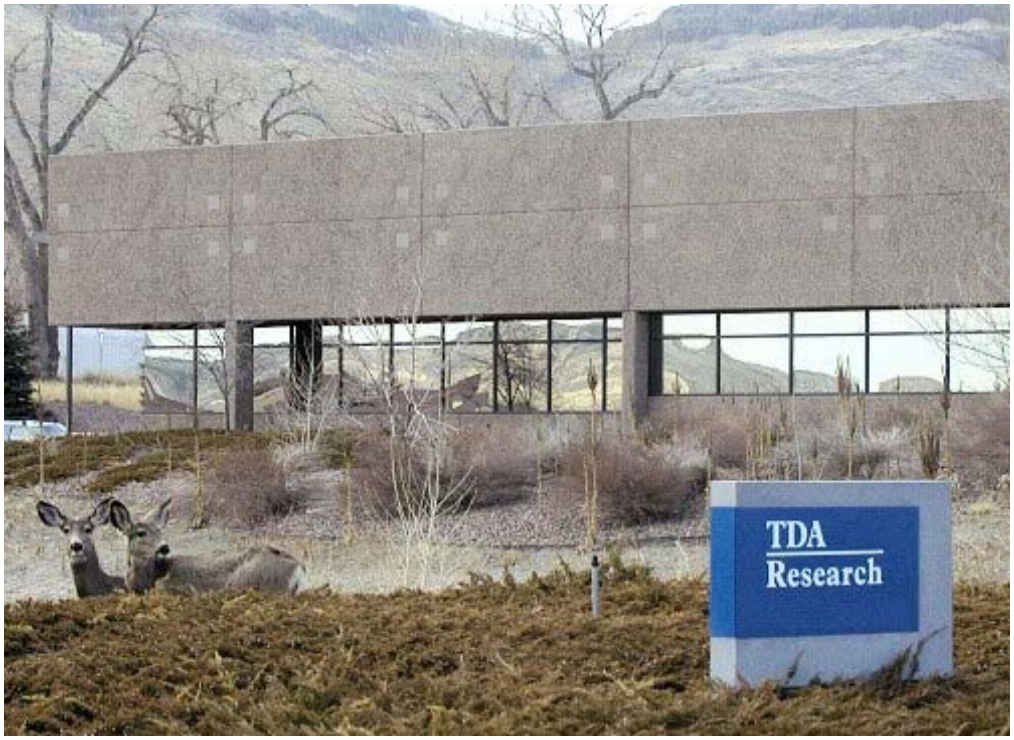
Cost Effective Air Separation System (Contract No. DE-FE-0024060)



Gökhan Alptekin
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DOE Gasification Systems and Coal & Coal-Biomass to Liquids Workshop

Morgan town, WV

August 10, 2015

TDA Research Inc. • Wheat Ridge, CO 80033 • www.tda.com

Project Objective

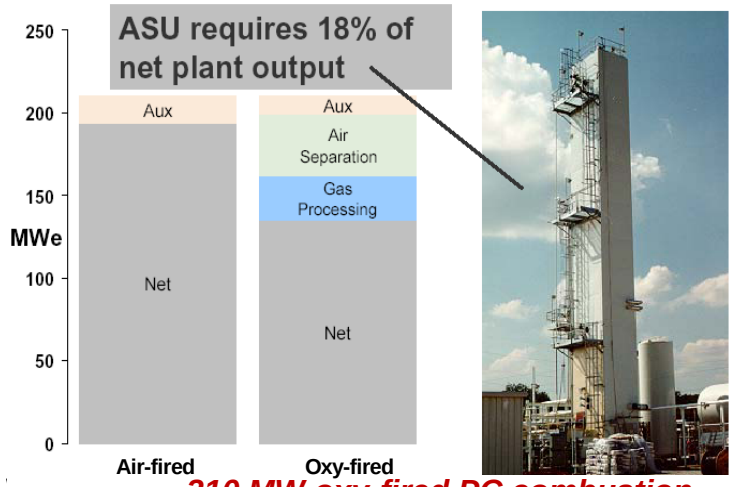
- **The project objective is to demonstrate techno-economic viability of a new air separation technology that can be integrated into the coal gasification and oxy-combustion process**
- **A high temperature chemical absorbent that is selective for O_2 removal is the key for the process**
  - Early proof-of-concept demonstrations in an SBIR Phase II project high oxygen uptake and stable performance
- **Project Tasks**
  - Sorbent optimization and scale-up
  - Testing in a fully-equipped sub-scale unit to fully demonstrate the concept at the bench-scale
  - Bench-top demonstration of life (min 10,000 cycles)
  - A high fidelity process design and cost analysis supported by Aspen Plus™ simulations
    - IGCC process and oxy-combustion

