Integrated Pollutant Removal with Oxy-Fuel Combustion:
Current Technology Applied to CO_2 and Multi-Pollutant Capture

Danylo Oryshchyn, Tom Ochs, Brian Patrick, Steve Gerdemann, Cathy Summers, Jake Armstrong, Paul Turner, Mark Schoenfield, Thomas Weber

Fifth Annual Conference on Carbon Capture & Sequestration

May, 2006

National Energy Technology Laboratory

Office of Fossil Energy

What is Integrated Pollutant Removal?
IPR

- **A means for achieving ultra-low emissions from a fossil-fuel burning power plant**

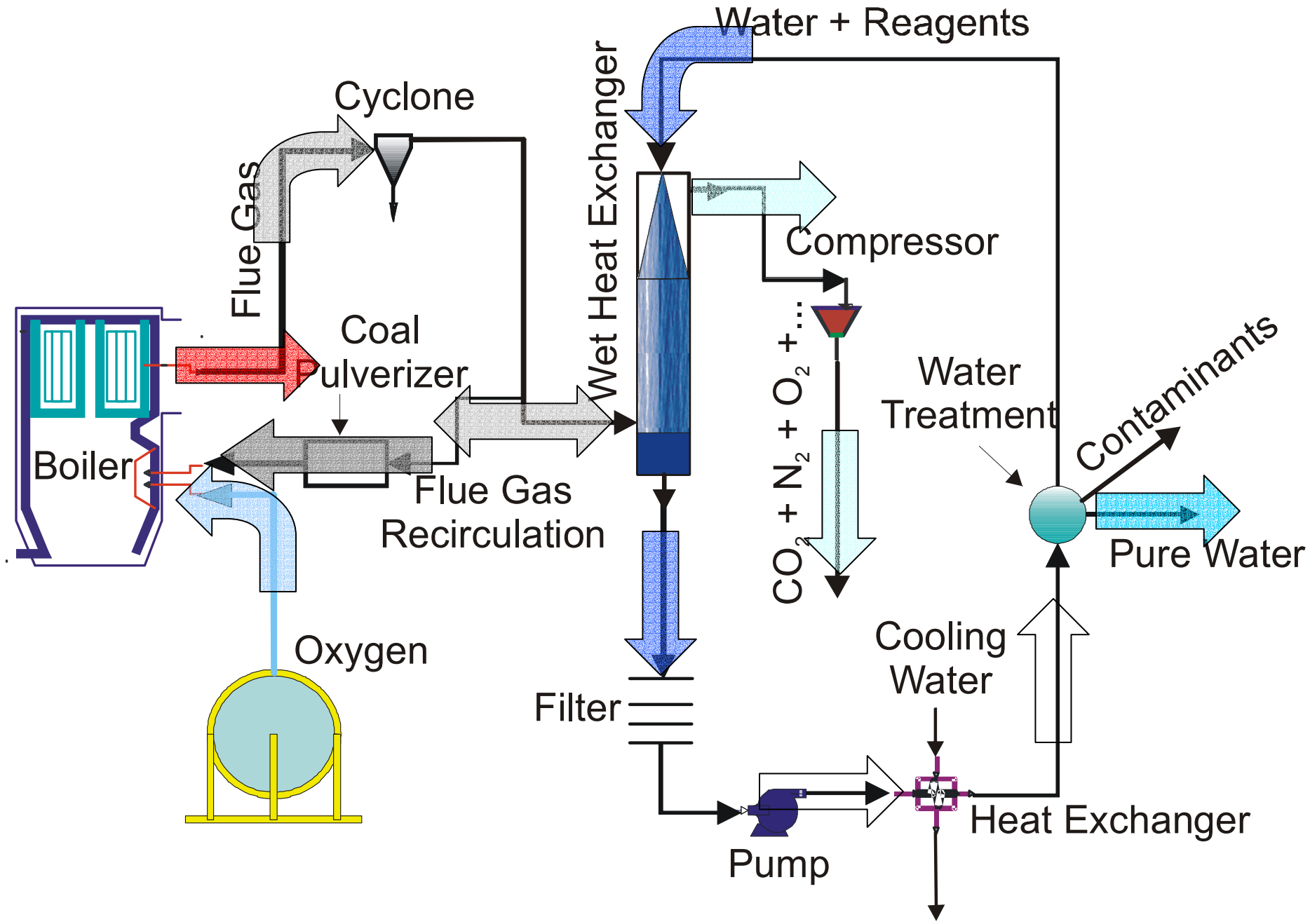
- **Capture ALL pollutants**
  - SO_X
  - NO_X
  - Particulates
  - Hg
  - And CO_2

