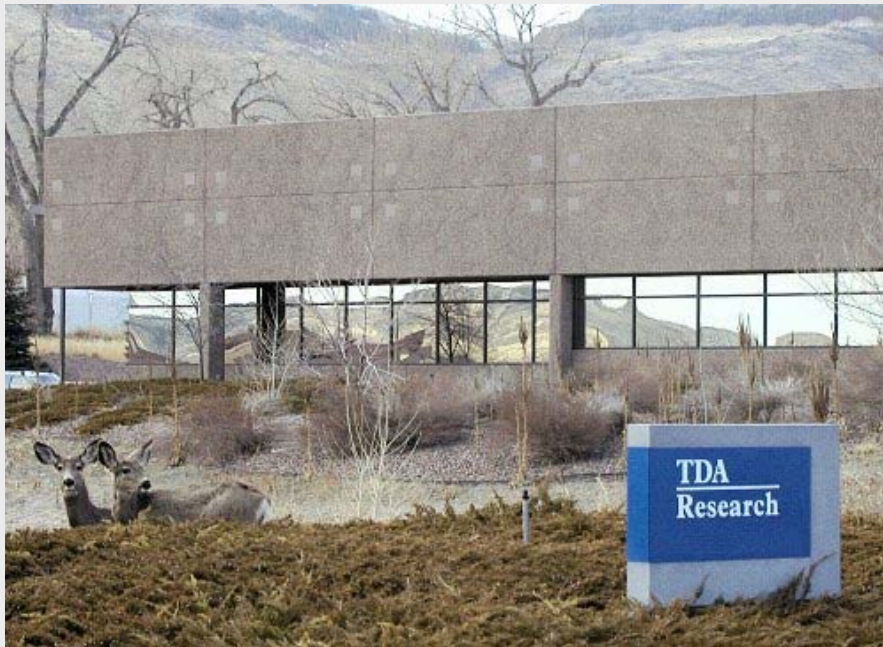


Low Cost Sorbent for CO₂ Capture on Existing Plants



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Dr. Girish Srinivas
Dr. Robert Copeland

July 8, 2013

Project Overview

DoE Project DE-NT0005497

Funding - Total Project \$1,714,846

- DOE: \$1,370,211
- Cost Share: \$344,635

Project Performance Dates

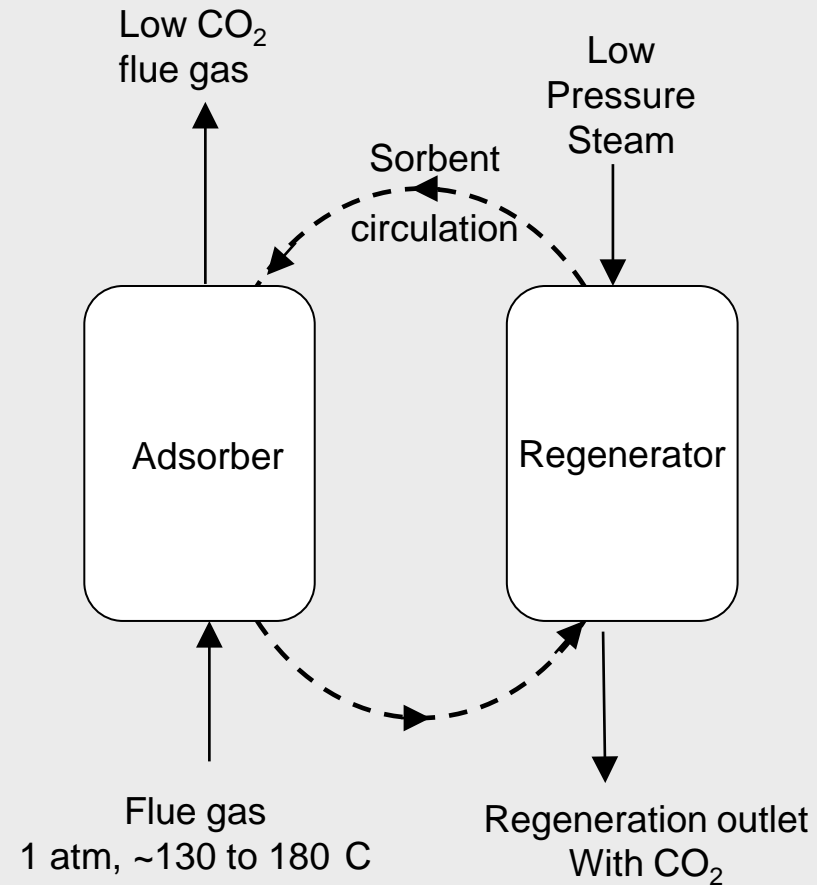
- November 1, 2008 to August 31, 2013

Project Partners

- TDA Research, Inc (TDA)
- Babcock & Wilcox (B&W)
- Louisiana State University (LSU)
- Western Research Institute (WRI)

TDA's Approach

- TDA Research, Inc., is developing a both a solid alkalized alumina adsorbent and a CO₂ capture process optimized for this approach



TDA's Post Combustion CO₂ Capture

- **Process advantages**
 - TDA's approach uses an inexpensive sorbent material
 - The sorbent is regenerated with low pressure steam
 - The system operates at near isothermal conditions
 - The process design has counter-current operation to maximize capture rate and loading with the physical adsorbent

Project Overview

- **Project goal:**

Demonstrate a CO₂ capture system designed around TDA's alkalized alumina adsorbent

- **Summary of Technical Progress:**

- Evaluated sorbent in bench-scale apparatus at TDA with simulated flue gas
- Extended cycling at TDA under simulated conditions
- Field testing with real coal derived flue gas at Western Research Institute
- Investigated new flow configurations in order to further optimize the process in continuous operation
- Advanced sorbent performance

Bench-scale Apparatus

- Demonstrates continuous capture of CO₂ from flue gas and continuous regeneration of the sorbent.
- Multiple fixed-beds apparatuses
 - Simulates counter-flow contact between the solids and gases
 - Bed cycle between adsorption and regeneration functions
 - Gas flows in series across regeneration beds
- Multiple fixed beds are flexible and can allow demonstration of multiple process design configuration



Multiple Fixed Bed Apparatus

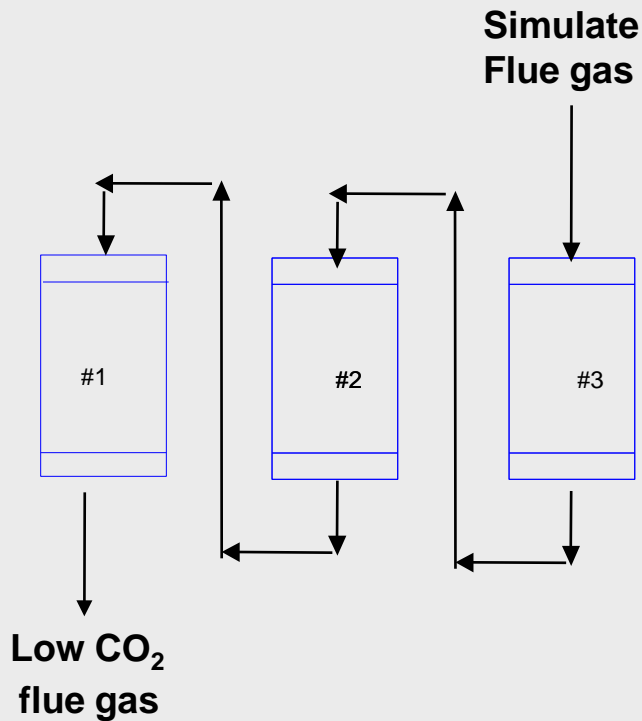
Beds 600cc (4.8L total sorbent)



