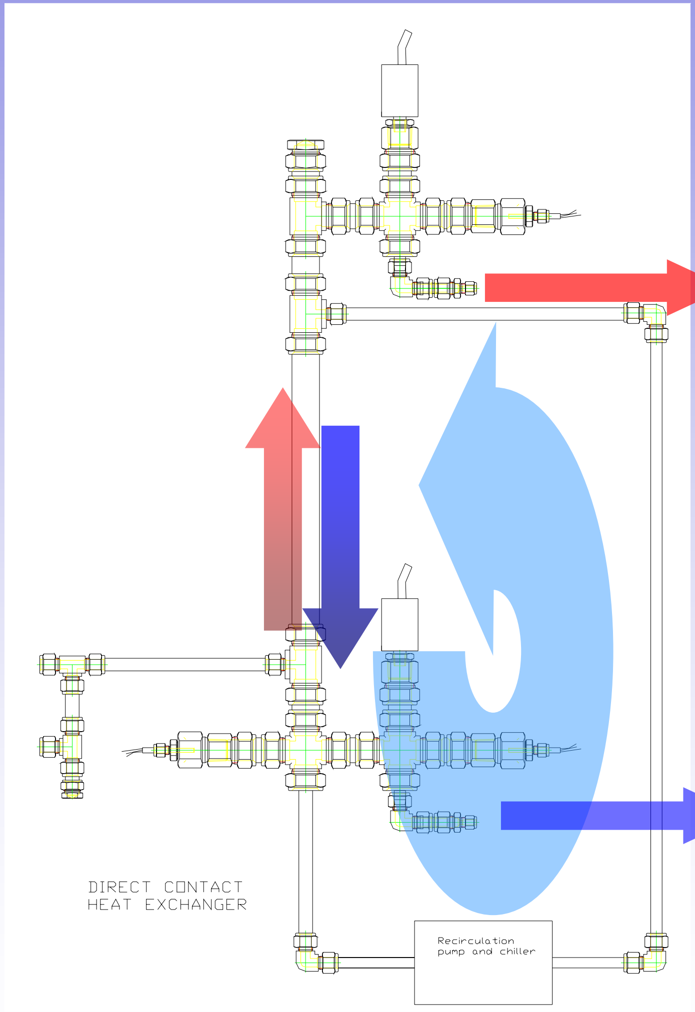
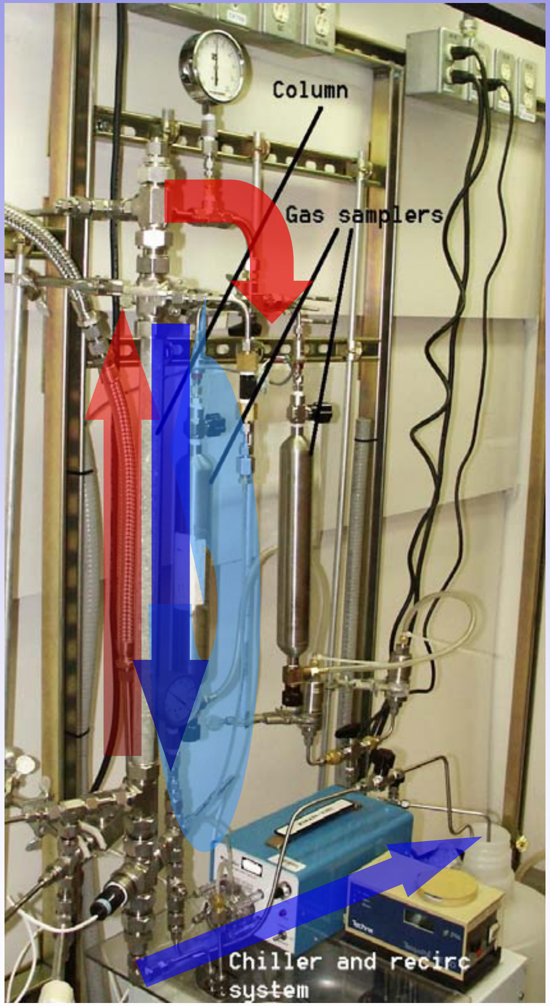
