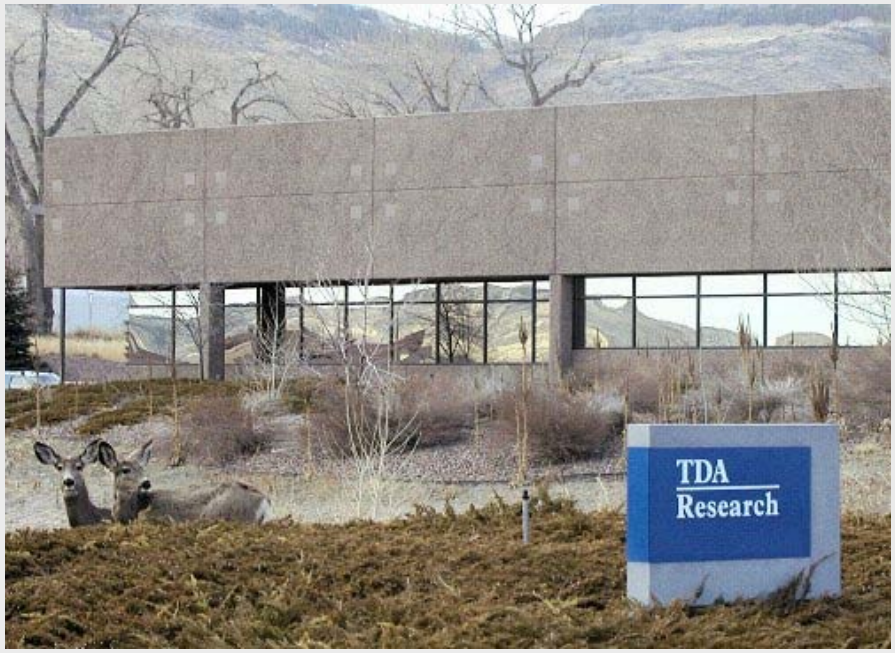
Post-Combustion CO_2 Capture with Alkalized Alumina



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

Project Overview

TDA Research, Inc is developing a material and process

- Dry, solid alkalized alumina regenerable physical sorbent
- Process design around that material

Funding - Total Project $1,373,380
- DOE: $1,097,839
- Cost Share: $276,541

Project Performance Dates
- November 1, 2008 to February 28, 2012

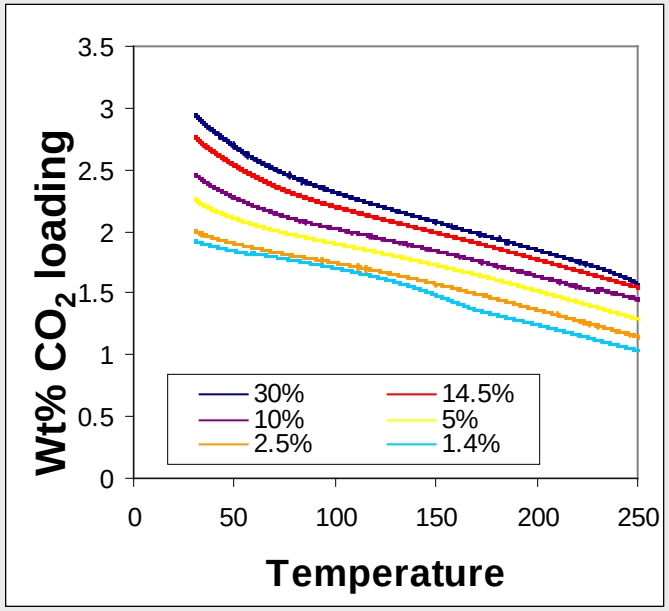
Project Partners
- Babcock & Wilcox (B&W)
- Louisiana State University (LSU)
- Western Research Institute (WRI)

TDA's Approach

- **Low cost sorbent material**
  - Inexpensive raw materials
  - Simple processing
- **Low regeneration energy requirements**
  - Physically adsorbed CO_2 can be readily absorbed and desorbed at lower energy requirements than chemical absorption
  - Low pressure steam regeneration
  - Rapid cycling
  - Near isothermal operation

TDA's System Design

- **Adsorbents loosely bind CO_2 to the surface**
  - Regeneration is fast and with low desorption energy requirement
  - High concentration of CO_2 during desorption



- **Adsorbents operate along a concentration gradient**
  - They absorb more CO_2 when the concentration is higher than when the concentration is lower.
- **Optimum bed design is counter-flow**
  - Maximizes the loading on the adsorbent by having the adsorbent contact the gas stream with the highest CO_2 concentration at the end of its reactor residence time.