Project Partners

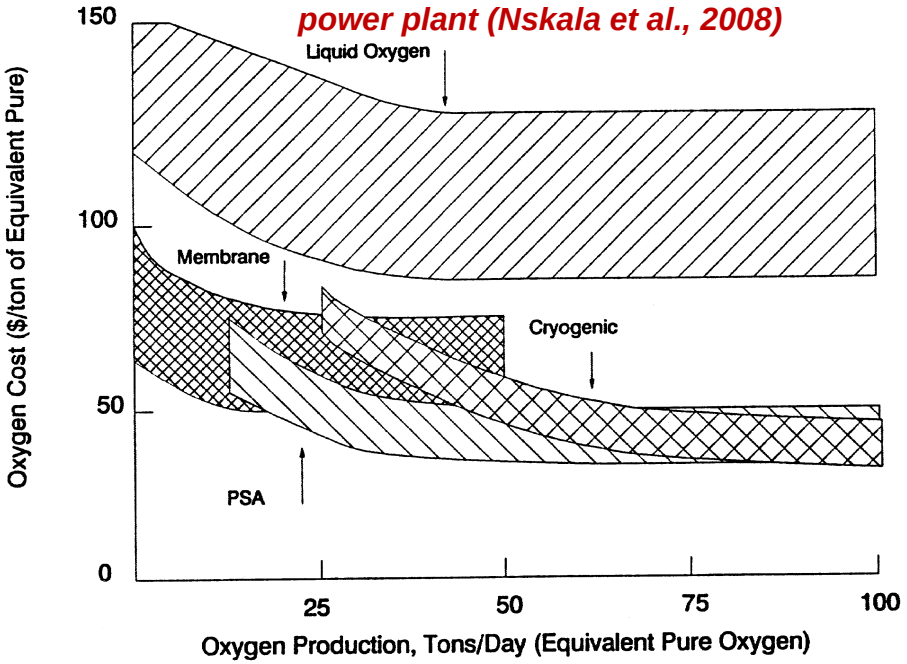
- **A second contract is being worked out to carry-out prototype evaluation (DE-FE-0026142)**

Introduction

- **Oxygen-blown gasifiers provides smaller size and higher efficiency and substantially reduce NO_x and improve gas purity with the removal of N_2**
- **ASU is one of the largest cost items in an IGCC plant (consumes 5% of plant power and constitutes ~15% of plant cost)**
- **Low cost oxygen is also critical for the oxy-combustion applications**
- **The cryogenic air separation is the choice of technology at large-scale**
  - 600 MW gasifier requires ~170 ton O_2/day
- **Cryo-separation is highly energy intensive due to the thermal inefficiencies inherent in the low operating temperatures**



210 MW oxy-fired PC combustion power plant (Nskala et al., 2008)



(Kobayashi, 2002)

TDA's Approach

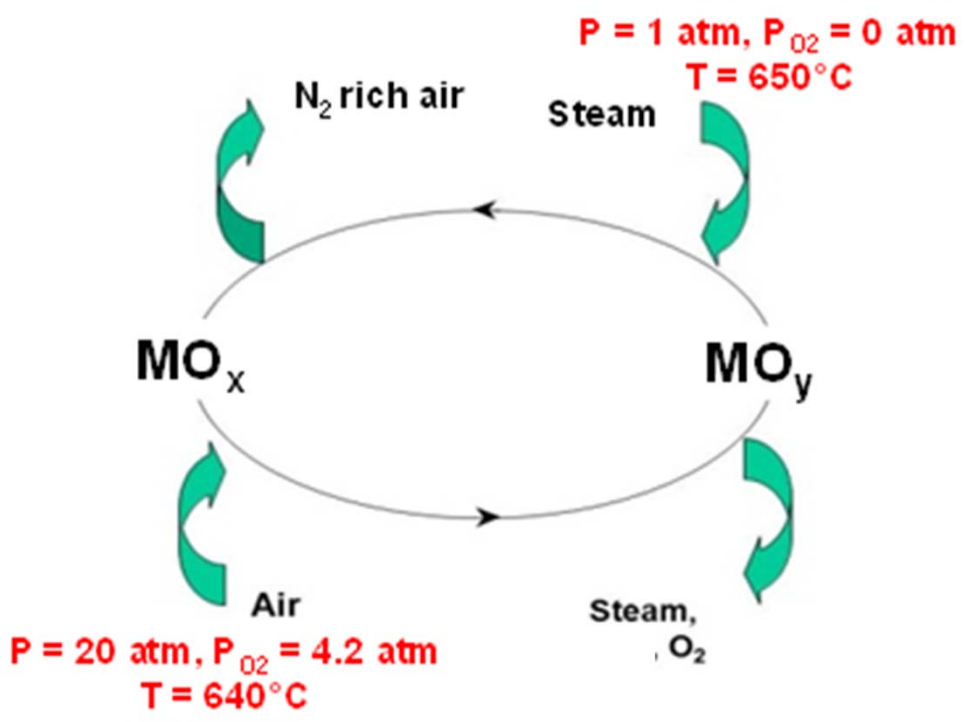
- **TDA's process uses a unique sorbent to support an oxidation-reduction (redox) process**
- **Unlike conventional chemical looping combustion sorbents that also work via a similar redox process, oxygen can be released by changing process conditions**
  - No use of reducing gases (e.g., CH_4, H_2, CO, syngas) that will consume oxygen

$$\mathbf{MO_x = MO_y + \textit{x/2y}\ O_{2(g)}}$$

- **The metal oxide phase auto-reduces by changing T, P, oxygen partial pressure**
  - The auto-reduction releases oxygen, which can be recovered as a pure product