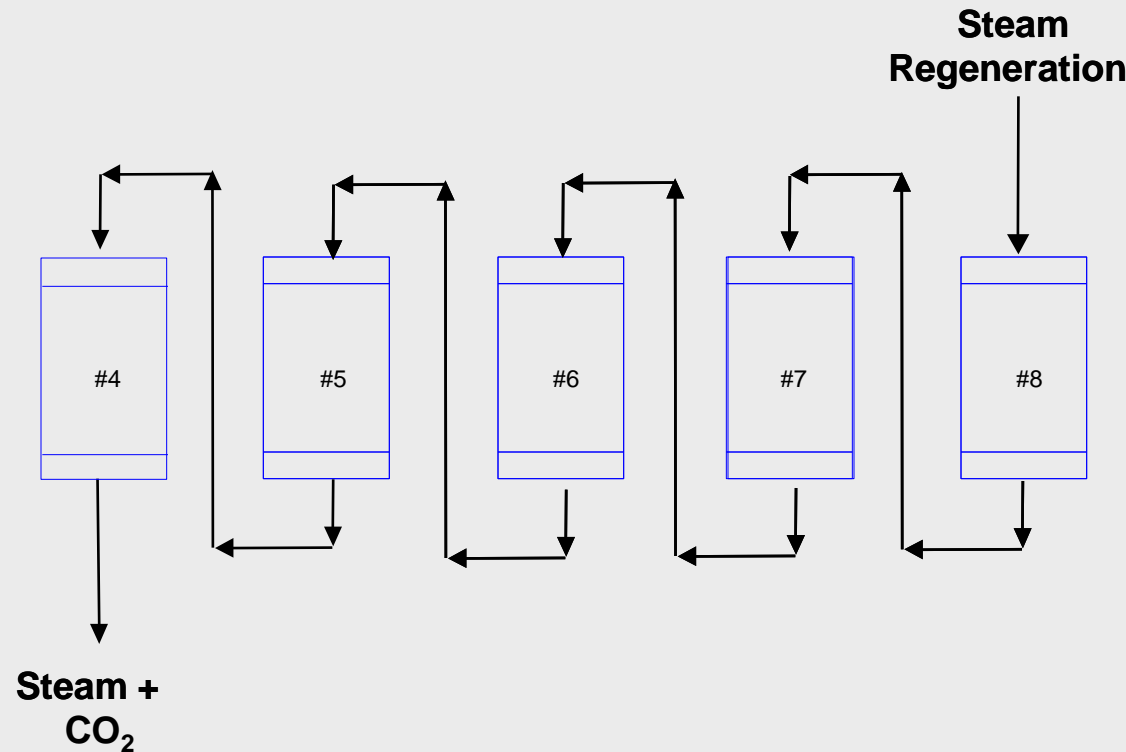
Operation of 8 Bed System

Previous configuration

Adsorption



Regeneration

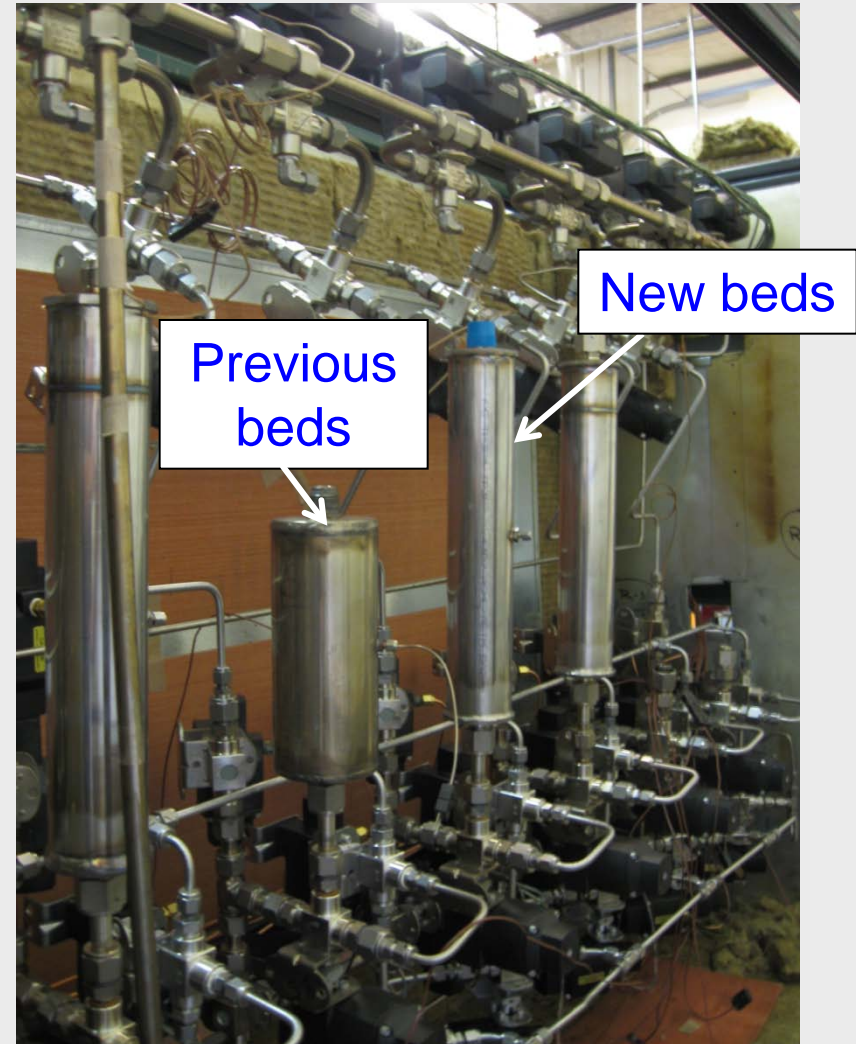


Beds rotate this way

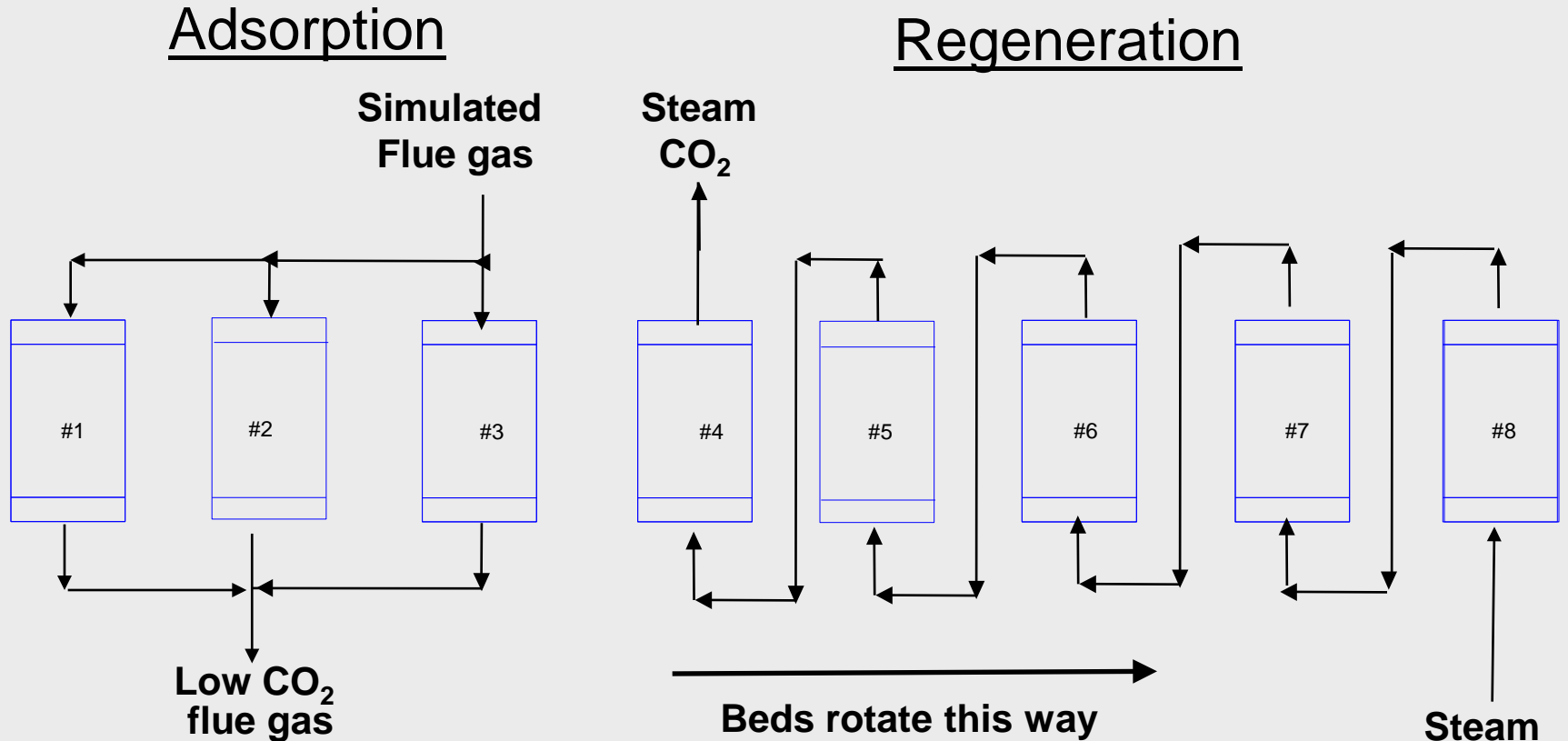


Update of 8 Bed Apparatus

- Adsorption beds run in parallel rather than series
 - Decreases pressure drop by factor of 9 (with 3 bed in adsorption)