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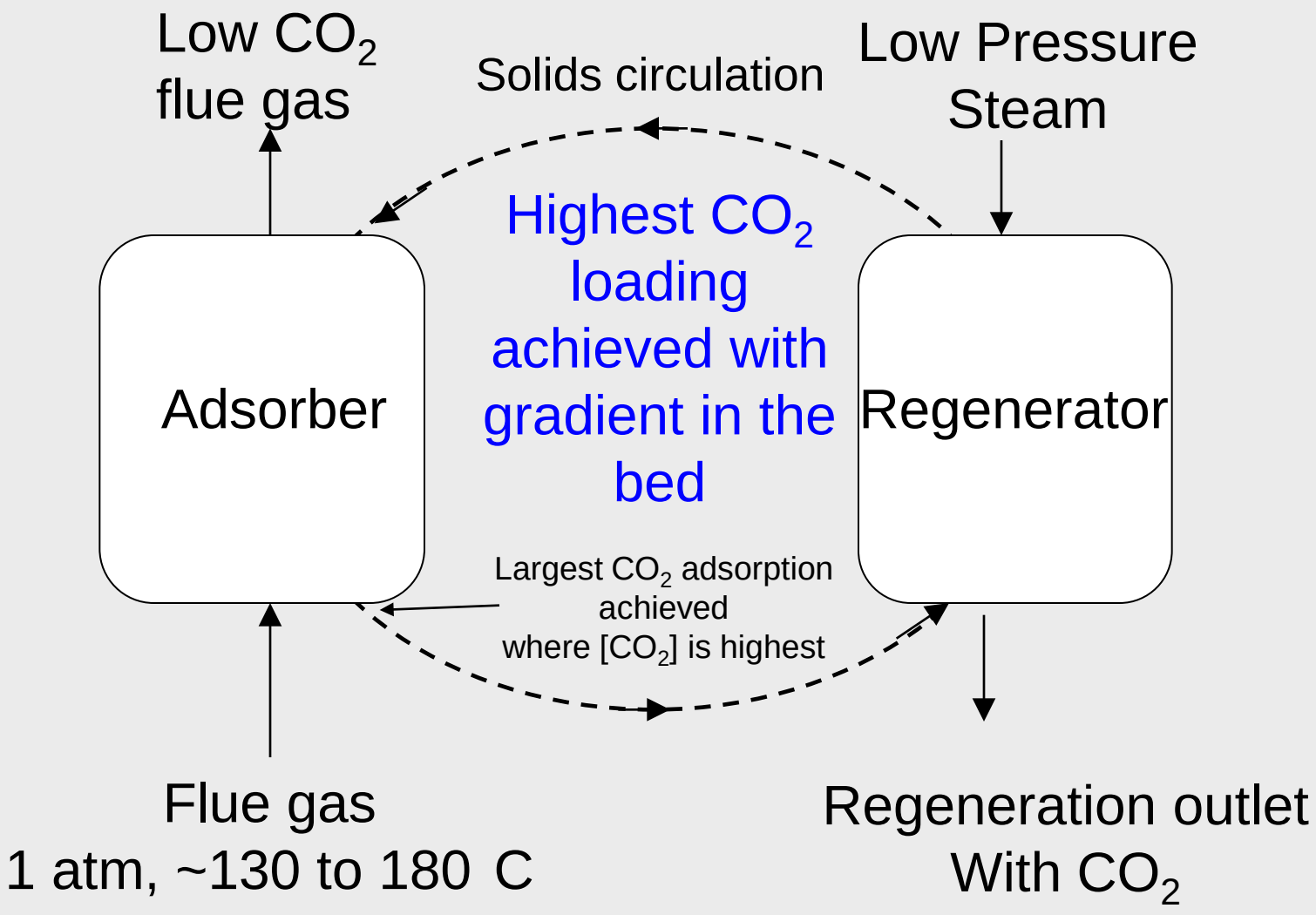
Counter Flow Schematic



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Project Status

- ***Project goal*:**

  Demonstrate CO_2 capture system designed around TDA's physical sorbent

  Technical Progress:

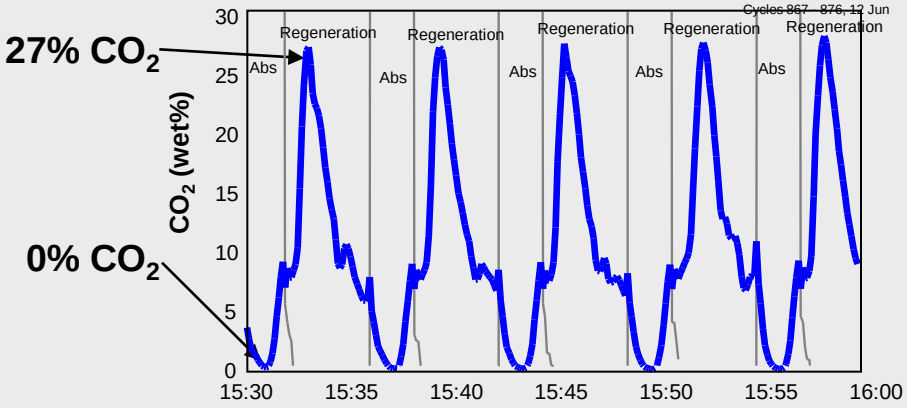
- Completed sorbent evaluation in single fixed bed
  - Characterization and optimization of sorbent
- Long-term cycling test on sorbent performance completed
- Designed and constructed a new sorbent testing apparatus to show continuous absorption and regeneration
  - Multiple fixed beds in series with counterflow

Fixed Bed Testing

- **To optimize sorbent experiments conducted over a range of conditions**
  - varying space velocities, temperatures, and cycle times
- **Flue gas is simulated**
  - 13% CO_2, 9% H_2O, 77% N_2 , (Sometimes SO_2,, O_2)