Integrated Pollutant Removal

- **Goals**
  - Remove all pollutants including CO_2 from exhaust stream of power plants
  - Minimize cost of pollutant removal
  - Use existing technologies
- **Reality**
  - CO_2 removal adds to cost of any power generation scheme
  - There is no driver for CO_2 removal without some form of incentive
  - Appropriate technologies exist

The 2 Parts of IPR

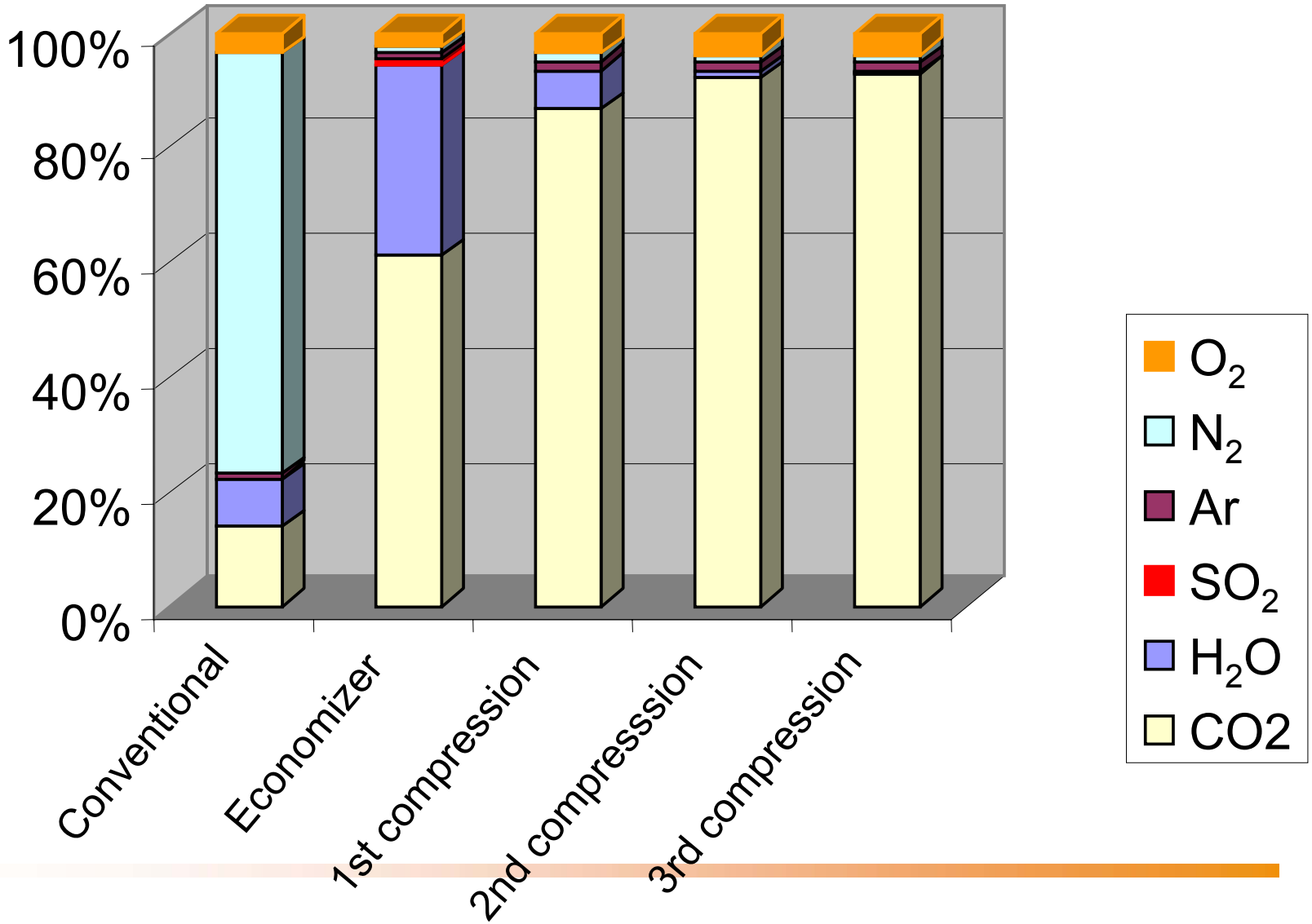
- **Create a suitable boiler exhaust**
  - Oxy-fuel combustion
    - Recycle flue gas and add oxygen
      - Changes exhaust composition
      - High CO_2 and H_2O; low N_2 and NO_X
    - Bleed stream is treated
- **Capture steps**
  - Filtration
    - Particulates and associated Hg
  - Compression and/or condensation
    - Fine particulates
    - Acid gases
    - Water and other condensables
    - Hg