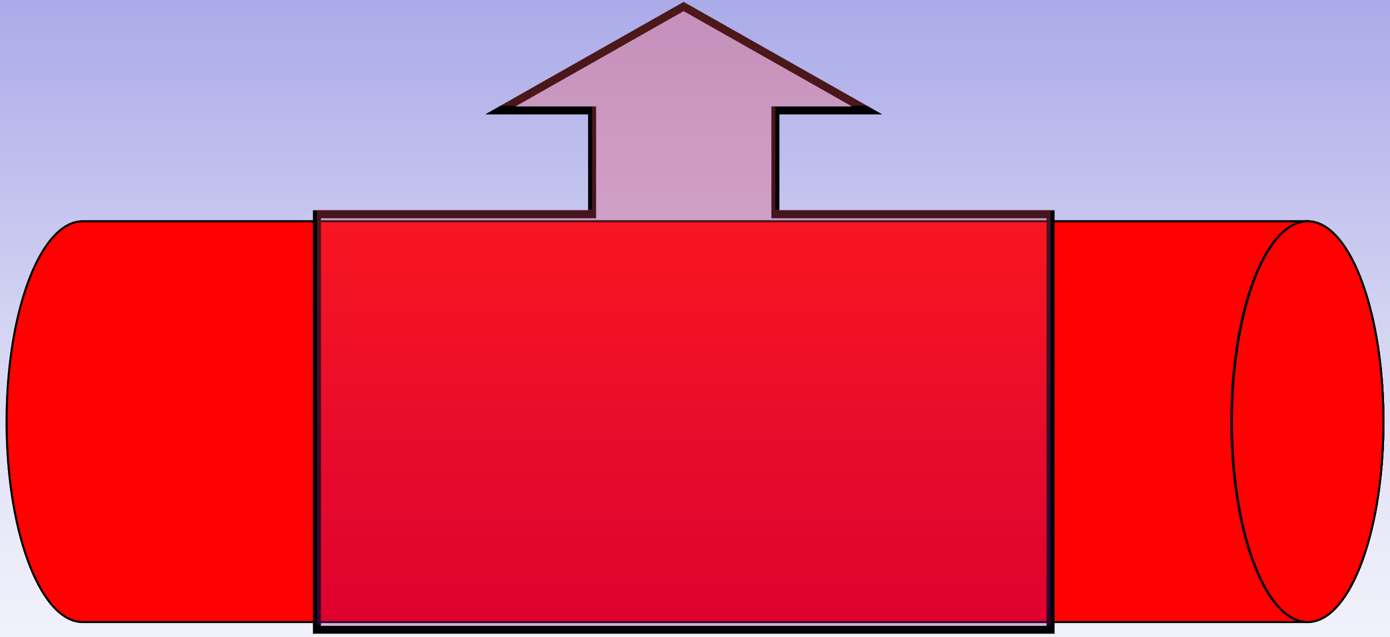
Laboratory Column Model