300 cc fixed bed reactor

- Automated equipment for unattended operation
- Online analyzer for continuous CO_2, SO_2 and humidity measurement
- Fixed bed apparatus has counter flow orientation for absorption and regeneration



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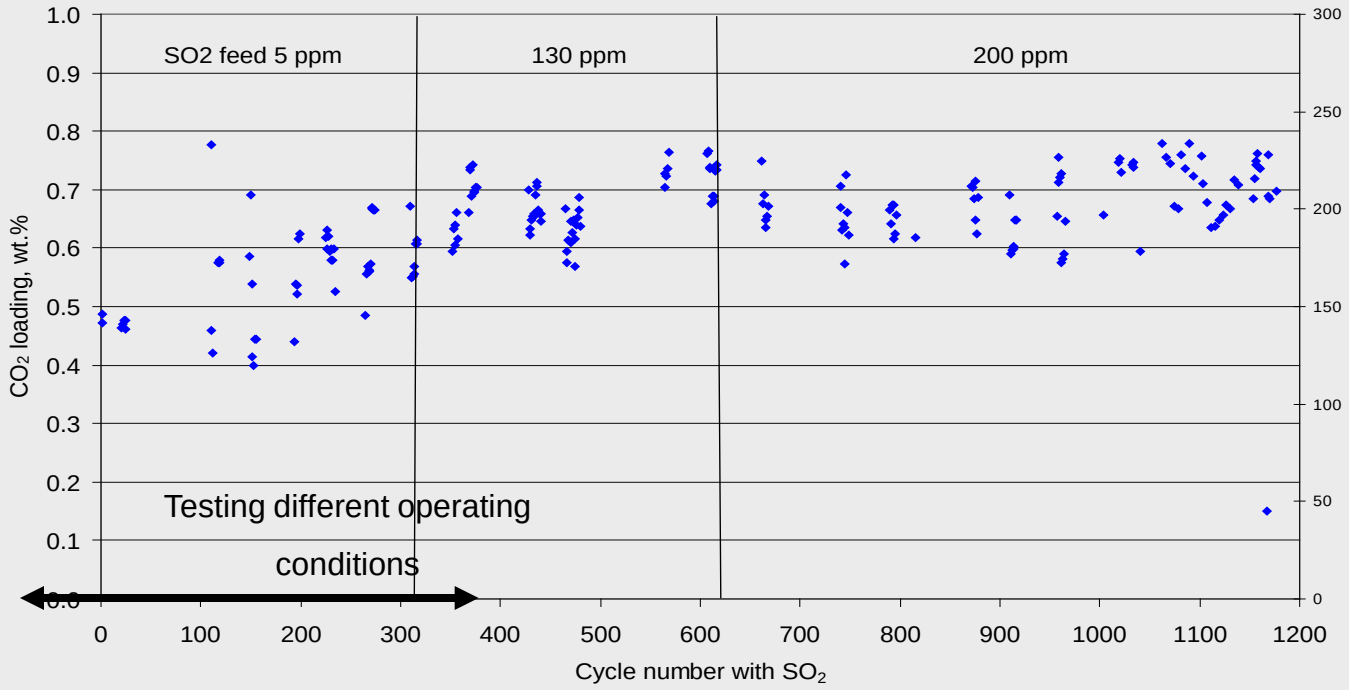
Extended Cycling Test

- **We conducted a long-term cycling tests**
  - **1500 hours, 62.5 days, >9300 cycles**
- **Flue gas is simulated during test**
  - 13.8% CO_2, 9% H_2O, 77.2% N_2, 3% O_2, 104 ppm SO_2
  - SO_2 level based on Conesville #5 plant without final SO_2 scrubber (DOE/NETL-401/110907)
- **SO_2 is also an acidic gas and may compete with CO_2 for adsorption on the sorbent**