Separation Process

- **Sorbent removes some (~30%) but not all the O_2 from high pressure air drawn into the gas turbine**
  - Vitiated high pressure air put back in the GT after boosting the pressure
- **Regeneration is carried out using warm sweep gas (superheated steam) ideally under isobaric/isothermal conditions**
  - Partial pressure difference to drive the O_2 from the sorbent
- **Other options**
  - Pressure swing assisted regeneration
  - Temperature swing assisted Pressure swing



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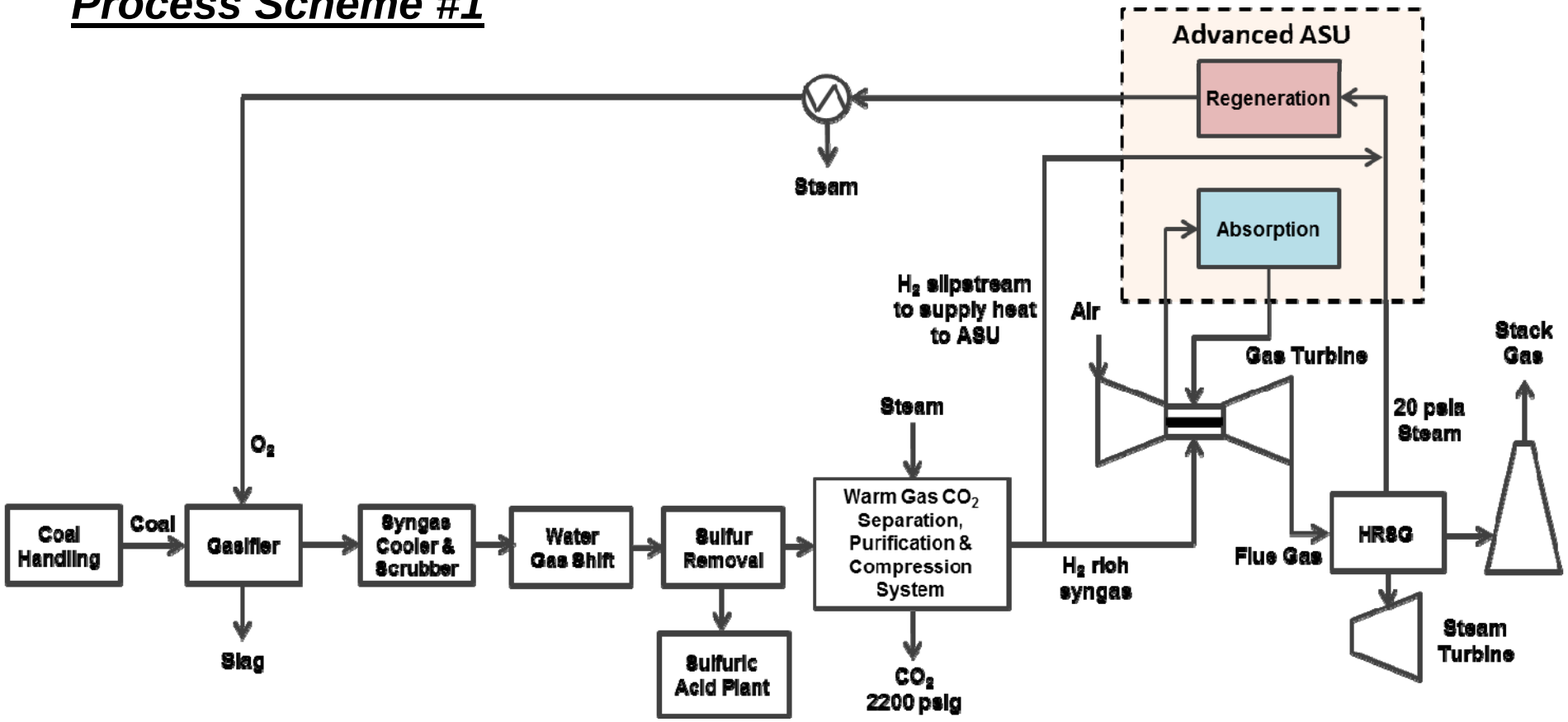
Integrated with IGCC Power Plant