Water + Reagents
Cyclone
Flue Gas
Wet Heat Exchanger
Compressor
Coal
Pulverizer
Boiler
Flue Gas
Recirculation
$CO_2 + N_2 + O_2 + \ldots$
Water
Treatment
Contaminants
Pure Water
Oxygen
Cooling
Water
Filter
Pump
Heat Exchanger

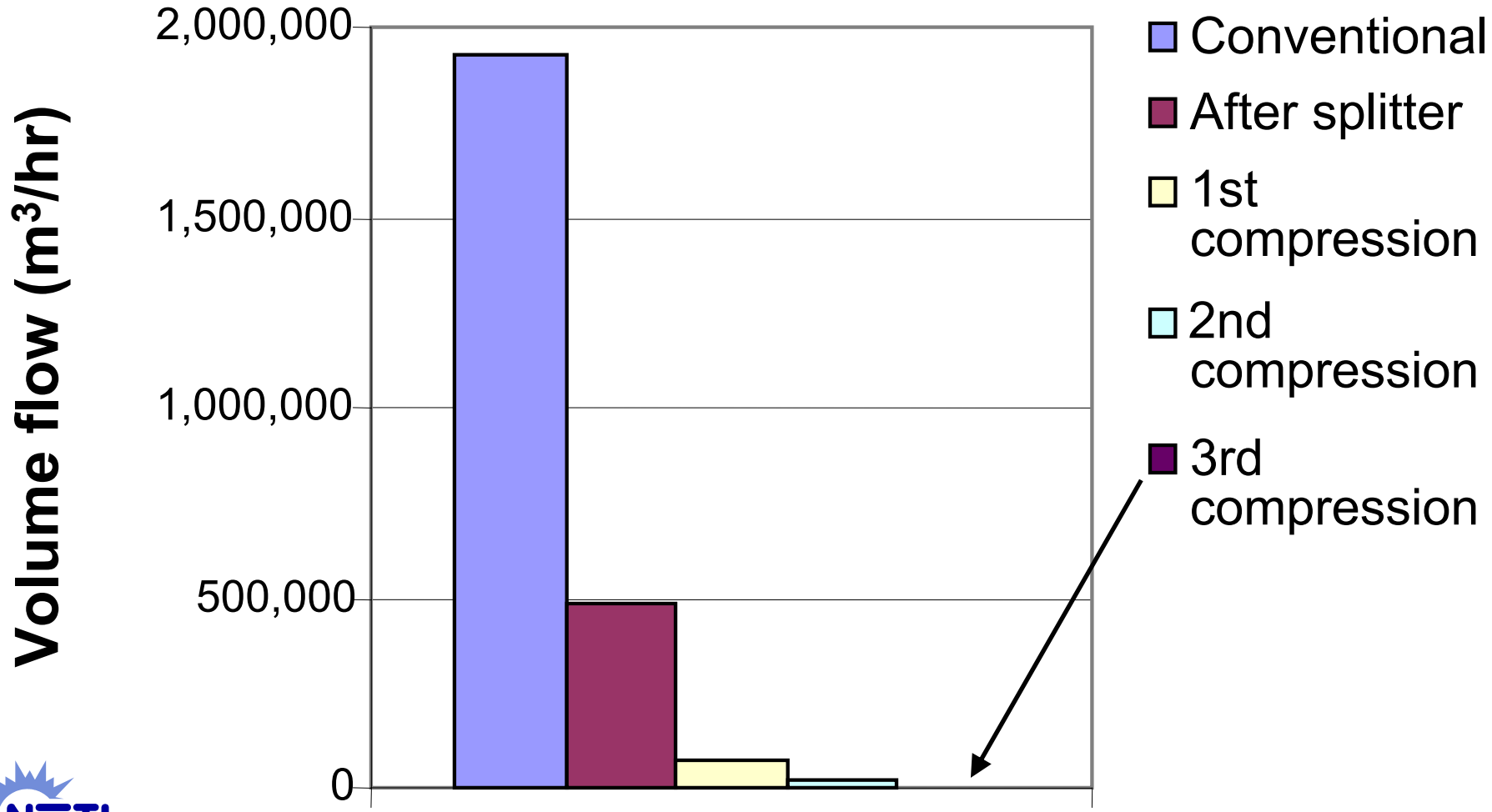
Computer Modeling
with GateCycle

- **Recirculating flue gas system with oxygen supplementation**
  - 99+% capture of CO_2 from a bleed stream
  - Capture and reuse of latent and sensible heat through condensation of water
- **Modeled thermal efficiency declines by ~ 5% compared to mildly supercritical pc system (34%)**