Effect of SO_2

- Initial tests showed CO_2 loading not affected by SO_2



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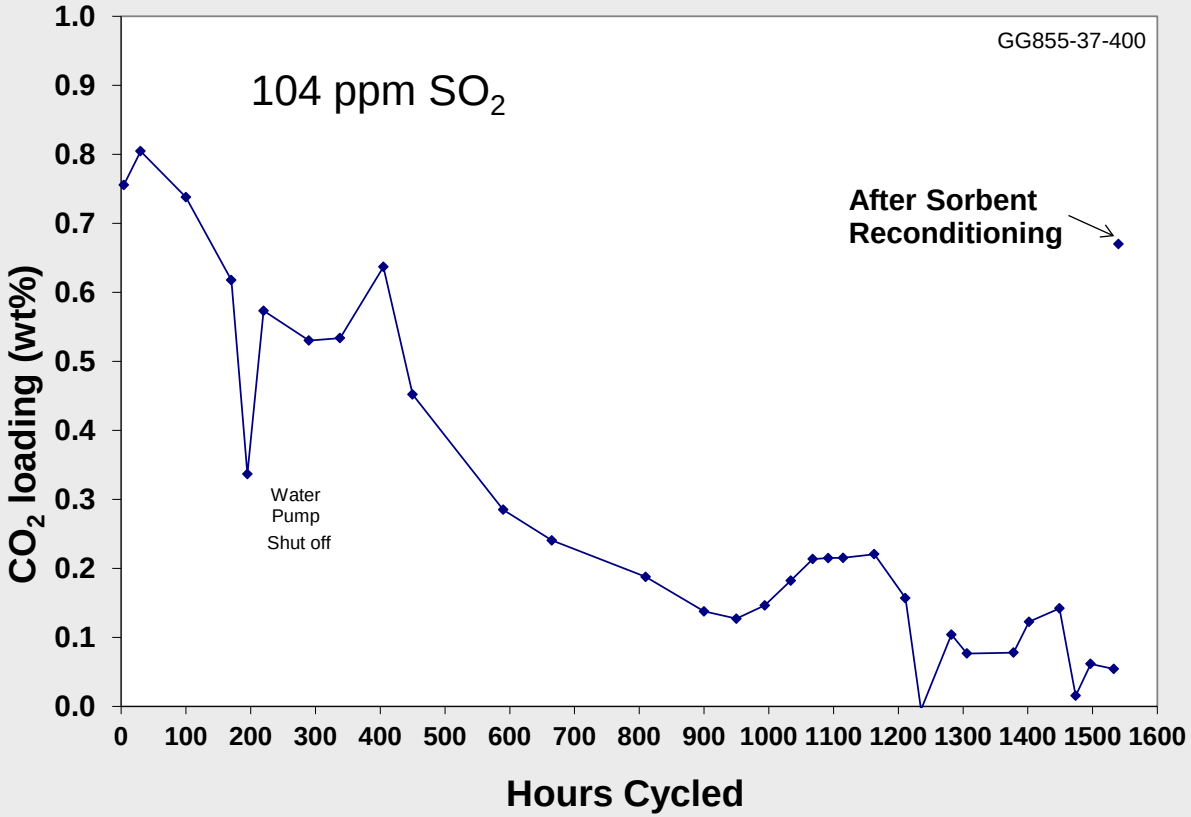
Long-term Cycling Test



- SO_2 is absorbing on to the sorbent and degrading performance
- After 1500 hours the sorbent was reconditioned. Initial loading was recovered

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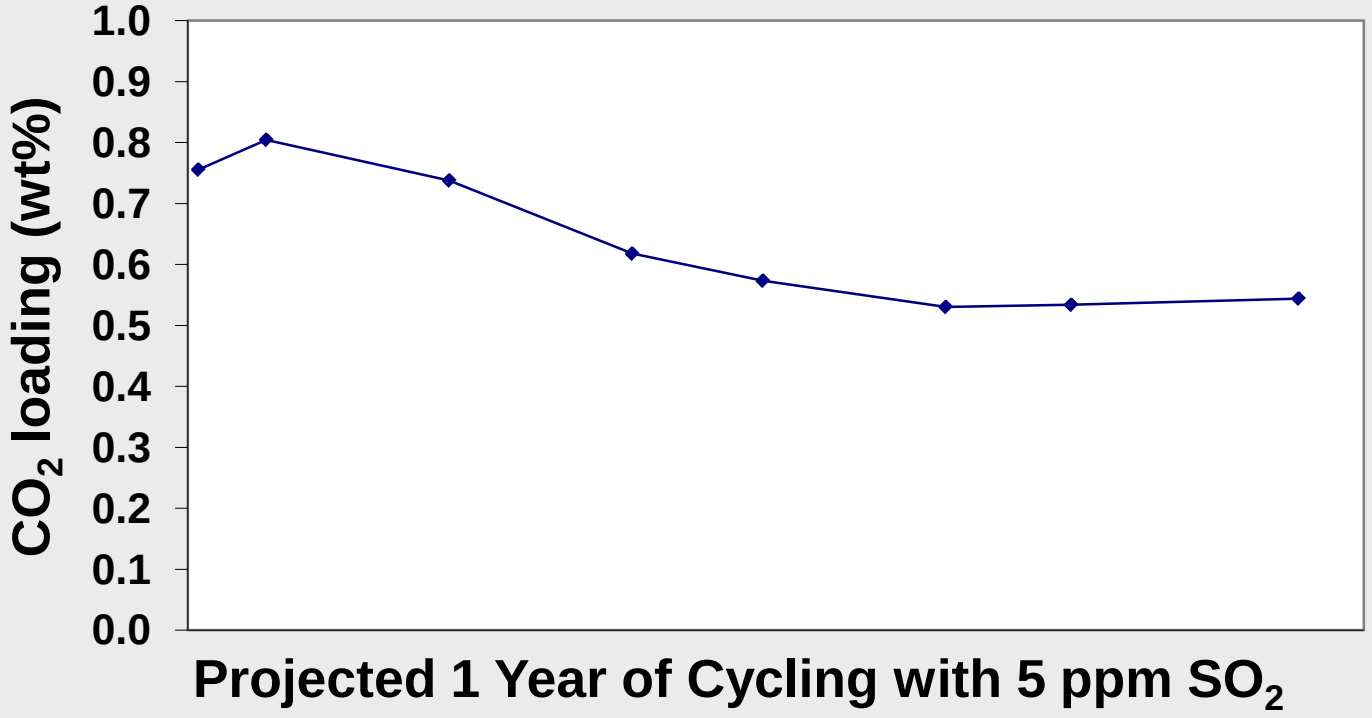
Annual Replacement of Sorbent

with additional SO_2 scrubber

- With 5 ppm sorbent lifetime would be 1 year.
- Sorbent can also be reconditioned
  - In a traditional moving bed a slip stream of sorbent could be removed for reconditioning