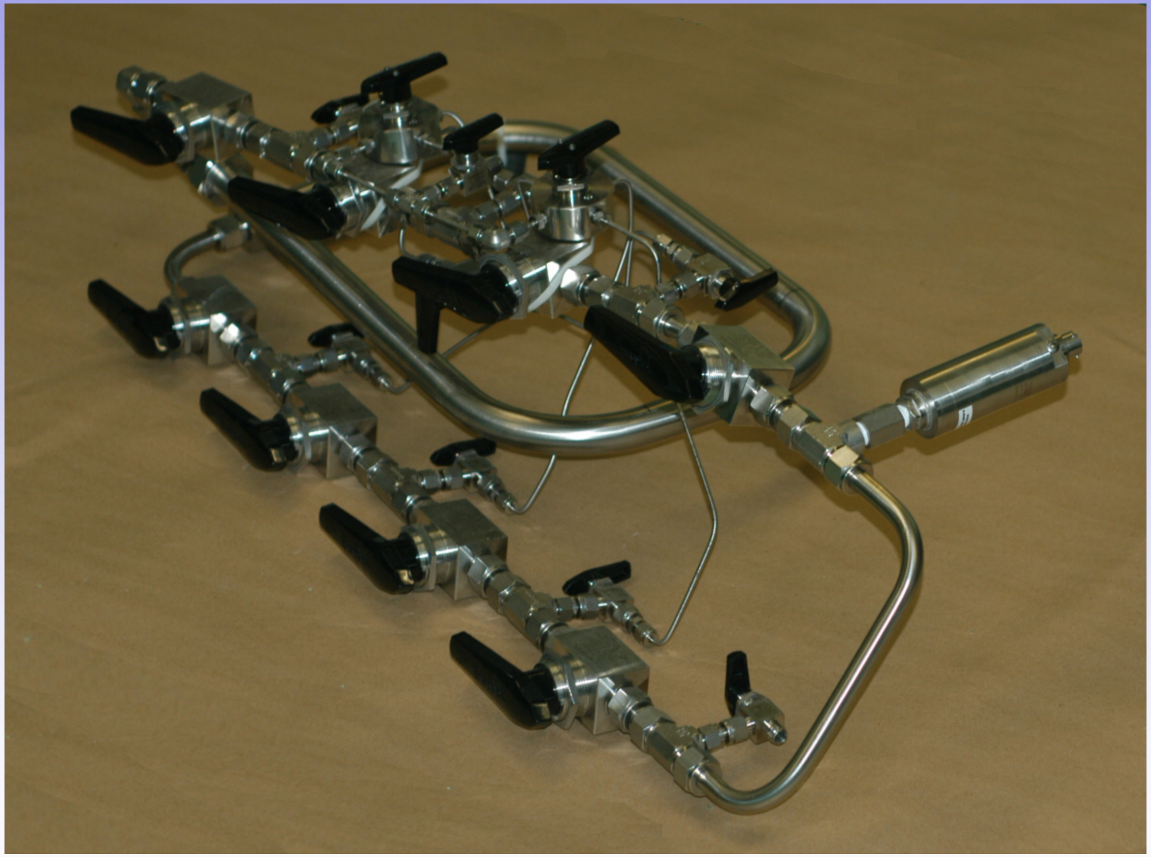


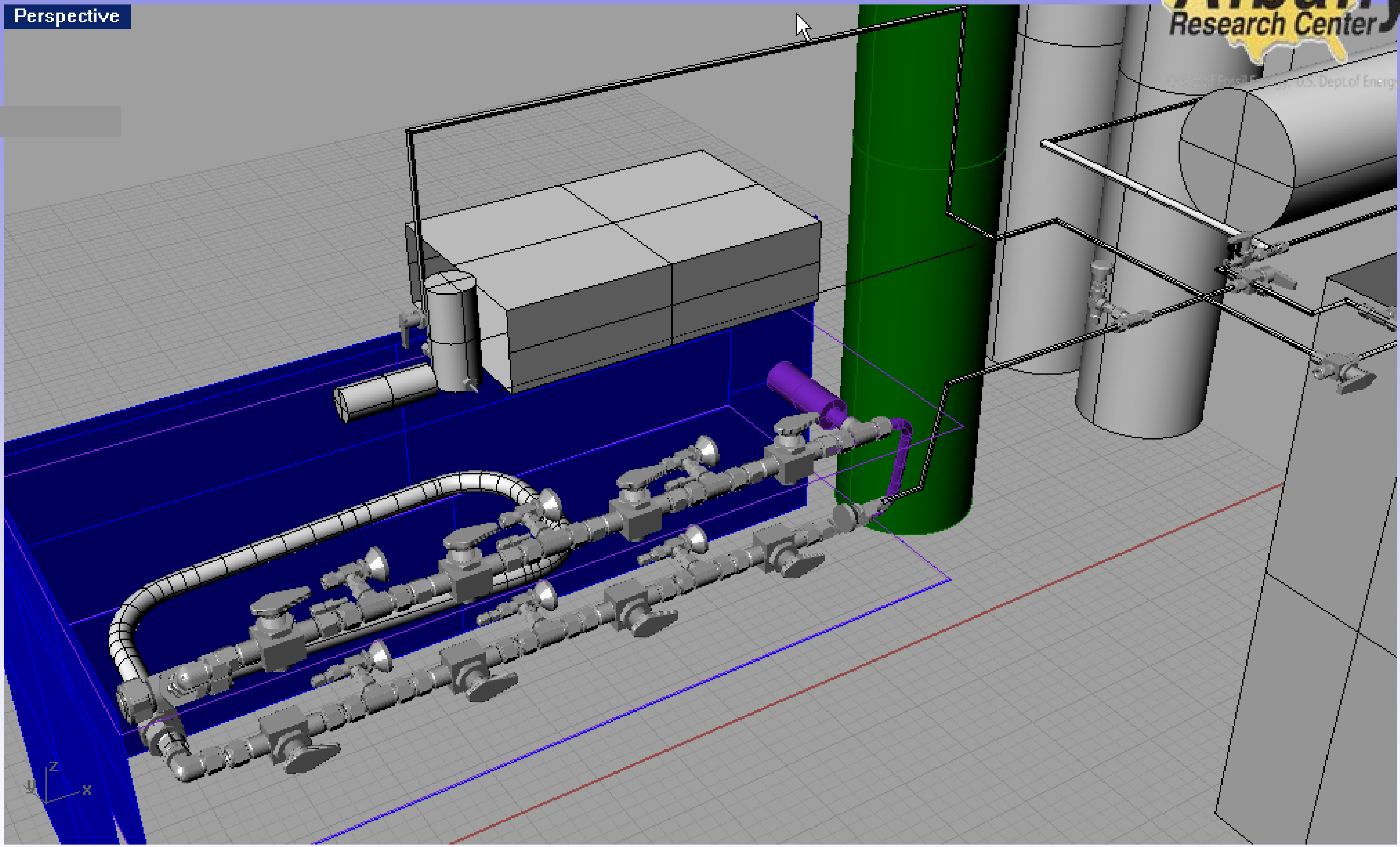


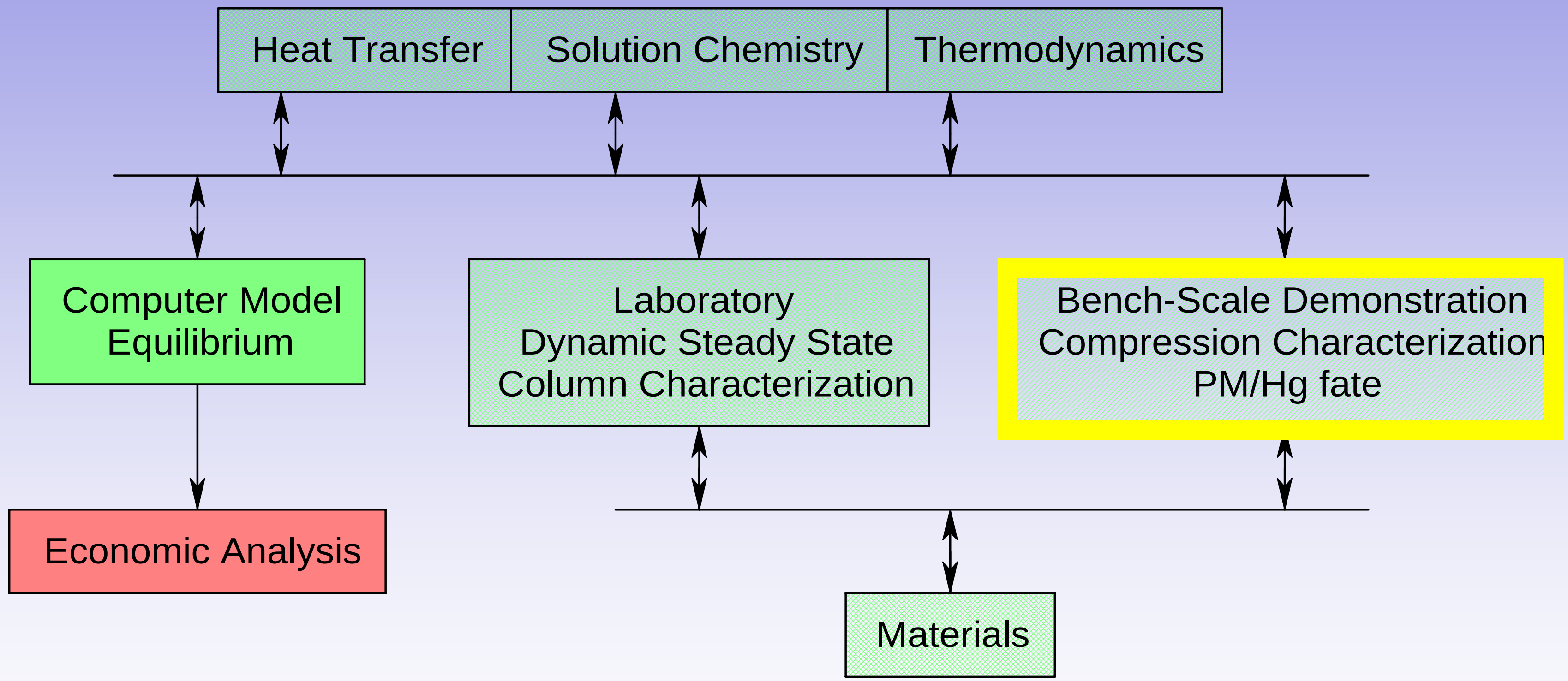
$N_2/O_2/CO_2$ Phase Distributions



Near Critical Phase Distribution

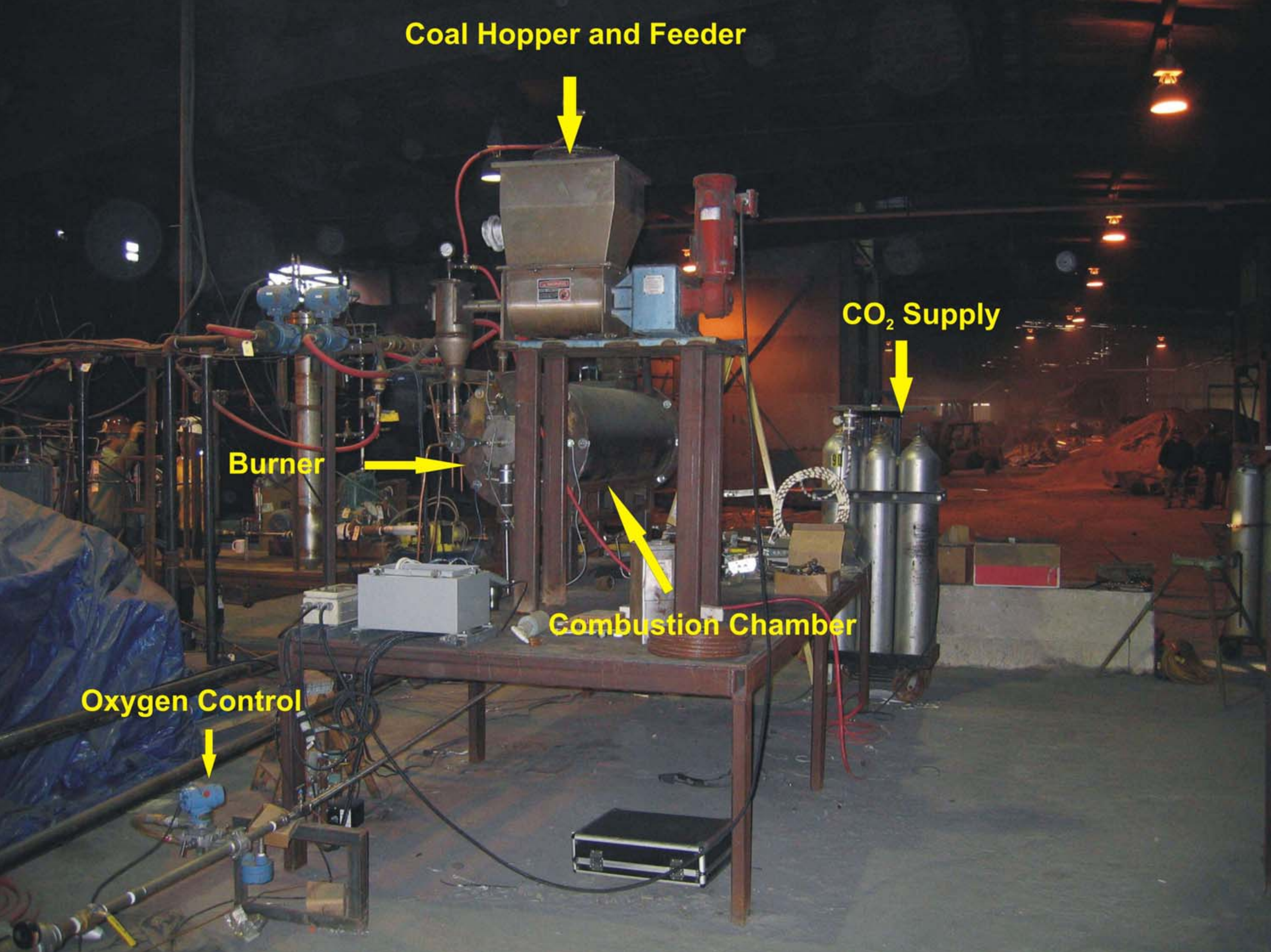


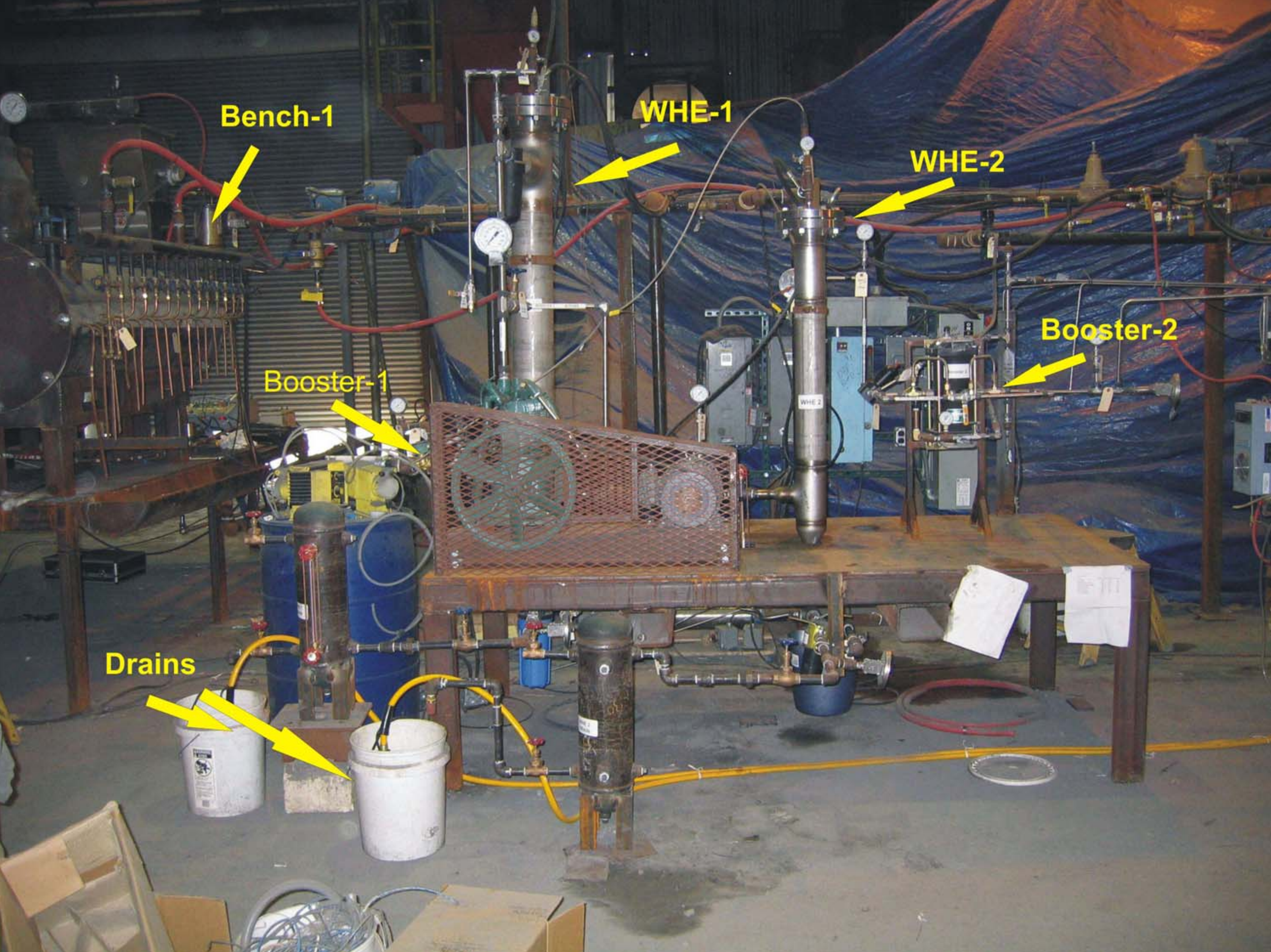

Perspective


Heat Transfer
Solution Chemistry
Thermodynamics