Process Scheme #1



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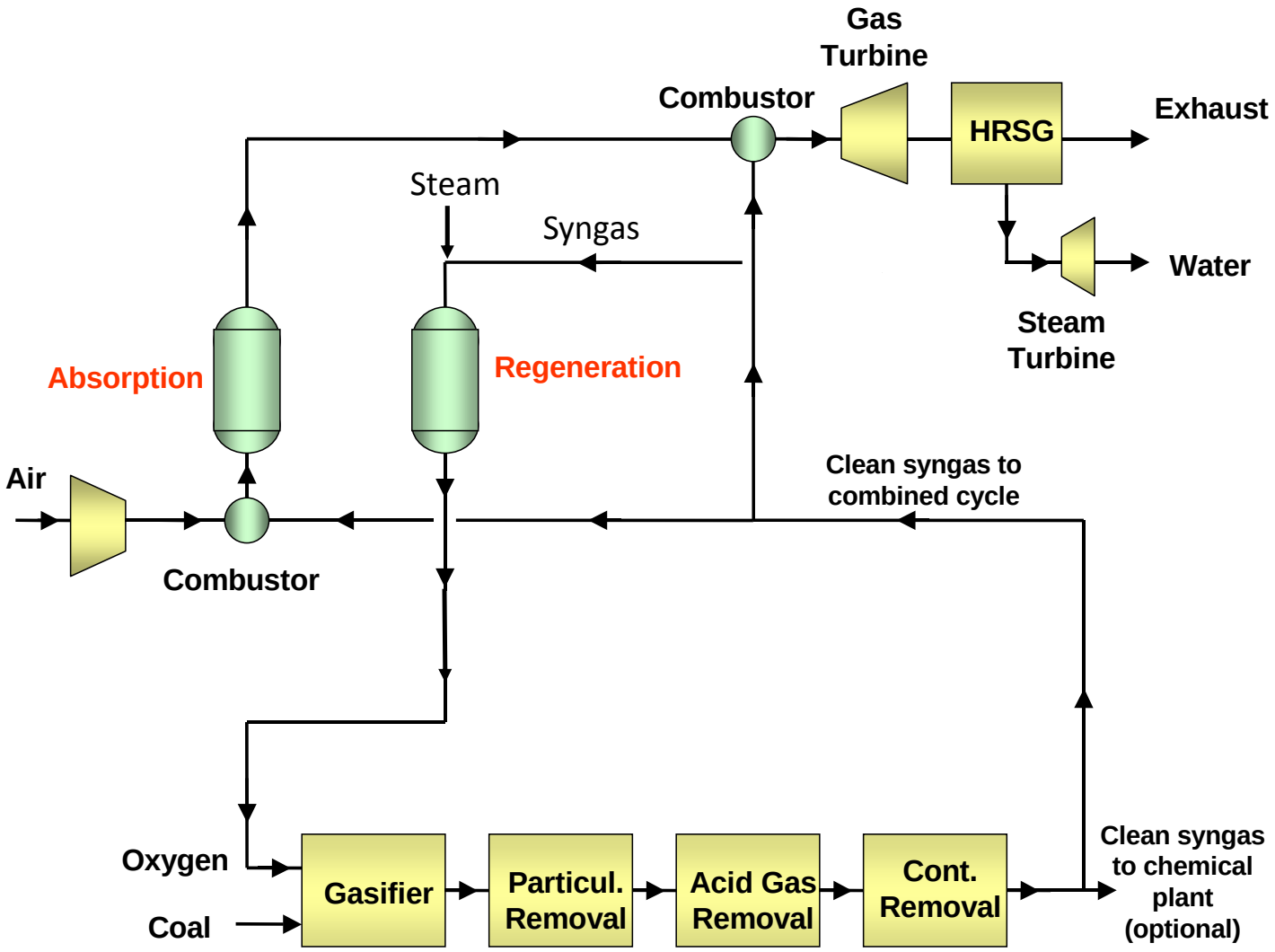
Integration to the IGCC/CTL Plant



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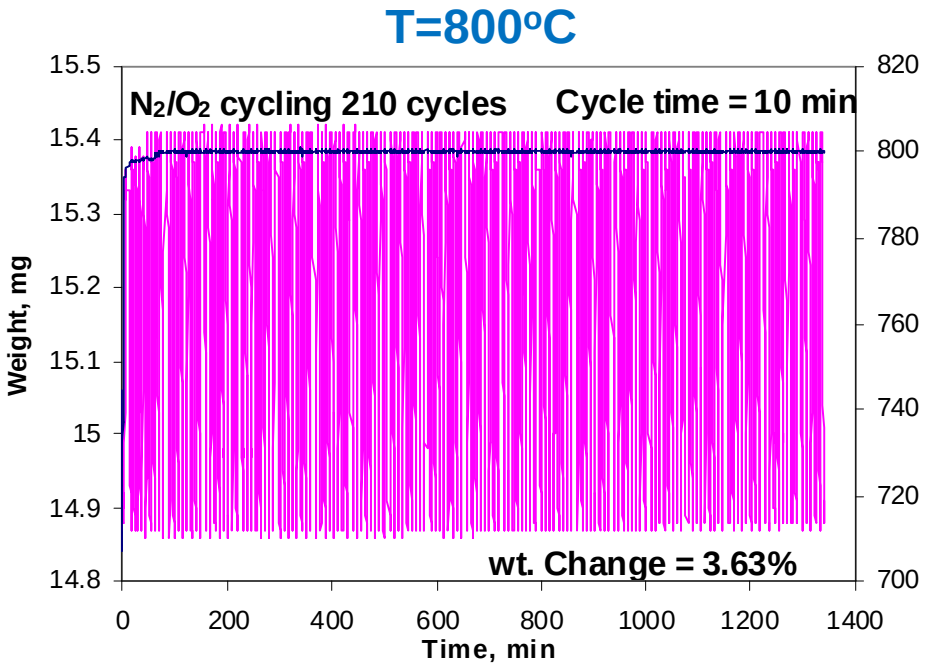
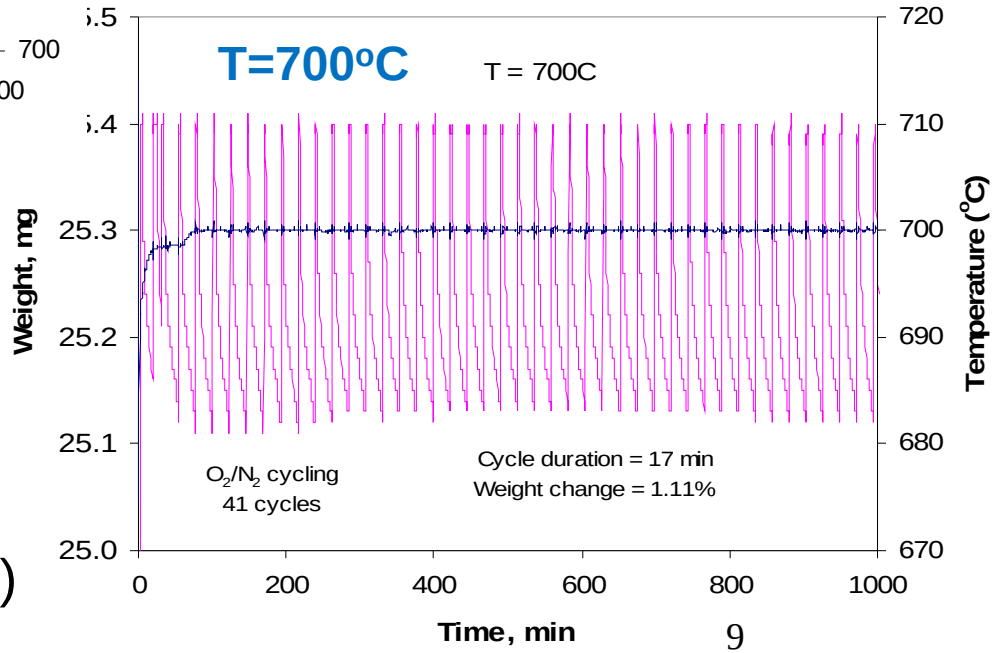
Early Results in TGA