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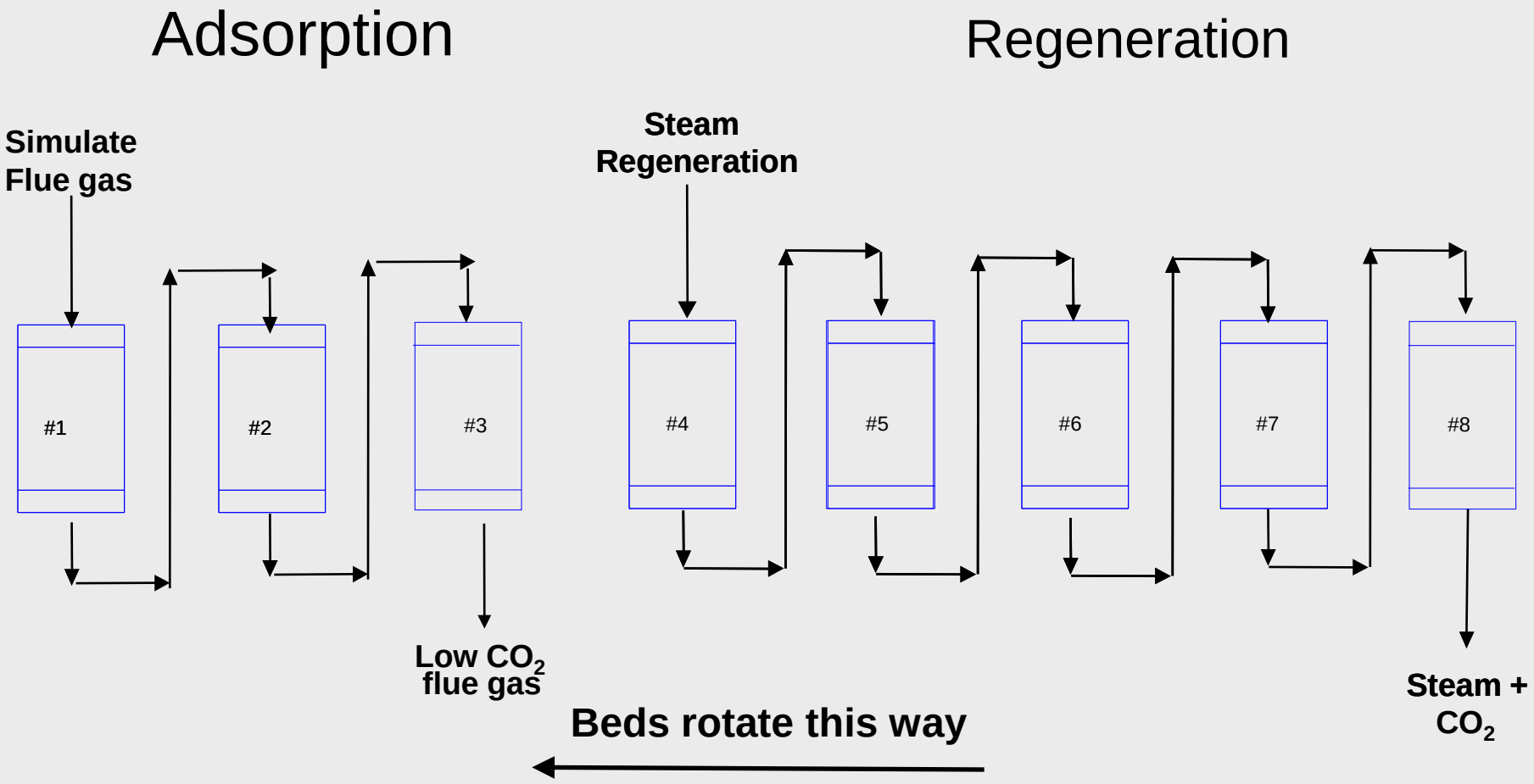
Larger-scale Apparatus

- **Designed to show continuous absorption and regeneration**
  - Current apparatus is single fixed bed which operates alternatively in absorption and regeneration
  - New apparatus will show continuous low CO_2 concentration in absorber outlet and high concentration in CO_2 in regeneration outlet gas
- **Selected multiple fixed beds in series apparatus**
  - Simulates counter-flow
    - Bed cycle between absorption and regeneration functions
    - Gas flows in series across absorption (or regeneration) beds, rather than in parallel
  - Fixed bed could be a viable commercial system

Series Fixed Bed Apparatus

8 Bed System



Counter flow design to maximize capture rate

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Multiple Fixed Bed Apparatus

Beds 600cc (4.8L total sorbent)