Gas Compositions



Volume Reduction



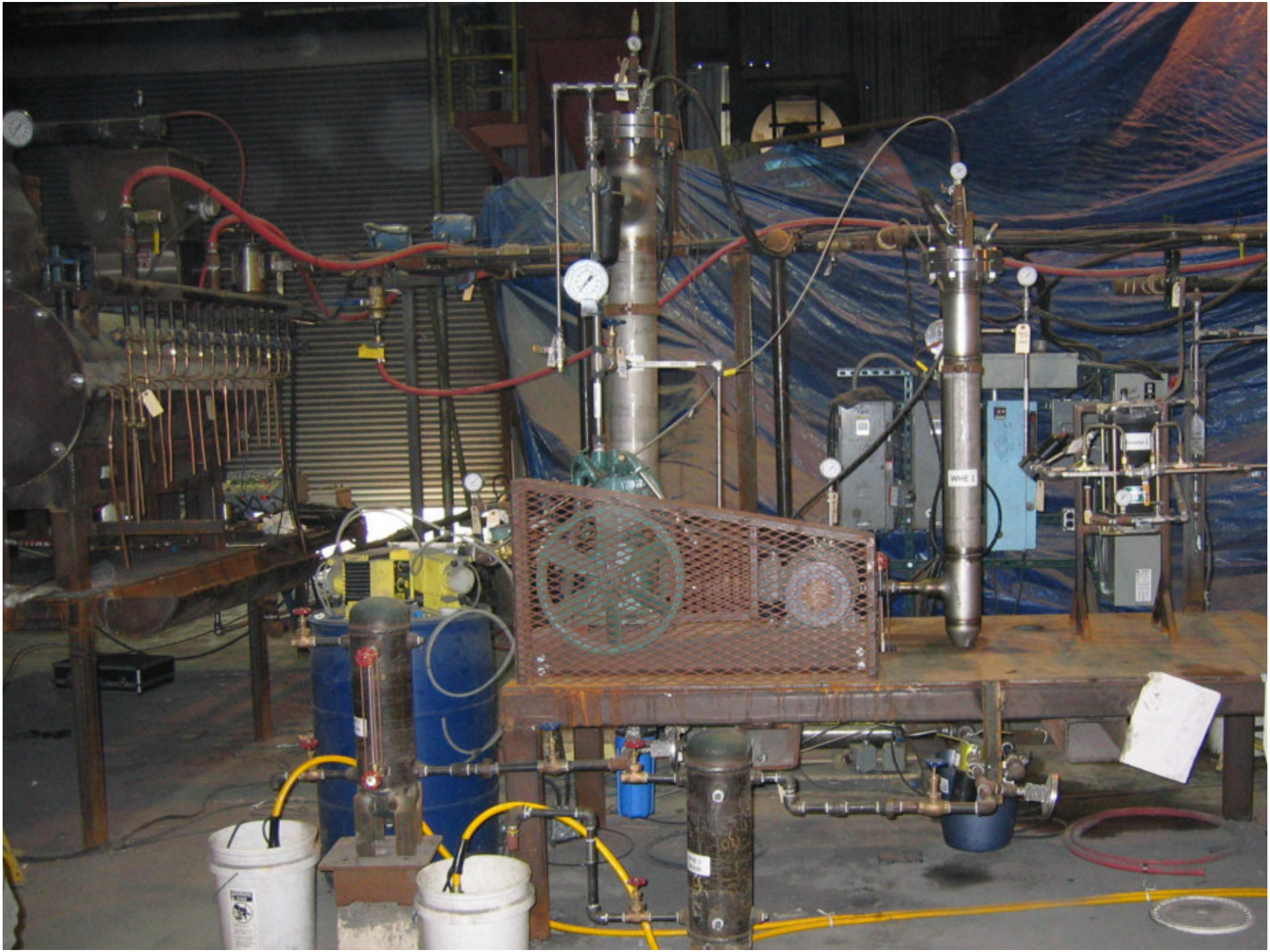
Benefits

- **Oxy-fuel combustion significantly reduces NO_X**
- **Compression and condensation decrease the volume flow rate**
  - Reduction in mass handled
  - Increase relative specific volume of Hg^0
- **Energy recovery through heat transfer improves thermal efficiency**

Proof of Concept

Demonstration with Jupiter Oxygen Corp.

- **Built and operated working oxy-fuel combustor and IPR system with CRADA partner (November 2004)**




WHE 3
Booster 3
BOOSTER 4
GAS OUT

Proof of Concept Test Results