- Flue feed and regeneration steam feed now in counter flow directions
- Gas and solids still in counter flow directions
- Higher aspect length fixed beds
 - Aspect ratio increased from 1.9 to 5.7
 - Increased superficial velocity

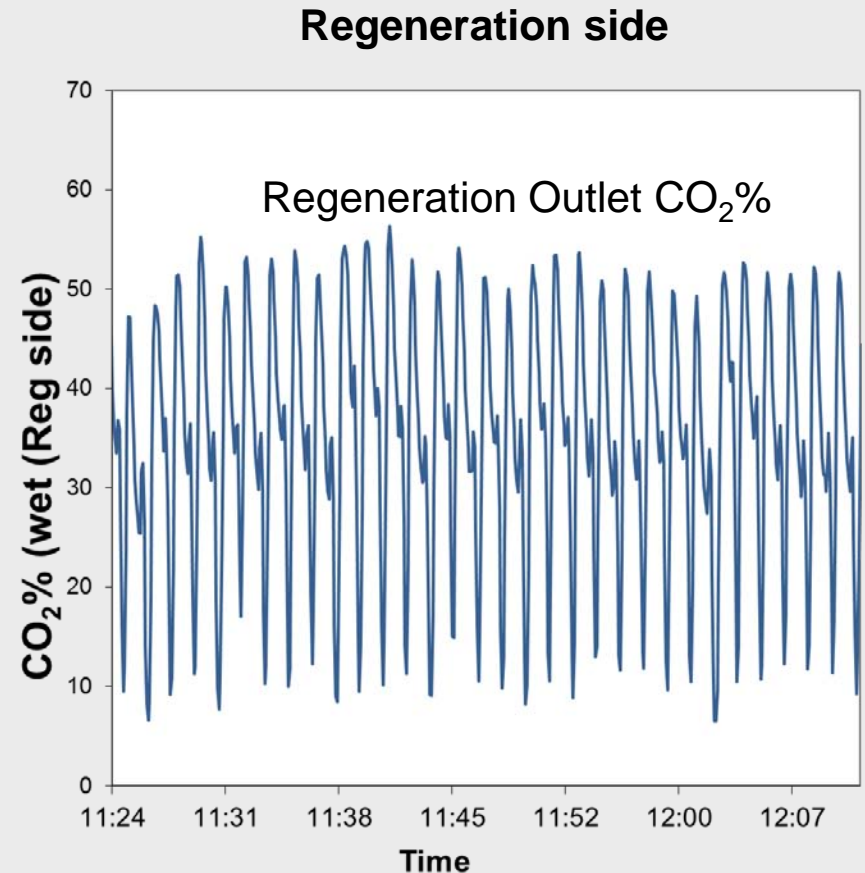
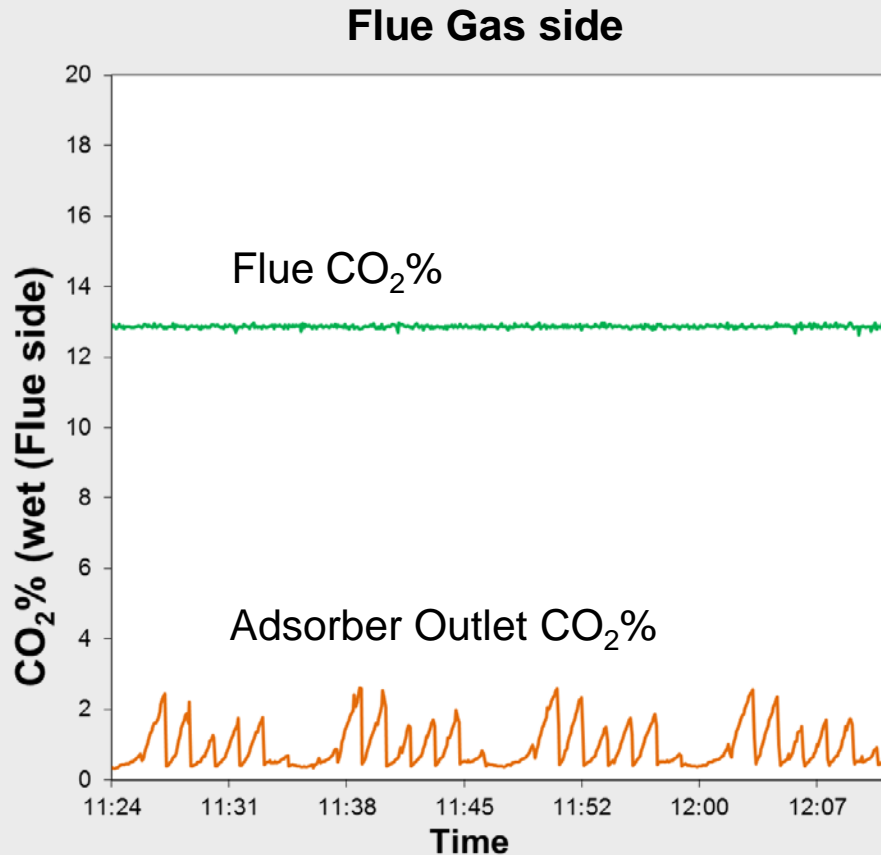