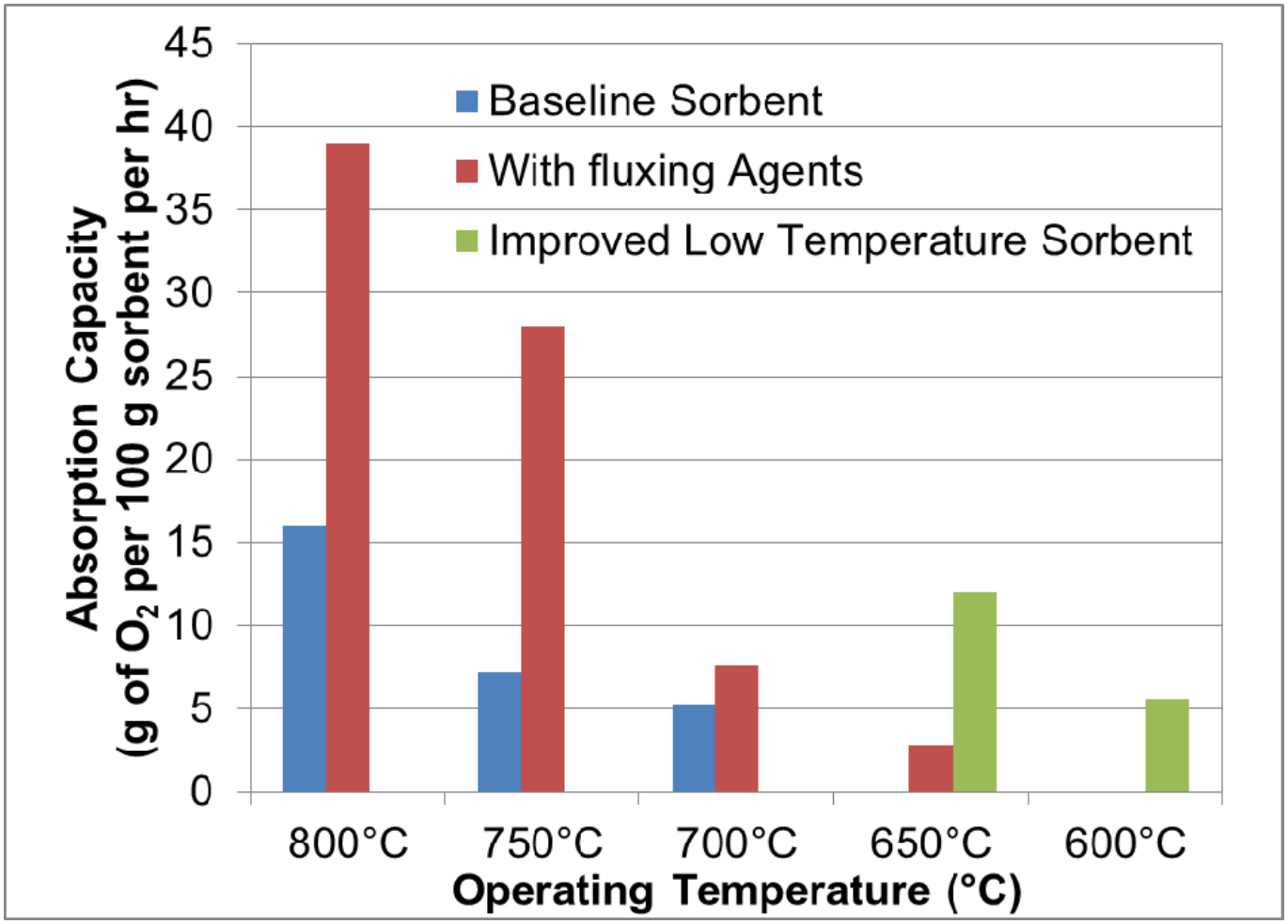


- **Similar trends at 700ºC**
- **Lower capacity if the same cycle time is maintained due to slower kinetics during regeneration**