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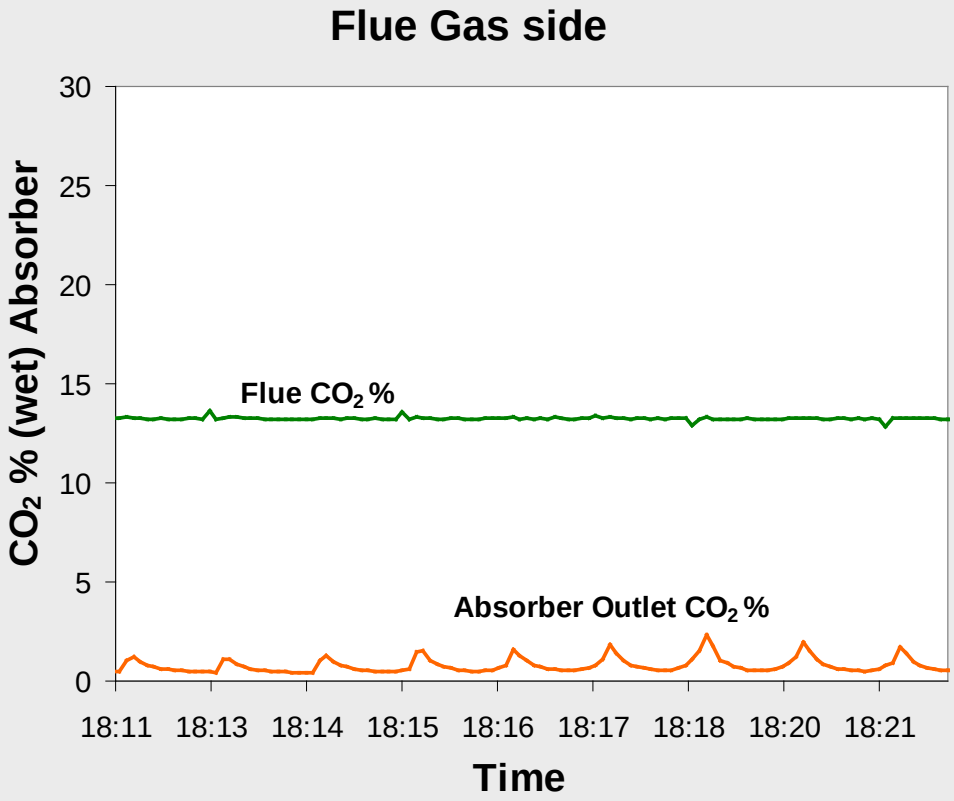
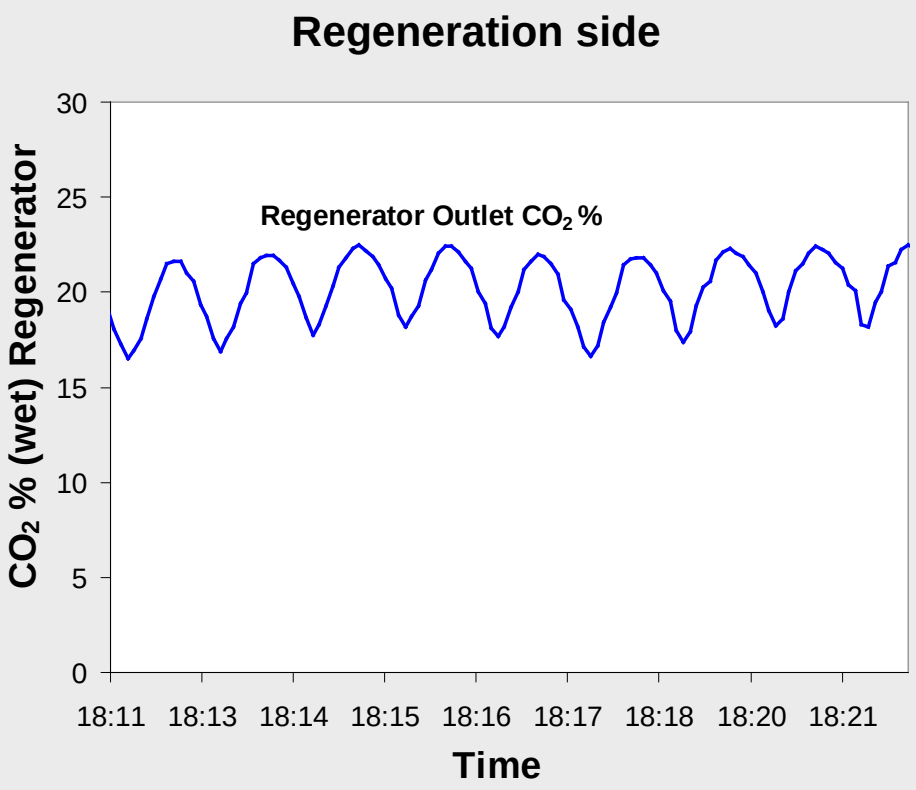
Continuous Capture Demonstrated





- 90% CO_2 capture achieved
- 1.0 wt% CO_2 loading
- Results similar to single fixed bed apparatus