Computer Model
Equilibrium
Laboratory
Dynamic Steady State
Column Characterization
Bench-Scale Demonstration
Compression Characterization
PM/Hg fate
Economic Analysis
Materials

Proof of Concept

- Challenge from Jupiter 8/5/04
- Acceptance of challenge 8/22/04
  - Off the shelf equipment
  - Primary air recirculation (oxy-fuel)
  - No applied heat recovery
- Beginning of detailed design 8/15/04
- Beginning of construction 8/30/04
- Successful operation 11/3/04


Coal Hopper and Feeder
CO2 Supply
Burner
Combustion Chamber
Oxygen Control



Bench-1
WHE-1
WHE-2
Booster-2
Booster-1
Drains
WHE 2


WHE-3
Booster-3
Booster-4
Bench 2
Accumulator
Liquid CO_2
Collection Cylinder

Results

- > 99% of SO_2 removed
- All flue gas condensable at 1,500 psia
- Hg capture volume reduced as predicted
- All particulates removed from system

Integrated Pollutant Removal – Summary

- Oxygen + flue-gas as combustion “air”
- Remove all pollutants and acid gases through compression and condensation
  - Remove coarse particulates and particle bound Hg (filtration)
  - Concentrate condensables and pollutant gases
  - Condense and remove H_2O and CO_2
    - Entrain particulates with fine particle bound Hg^{2+}
    - Dissolve and react SO_x, NO_x, Hg^{2+}
  - Decrease volume flow rate through compression and condensation
    - Increase relative volume of Hg^0
- Recover energy through heat transfer and expansion