- **0.088 lb/mmBtu NO_X in offgas**
- **All gas captured ~ 1500 psi**
- **Off-gas cleaned of SO_2**
  - Mass balance unsatisfactory
- **Incomplete removal of Hg**

Issues

- **Cost of Oxygen for oxy-fuel combustion**
  - CRADA partner Jupiter Oxygen expertise
- **Best capture method for SO_2**
- **Mercury capture**
  - What will be an effective capture technology for elemental mercury?
- **What product was captured?**

Product of IPR

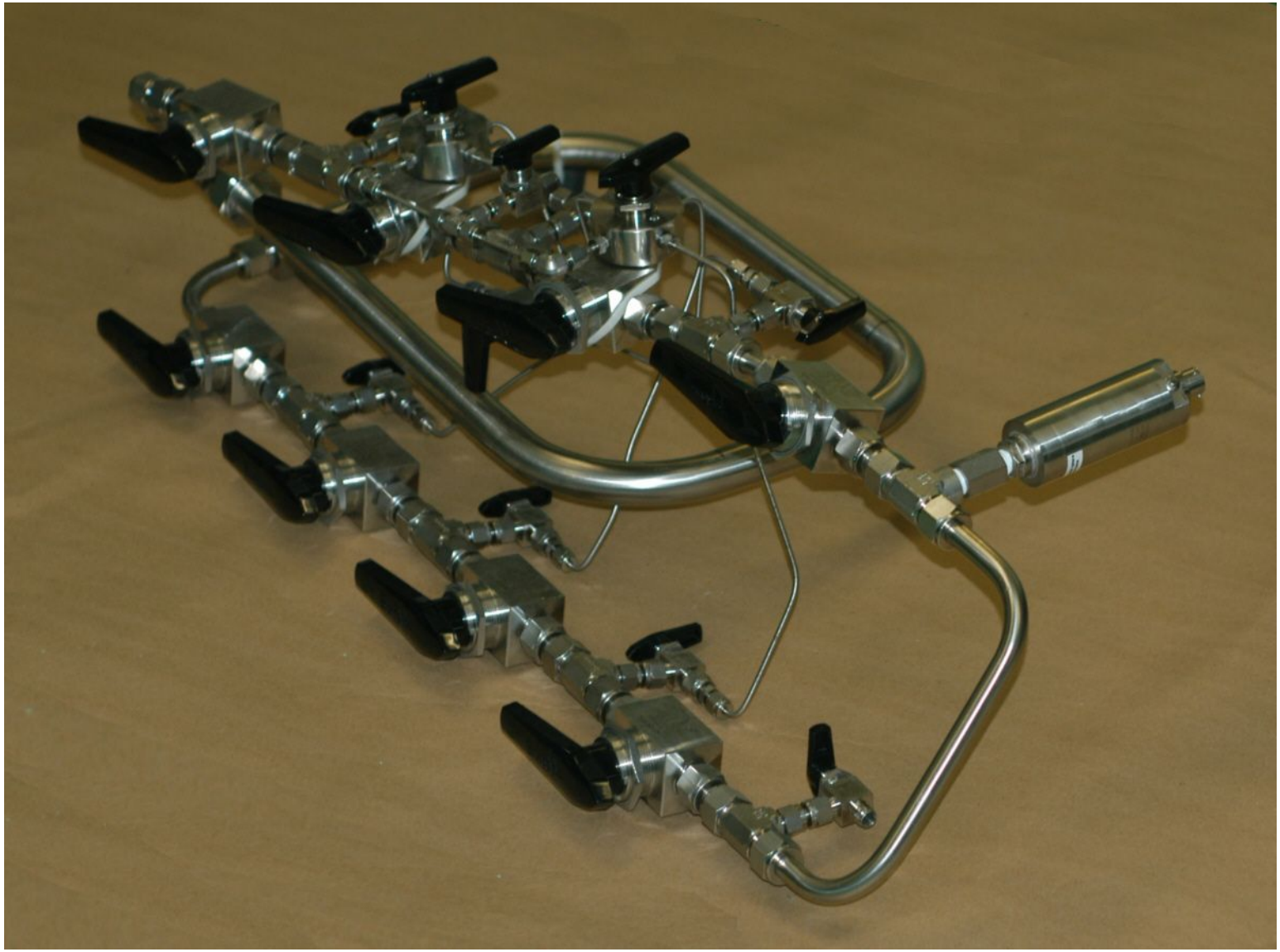
- **Given the pressure of capture in the POC…**
- **Given the captured product analysis…**
- **Given modeling results…**