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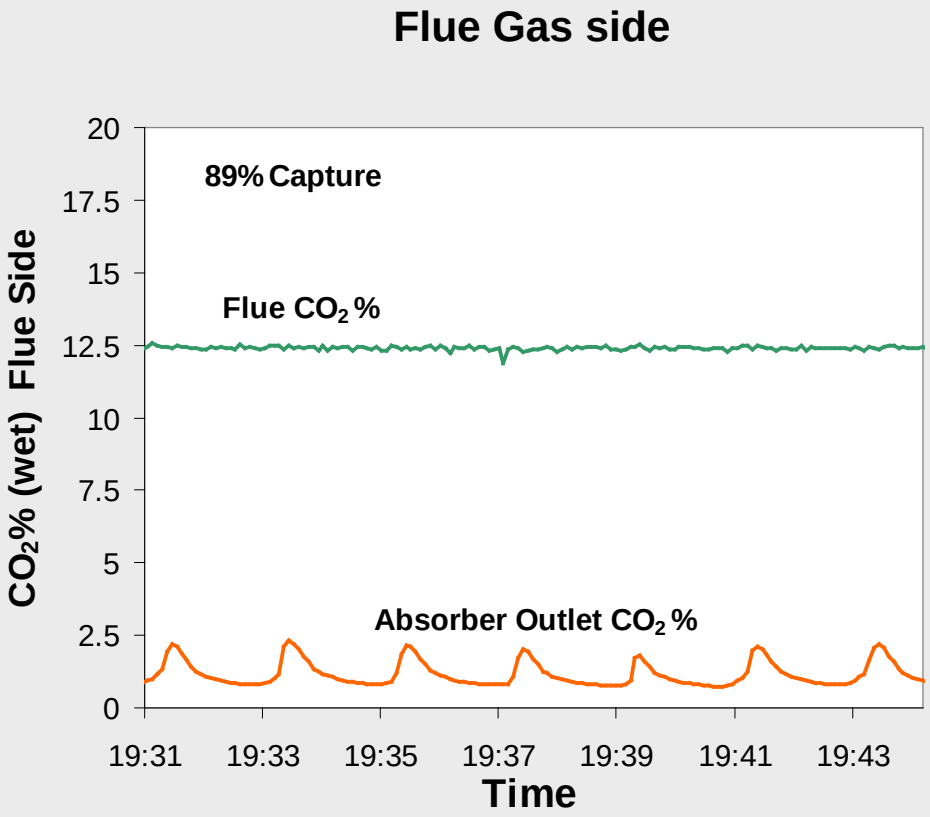
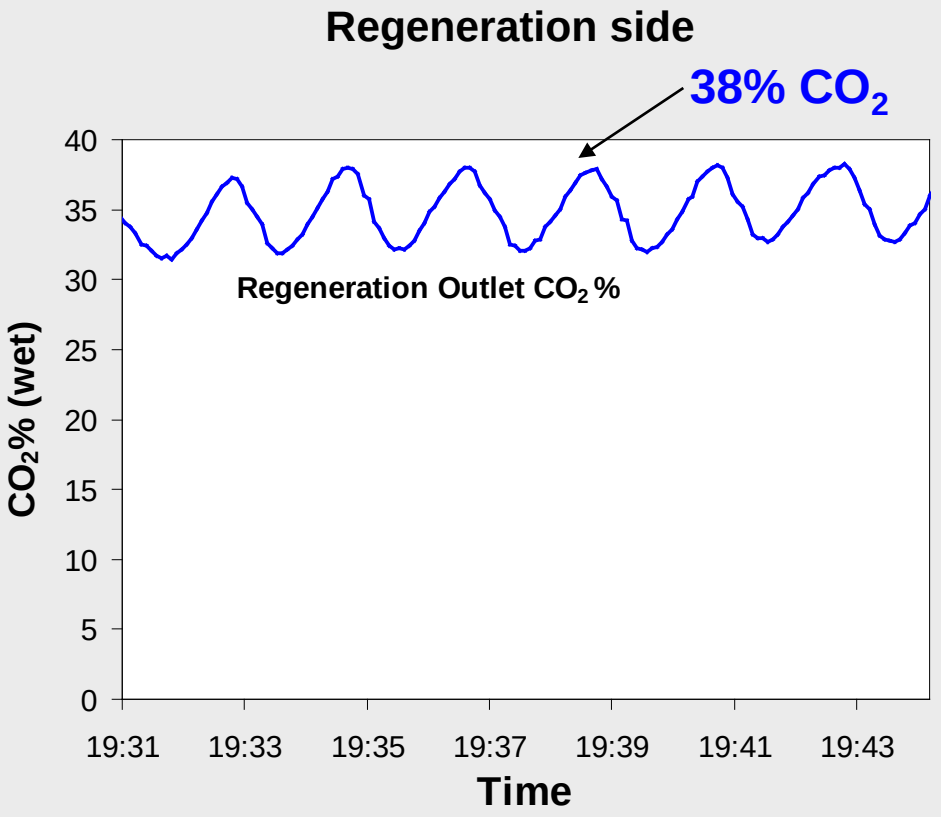
Optimizing Operating Conditions





- **Experiments are on going to optimize operating conditions: SV, cycle time, number beds in absorption vs. regeneration**