Updated Flow Pattern for Beds



- **Parallel flow configuration will reduce pressure drop in adsorption**

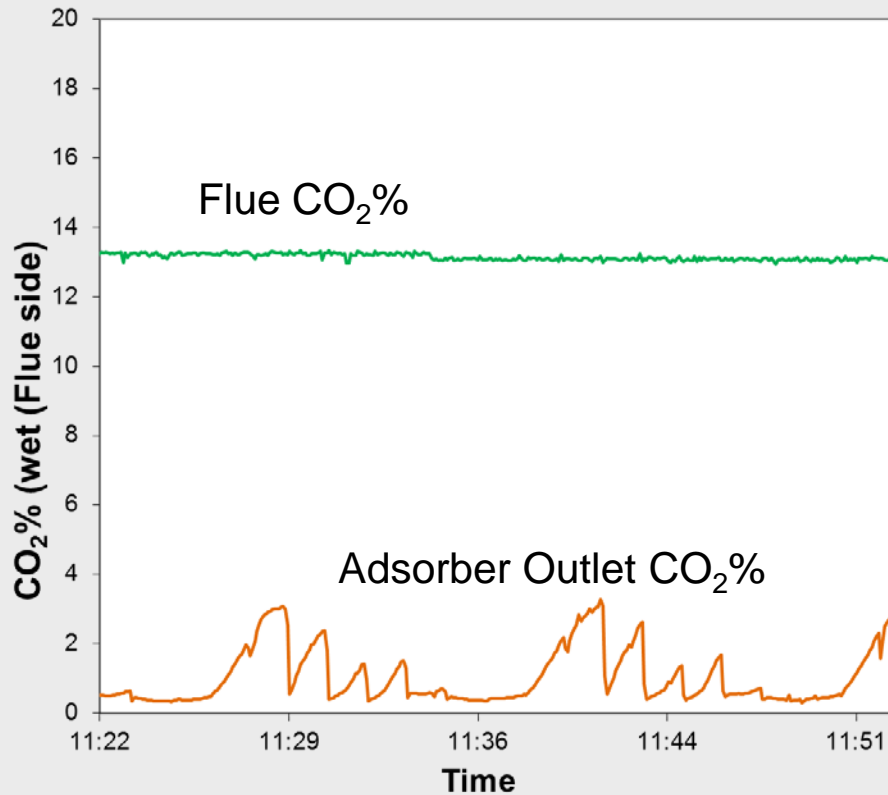
3 Beds Adsorption 5 Beds Regen



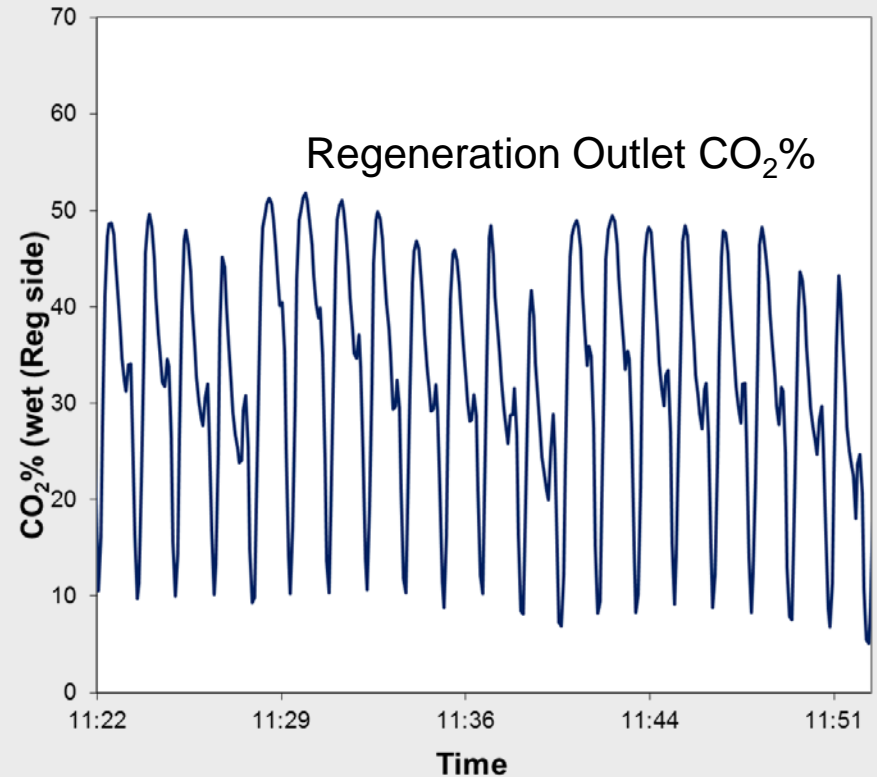
- New system configurations achieves 90% capture with adsorber beds in parallel
- Loading 0.83 wt% and 90.3% capture