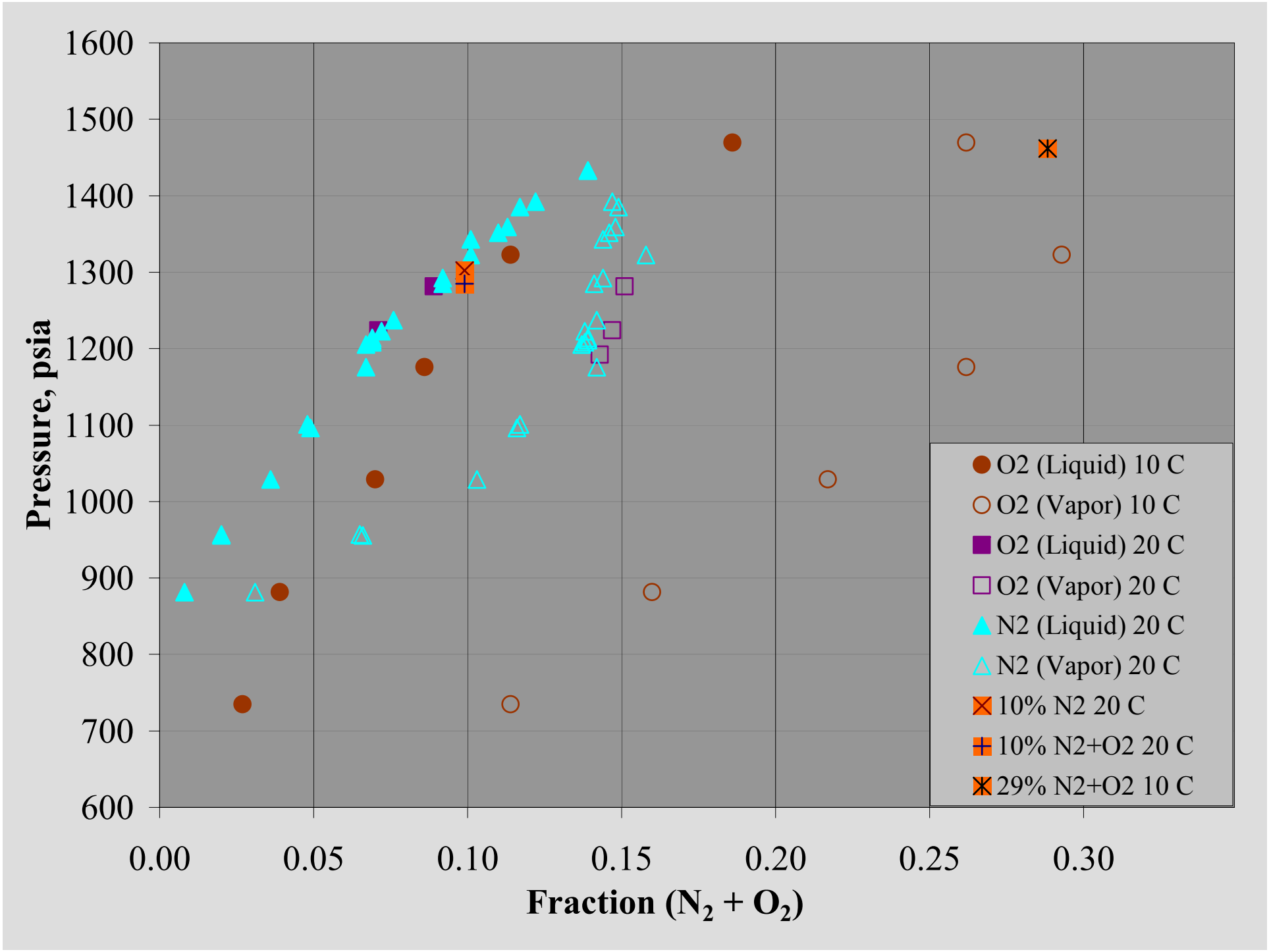
Average Analysis of Captured Product (n=2)	
O_2 (%)	11.85
CO_2 (%)	79.0
CO (ppm)	170
SO_2 (ppm)	0.5
NO (ppm)	0.15
NO_2 (ppm)	0.05
N_2 (%-balance)	9.15