- **Sorbent can be regenerated by concentration swing**
  - Switching from pure O_2 to pure N_2
- **Higher capacity at 800ºC**
  - 3.63% wt. O_2 loading at 800ºC (10 min full cycle time)



Sorbent Optimization



- **Oxygen release was documented over a wide range of temperatures**

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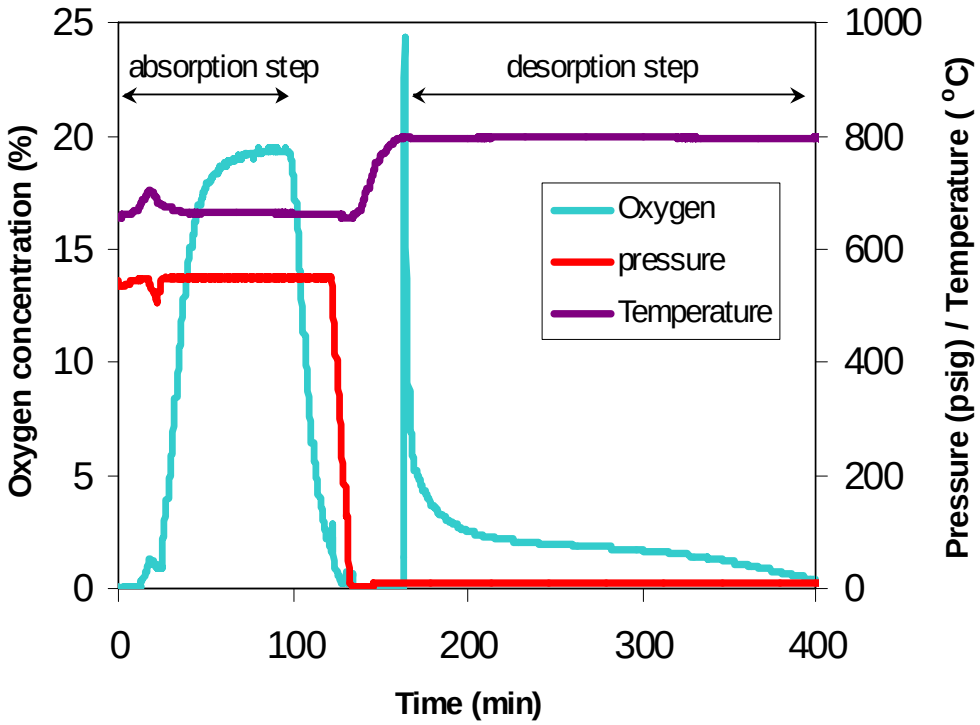
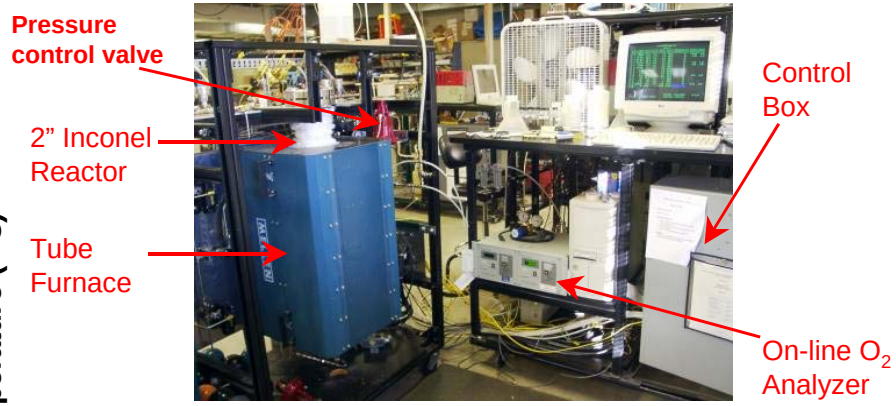
Flow Experiments in Small & Large Reactors