4 Beds Adsorption 4 Beds Regen

Flue Gas side



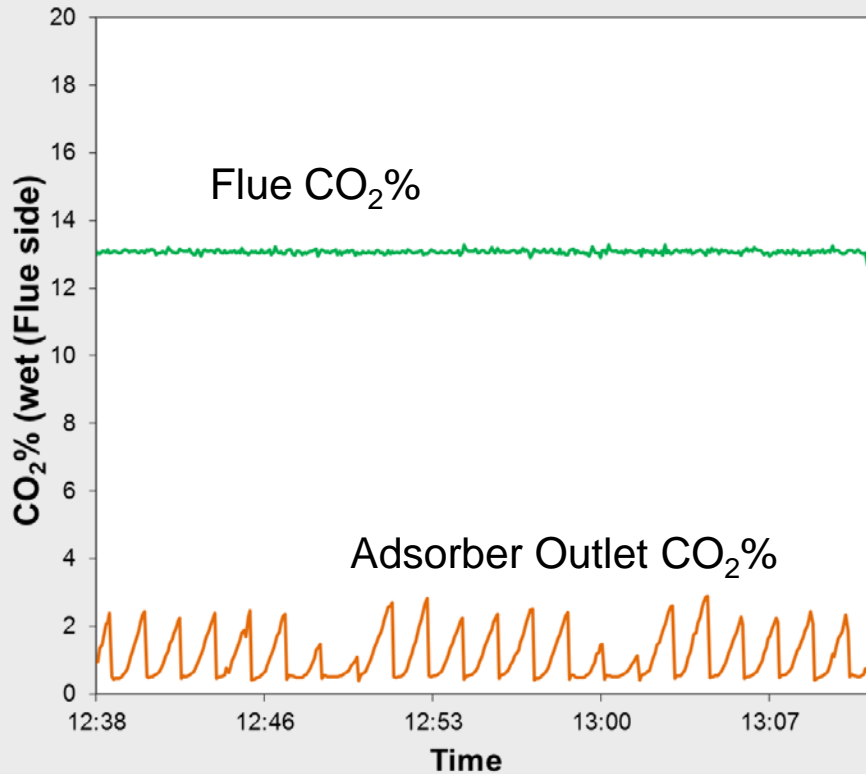
Regeneration side



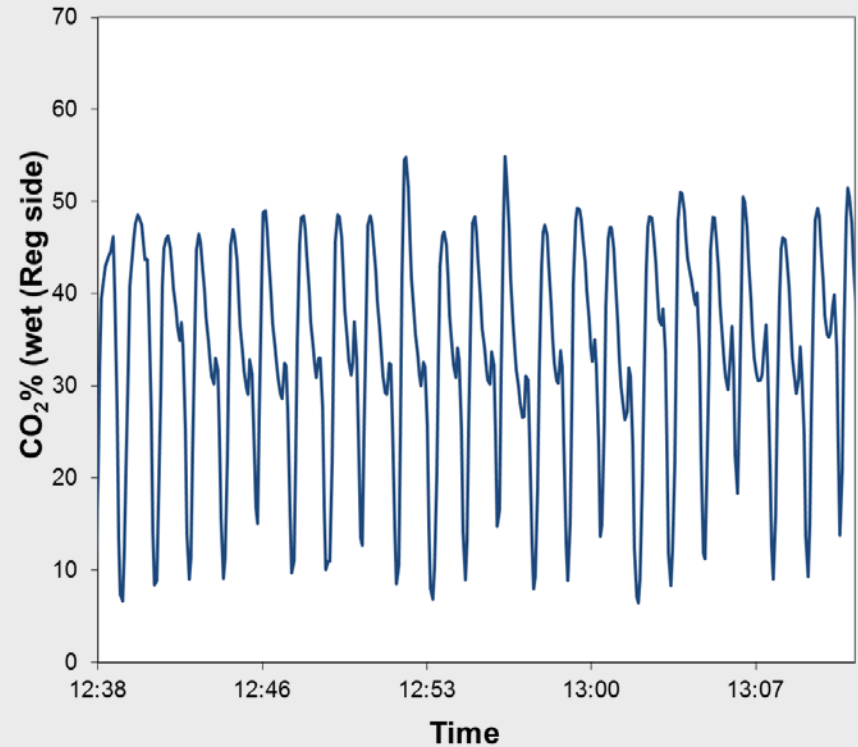
- Loading 0.83 wt% and 88.7% capture
- Almost the as effective as 3 + 5 beds

2 Beds Adsorption 6 Beds Regen

Flue Gas side

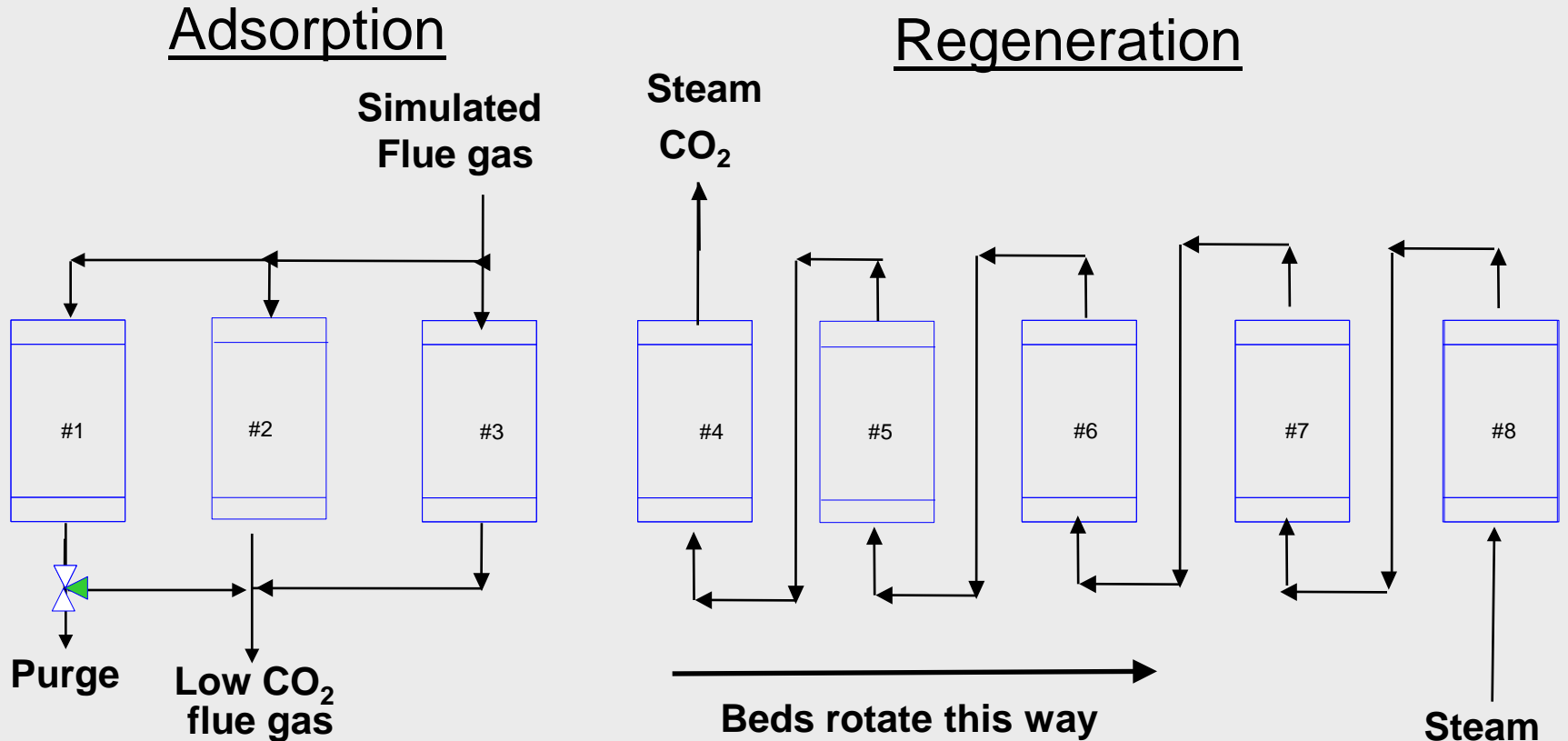


Regeneration side



- Loading 0.82 wt% and 88.3% capture
- Also very similar to 3 + 5 beds

Alternative Process Operation



- Purge performed for part of cycle rather than taking a bed offline the entire cycle time
- Capture rate 91.7% and loading 0.86 wt% with operation at higher space velocity than WRI field test