What is the Final Captured Product?

- Equation of State models unreliable near the critical point
- NIST data for 2 and 3-component systems CO_2 - O_2 - N_2
- Experimentation
- What is the definition of sequestrable?

Near-Critical Phase Determinations

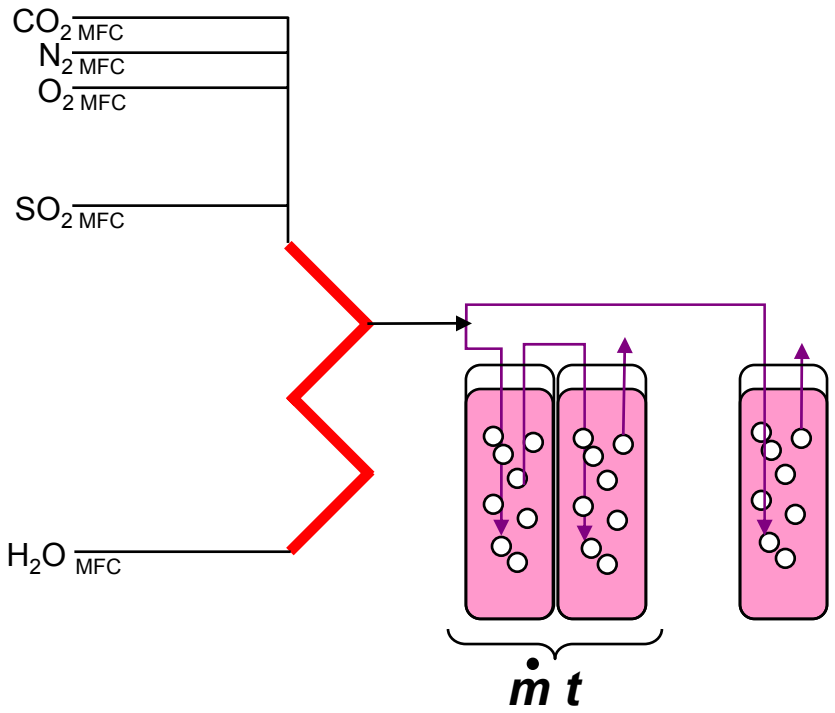



1600
1500
1400
1300
1200
1100
1000
900
800
700
600
Pressure, psia
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Fraction (N2 + O2)
O2 (Liquid) 10 C
O2 (Vapor) 10 C
O2 (Liquid) 20 C
O2 (Vapor) 20 C
N2 (Liquid) 20 C
N2 (Vapor) 20 C
10% N2 20 C
10% N2+O2 20 C
29% N2+O2 10 C

Getting the SO_2 Out

- How will an oxy-fuel combustion gas respond differently than gas from an air-fired system?

SO_2 Scrubbing Comparison Section



Scrubbing Oxy-Fuel Gas

- **Test matrix parameters**
  - Reagent
    - $CaCO_3$
    - Na_2CO_3
  - Gas composition
    - CO_2
    - H_2O
    - SO_2
- **SO_2 solubility decreases with increasing CO_2 partial pressure**

Upcoming Work

- Complete scrubbing tests
- Jupiter burner test facility with IPR gas treatment

Conclusions: CO_2 Capture

- Current mature technologies will allow for capture from oxy-fired fossil fuel power plants
- A compression / condensation IPR process is an economical alternative to amine absorption