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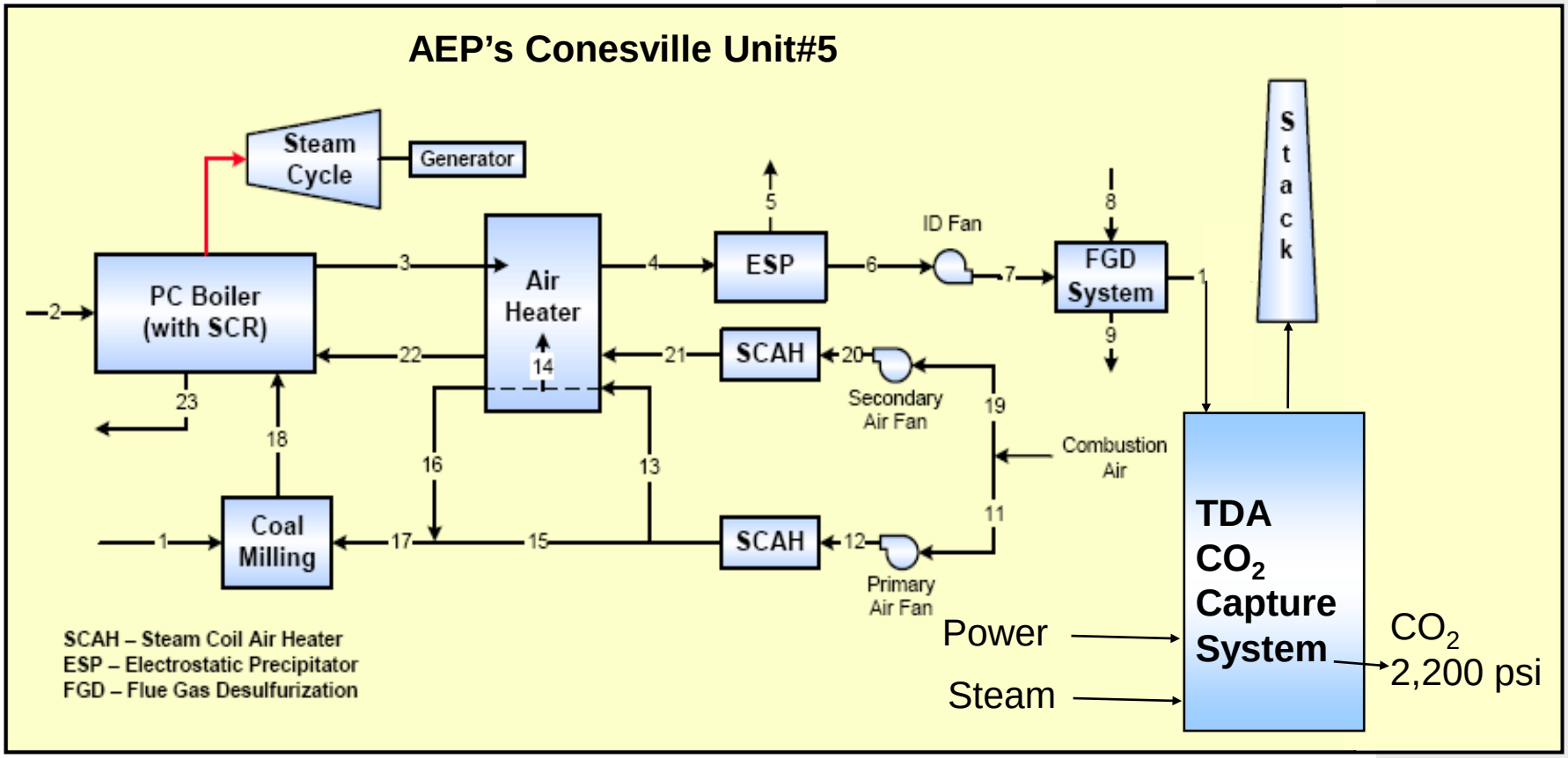
System Analysis



Integration of TDA's system as a retrofit to Conesville Unit #5

433.7 MW plant, 10,393 tons/day CO_2 generated (DoE/NETL-401/110907)

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System Economics

- **TDA will conducted updated economics study after completed of experimental testing**
- **NETL Pathways Study**
  - The pathways study quantifies the performance and cost benefits of several different post combustionCO_2 capture methods
  - Assumes engineering projections of the technology's potential
  - TDA's CO_2 capture technology was included in this pathways study
  - Cost analysis is based on a ASPEN system model developed by DoE Office of Program Planning and Analysis

Future Work

- Complete testing of sorbent in series fixed bed apparatus with continuous absorption and regeneration functions
- Update system analysis with experimental data and determine process economics
- Demonstrate system on coal derived flue gas at Western Research Institute

About TDA

- **Began operations in 1987**
- **Today**
  - 85 employees, over 60% with advanced degrees
- **Facilities**
  - Combined 50,000 ft^2 in Wheat Ridge and Golden, CO

Areas

  - New materials development
  - Processes for Energy/chemicals
- **Business Model**
  - Perform R&D, primarily under government contract
  - Secure intellectual property
  - Commercializes technology by licensing, joint ventures, internal business units

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Acknowledgments

- **DOE project funding**
- **Collaborators**
  - B&W
  - LSU
  - WRI