Conclusions on Process Design

- Beds can be run in parallel during adsorption
- We can still achieve 90% capture but with 1/9 the pressure drop
 - Pressure drop through the adsorber beds is a parasitic cost
- Several adsorption/ regeneration bed configurations tested (3+5, 4+4, 2+6).
 - Results of different configurations were similar
 - Slight advantage with 3 adsorbers 5 regenerators

Sorbent Advancement

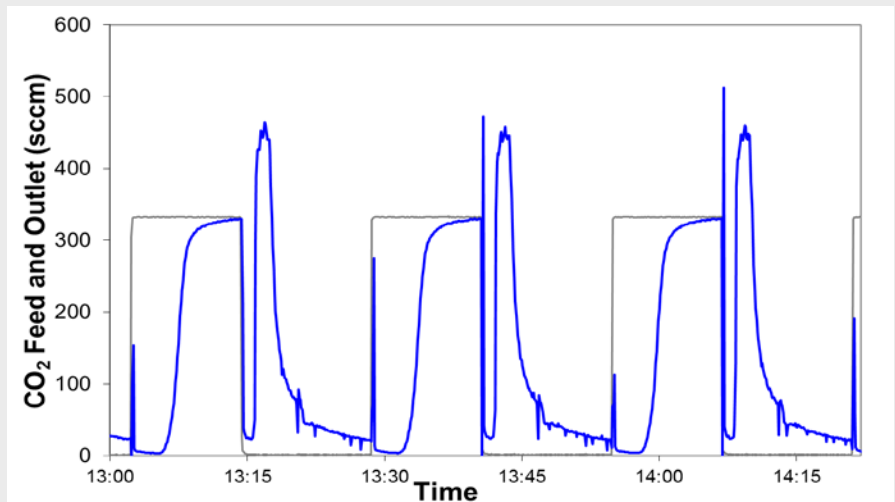
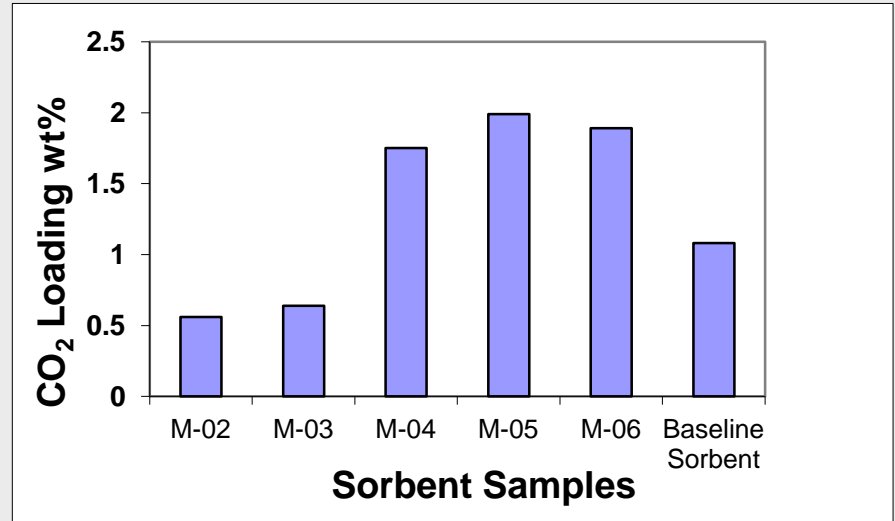
- **Baseline alkalized alumina sorbent was used in last year's field testing at WRI and in process design experiments**
- **Sorbent has been advanced in recent sorbent development work**
- **Sorbent evaluated in TDA's fixed bed apparatus to screen candidate sorbent compositions**
- **Additional testing in TGA**



300 cc fixed bed reactor
Online analyzer for continuous CO₂ and humidity measurement
counter flow orientation for adsorption and regeneration

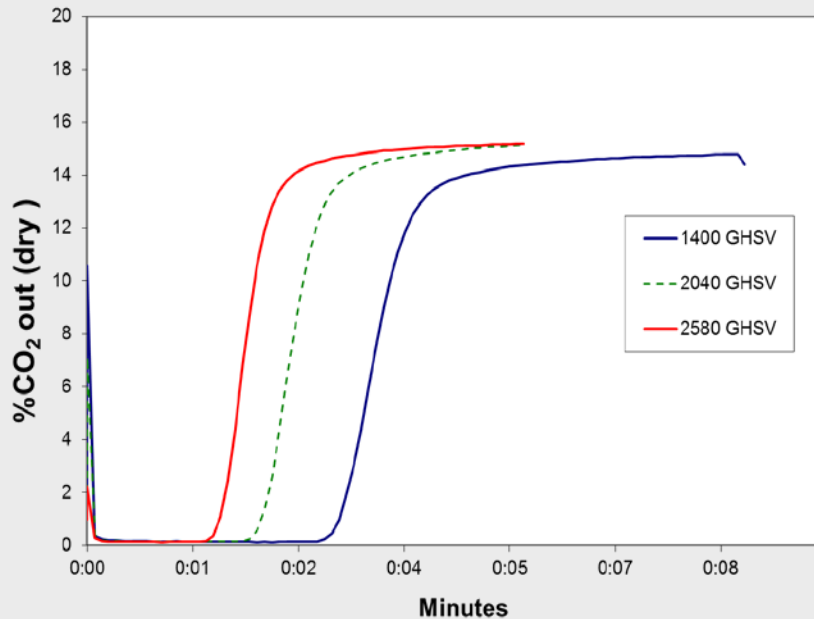
CO₂ Loading Capacity

- **Loading capacity measured under cyclic conditions in fixed bed**
 - 13% CO₂, 8% H₂O simulated coal flue
 - Steam regeneration
- **Sorbent candidates M-04, M-05 and M-06 have significantly improved performance over Baseline Sorbent**
- **M-05 and 06 selected for further study and characterization of kinetics**