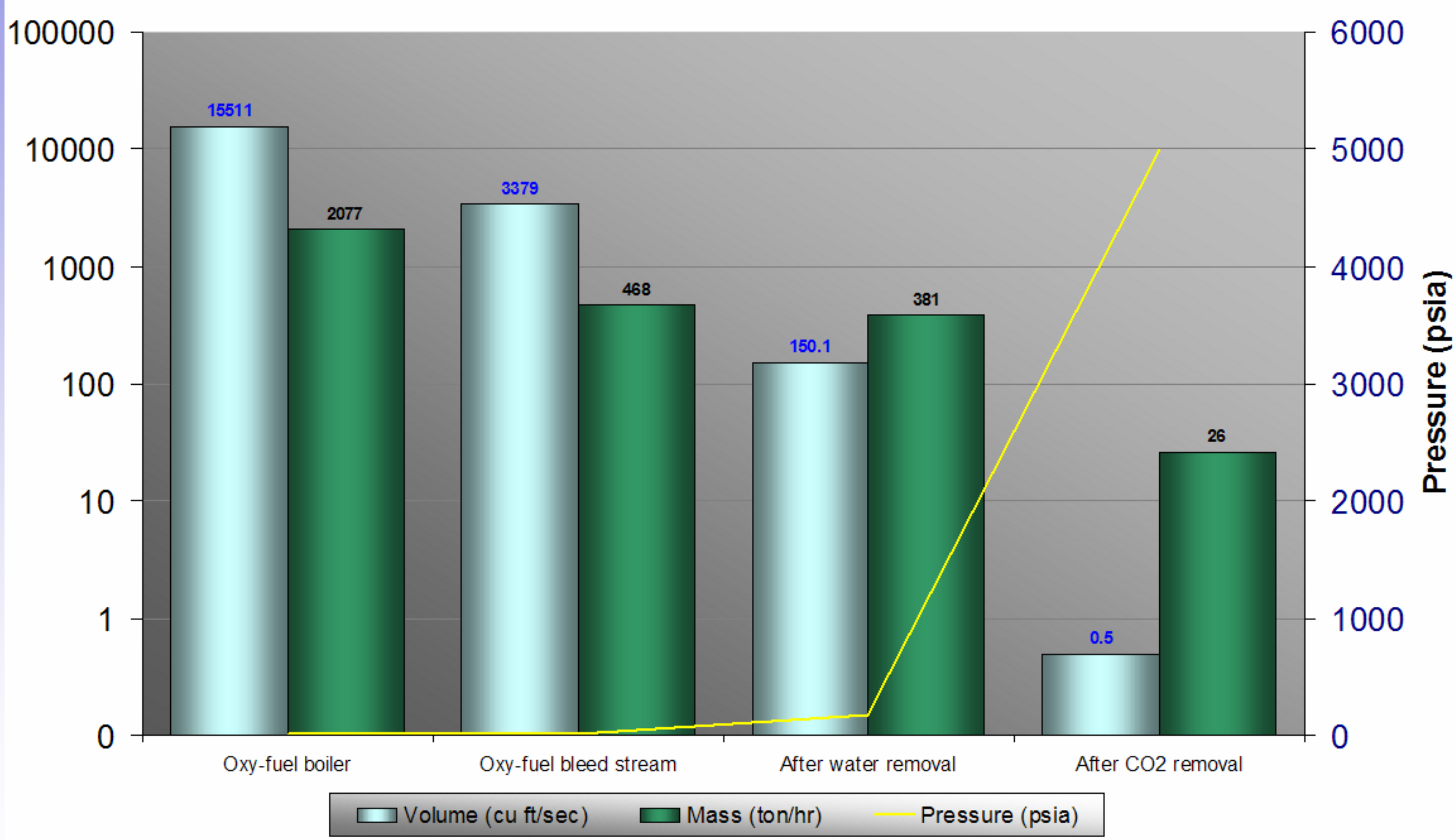
Future Work

- Increased Scale
- Scrubbing
- $N_2/O_2/CO_2$ phase distributions
- Column Characterization
- Materials testing

Thank you for your attention.

Albany Research Center

Characteristics of the Flue Gas Stream



Oxygen Costs For 400 MW Coal Plant

Capital cost: $160,000,000 ($20,000/ton/hr/day)

Power Required for Operation

- 250 kWh/ton (Cryogenic)=> 82.5 MW (Used in model*)
- 235 kWh/ton (Cryogenic) => 77.55 MW
- 147 kWh/ton (Ion Transport Membrane)=> 48.51 MW

*330 ton/hr O_2

*153 ton/hr #6 Illinois Old Ben mine 26 coal