- **Oxygen release was documented over a wide range of reactor configurations**

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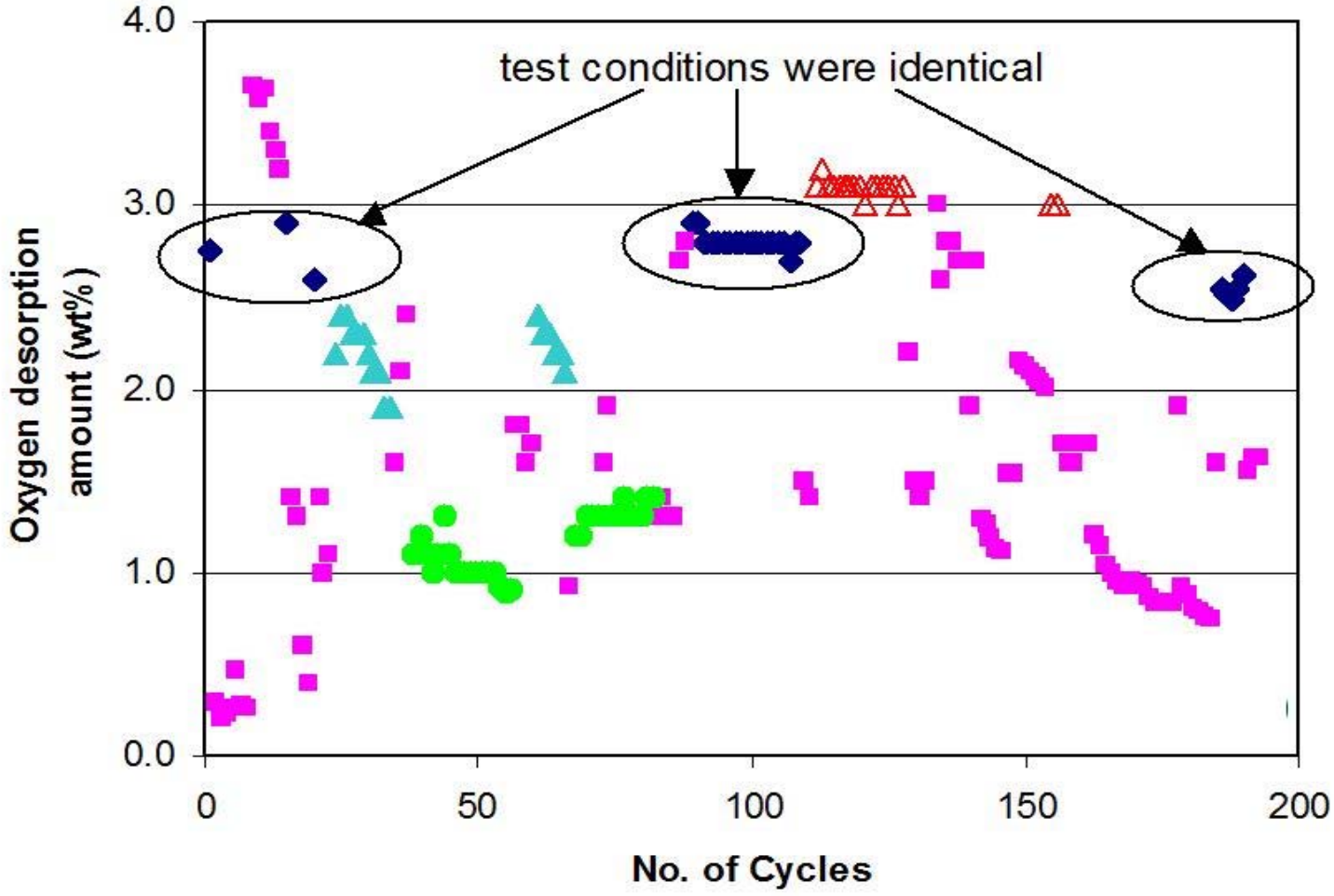
Long-term Durability