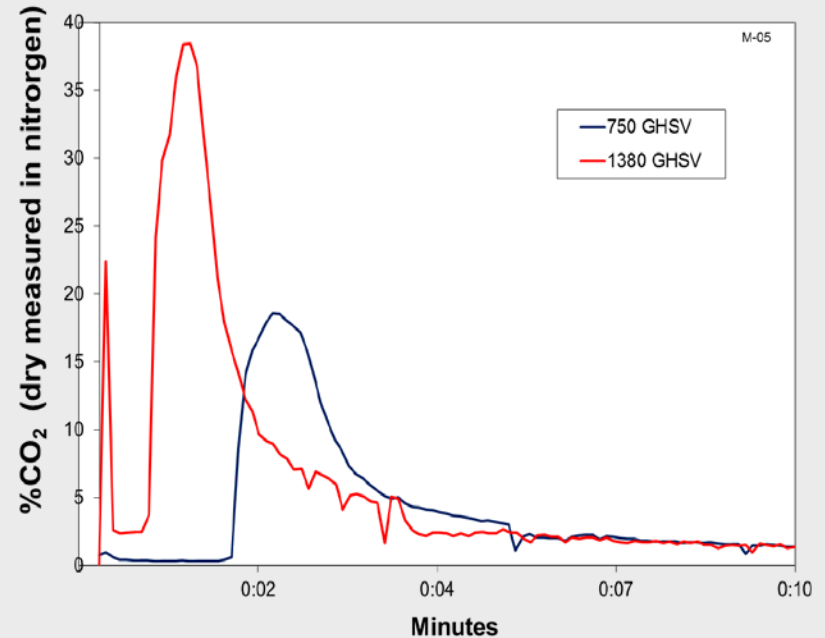


Breakthrough Curves M-05

Adsorption



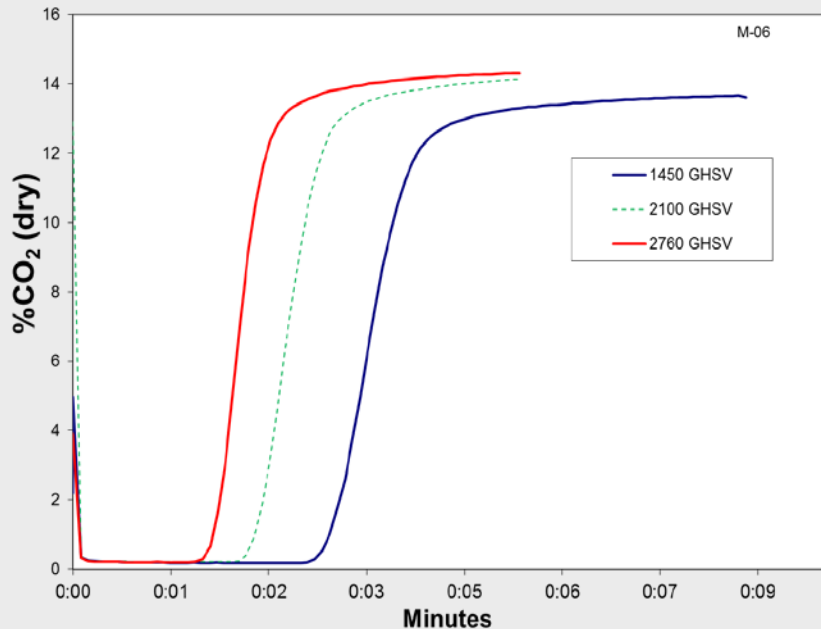
Regeneration



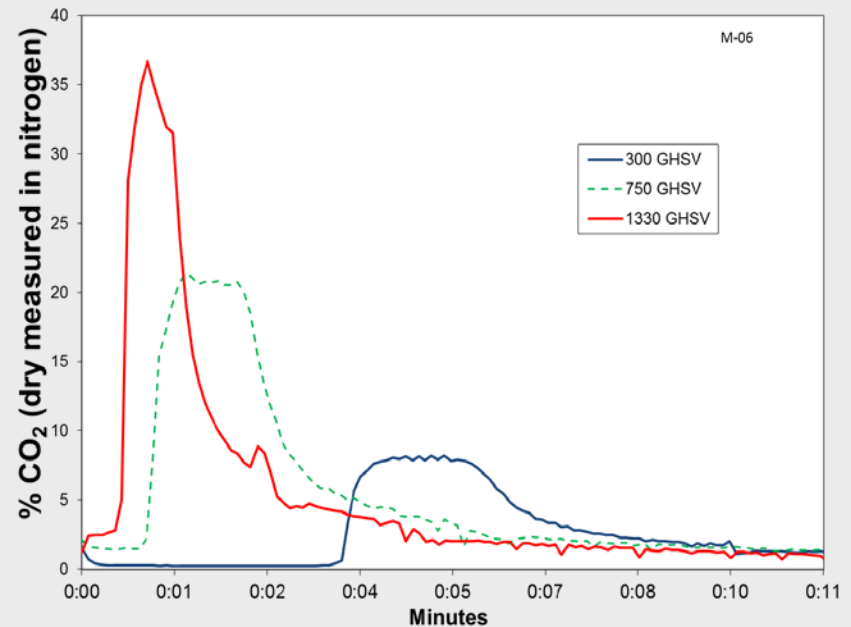
- **New sorbent has very high CO₂ removal efficiency at faster rates of adsorption and desorption**