- **Sorbent maintained performance for 200 cycles**

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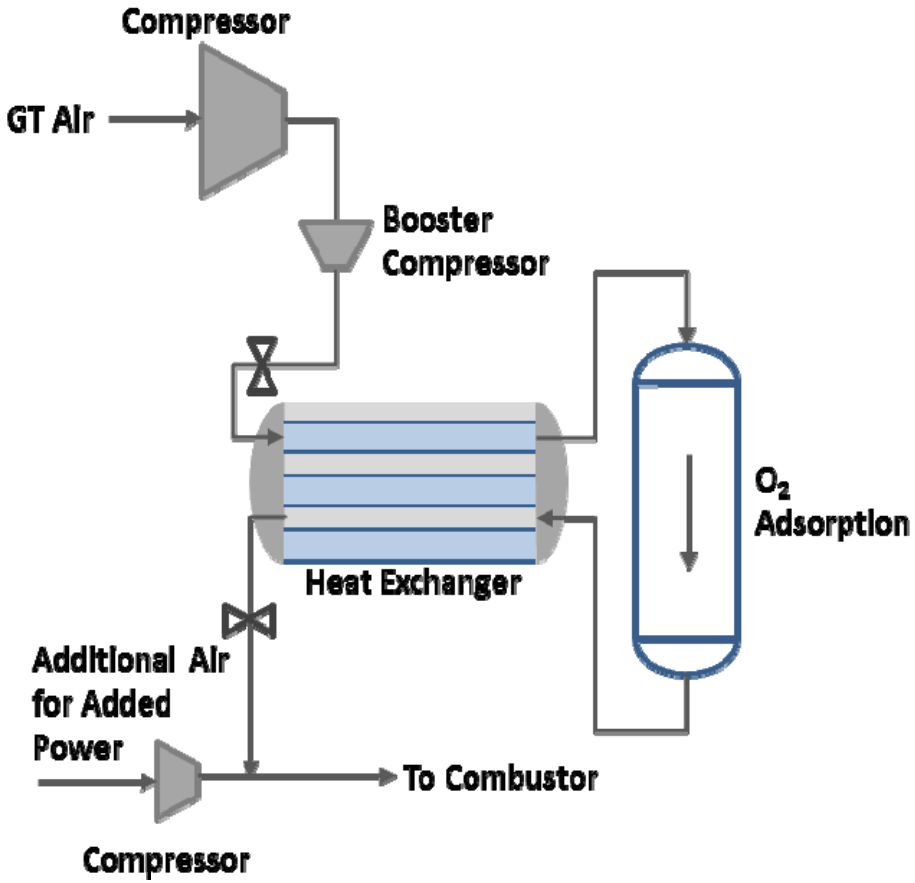
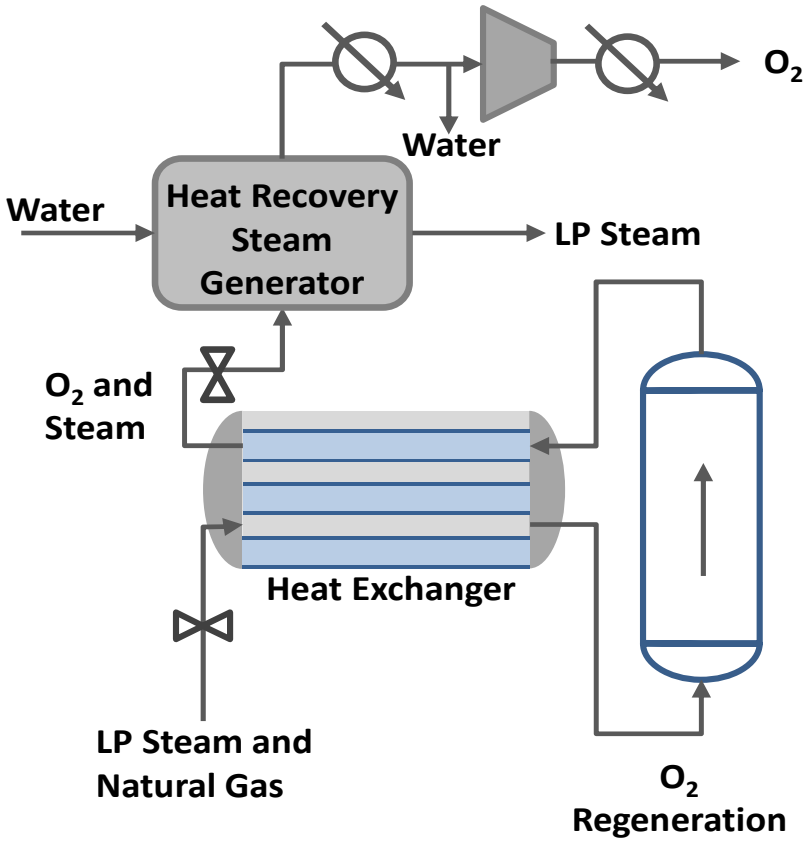
System Design



Absorption Process



Regeneration Process

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IGCC without CO_2 Capture

GE Gasifier

TDA Steam Plant Changes	
Scaled up Steam Plant	292,692
Steam extration	-43,351
LP steam Generated	11,194
Methane expander	540
Net Steam Power	261,075

Auxiliary Power	
GT Air Boost	584
Added Air Compressor	60,617
O2 Compressor	10,260
Internal O2 Compressor	10,981
Net Axilary Load changes	82,441

Power Summary	
Gas Turbine Power, kW	515,395
Sweet Gas Expander, kW	7,500
Stem Turbine, kW	261,075
Total Power, kW	783,970
Auxiliary Load, kW	109,771
Net Power, kWe	674,199
Net Plant Efficiency %, HHV	40.43%

Preliminary Process Analysis

IGCC without CO_2 Capture (GE Gasifier – DOE Case 1)

- **New sorbent-based ASU can increase the plant efficiency to 40.4%, in comparison to 39% with the same plant equipped with cryogenic separation**
- **Cost of electricity (COE) on a $2011 basis is expected to be $93.2 per MWhr (versus $101.2 per MWhr with cryogenic ASU)**

IGCC with CO_2 Capture (GE Gasifier – DOE Case 2)

- **New sorbent-based ASU could reduce the cost of CO_2 captured on a $ 2011 basis, for both the conventional Selexol-based and TDA's warm gas CO_2 capture technology to $38.8/tonne and $29.3/tonne respectively**

Assumption = Cost of the new ASU is the same as cryogenic plant

Vision for Commercialization

- Slipstream to pilot-scale demonstrations to increase technical maturity from TRL = 4 to TRL = 6
- Develop a complete technology package for licensing
  - Intellectual Property
  - Process Design Package
  - Sorbent Manufacturing






- Privately Owned / Began operations in 1987
- Two facilities in Wheat Ridge and Golden, CO
  - 50,000 ft^2 of office and lab space
- 82 full-time technical staff
  - More than half with advanced degrees (28 PhDs)

TDA Research

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