Breakthrough Curves M-06

Adsorption



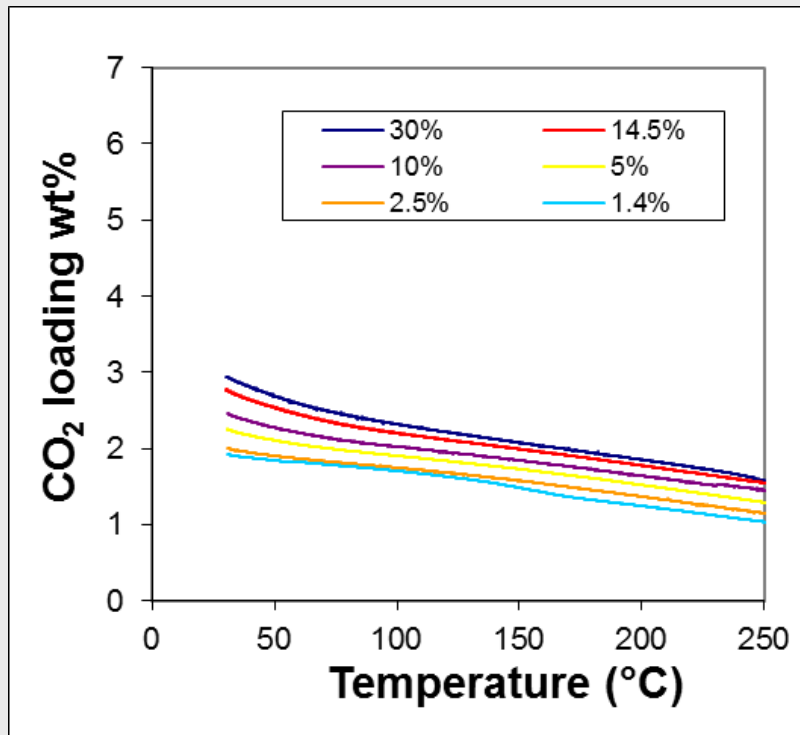
Regeneration



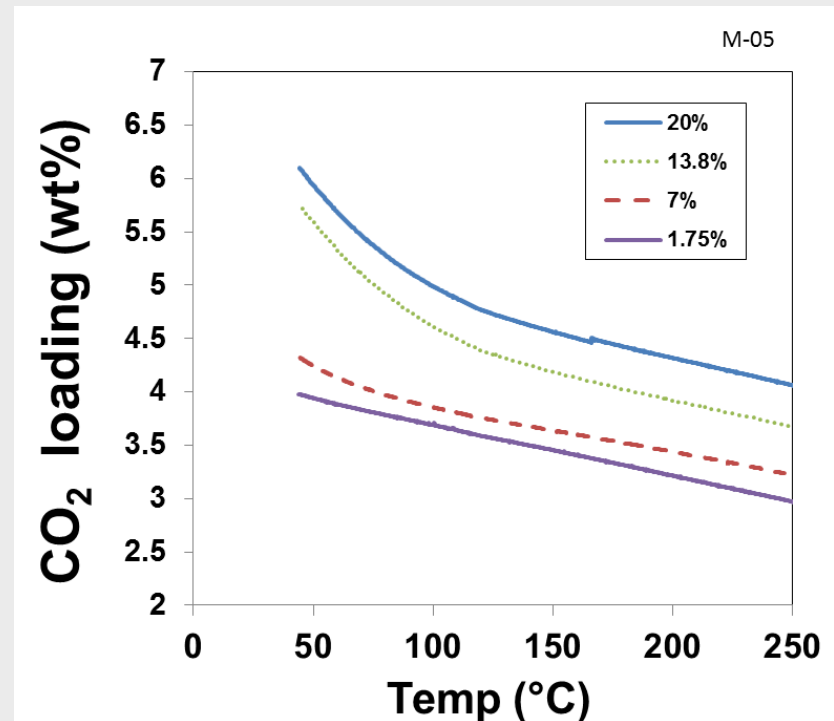
- **M-06 also shows good kinetic behavior showing it can be used at high space velocities**

Sorbent Isotherms

Baseline Sorbent

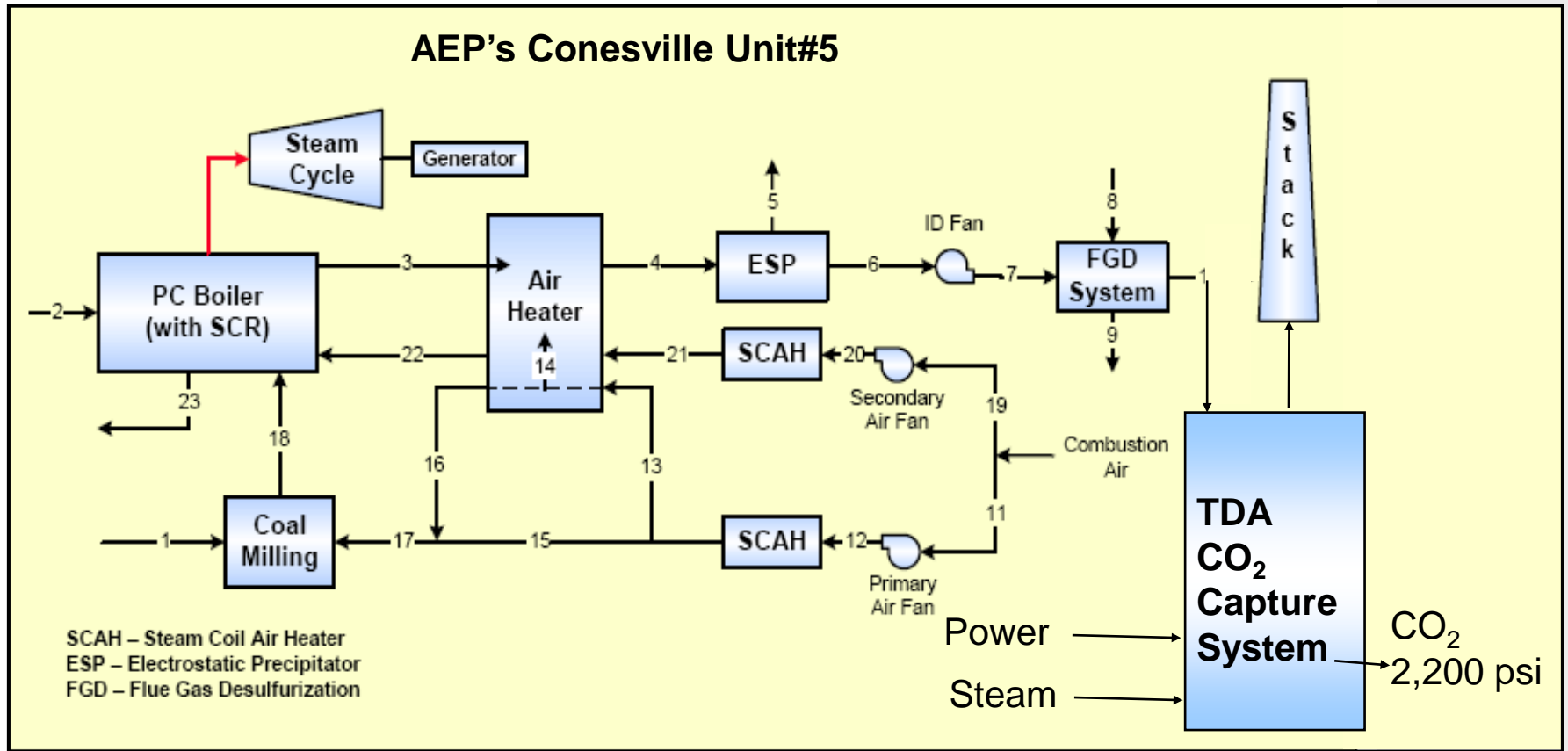


Sorbent M-05



- Isotherms test run in the TGA under range of CO₂ concentrations
- New sorbent M-05 has about twice ultimate capacity of baseline sorbent

System Analysis



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

433.7 MW plant, 10,393 tons/day CO₂ generated (DoE/NETL-401/110907)

System Economics

- Retrofit of an existing subcritical 433.7 MW coal fired power plant
 - 90% Capture
 - Assumed clean up of SO_x down to < 5ppm
 - Transportation, storage and monitoring not included
- Based on expected performance of improved sorbent in new flow configuration
- Net Power Output
 - 333.9 MW for TDA system
 - 303.3 MW for amines (DoE/NETL-401/110907)
- Incremental LCOE increase
 - 4.77 ¢/kWhr for TDA system
 - 6.92 ¢/kWhr for amines (DoE/NETL-401/110907)
- Cost of CO₂ avoided reduced by 33%
 - \$60/ tonne for TDA system on retrofit of subcritical plant
 - \$89/ tonne avoided for amines (DoE/NETL-401/110907)

Summary

- TDA has advanced both the sorbent and the process for post-combustion CO₂ capture on coal fired power plants
- New flow configuration demonstrated with lower pressure drop and 90% capture
- Improved sorbent increases CO₂ loading by over 50%
- Economic study shows the approach is promising

Future Work

- Evaluate advanced sorbent in optimized 8 bed process
- Finalized process economics based on experimental data of advanced process

About TDA

- **Began operations in 1987**
- **Today**
 - 85 employees, over 60% with advanced degrees
- **Facilities**
 - Combined 50,000 ft² 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



Acknowledgments

- **NETL Project Funding**
 - DE-NT0005497
- **Program Manager: Andrew O’Palko**
- **Collaborators**
 - B&W
 - LSU
 - WRI