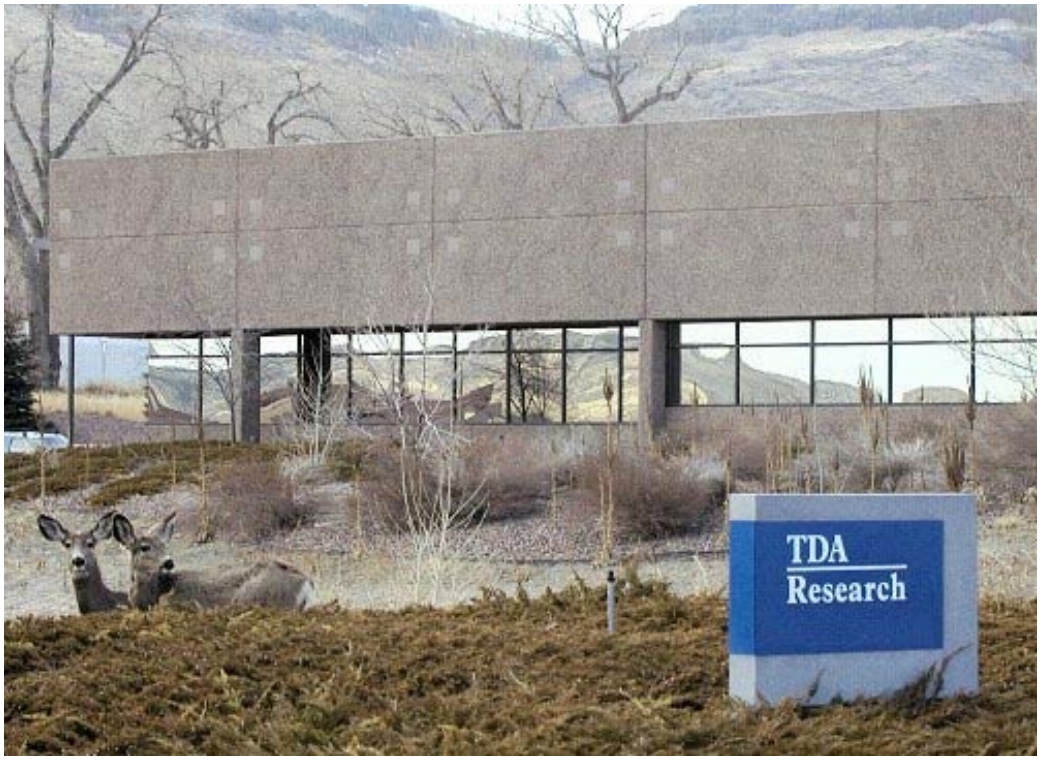
Post-Combustion CO_2 Capture System for Existing Coal-fired Power Plant

Project Review (DE-FE-0007580)



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NETL CO_2 Capture Technology Meeting

Pittsburgh, PA
July 10, 2012

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

Project Summary

- **The objective is to develop a post-combustion capture process for coal-fired power plants and demonstrate technical feasibility (at bench-scale) and economic viability of the concept**
- **A mesoporous carbon adsorbent is used to selectively remove CO_2 from the flue gas, regenerating under very mild conditions**

Budget Period 1

- **Sorbent optimization and laboratory scale evaluations**
- **Process design and system analysis**

Budget Period 2

- **Long-term Sorbent Cycling**
- **Design of a Breadboard Prototype Test Unit**
- **High Fidelity Process Optimization and Design**

Budget Period 3

- **Fabrication of the Prototype Test Unit**
- **Concept Demonstration**
- **System Analysis, Economic Evaluation and EH&S Assessment**

Project Partners

TDA Research

UNIVERSITY of CALIFORNIA • IRVINE

B&W thebabcock&wilcoxcompany

gti

MWV MEADWESTVACO

Project Duration

- **Start Date = October 1, 2011**
- **End Date = September 30, 2014**

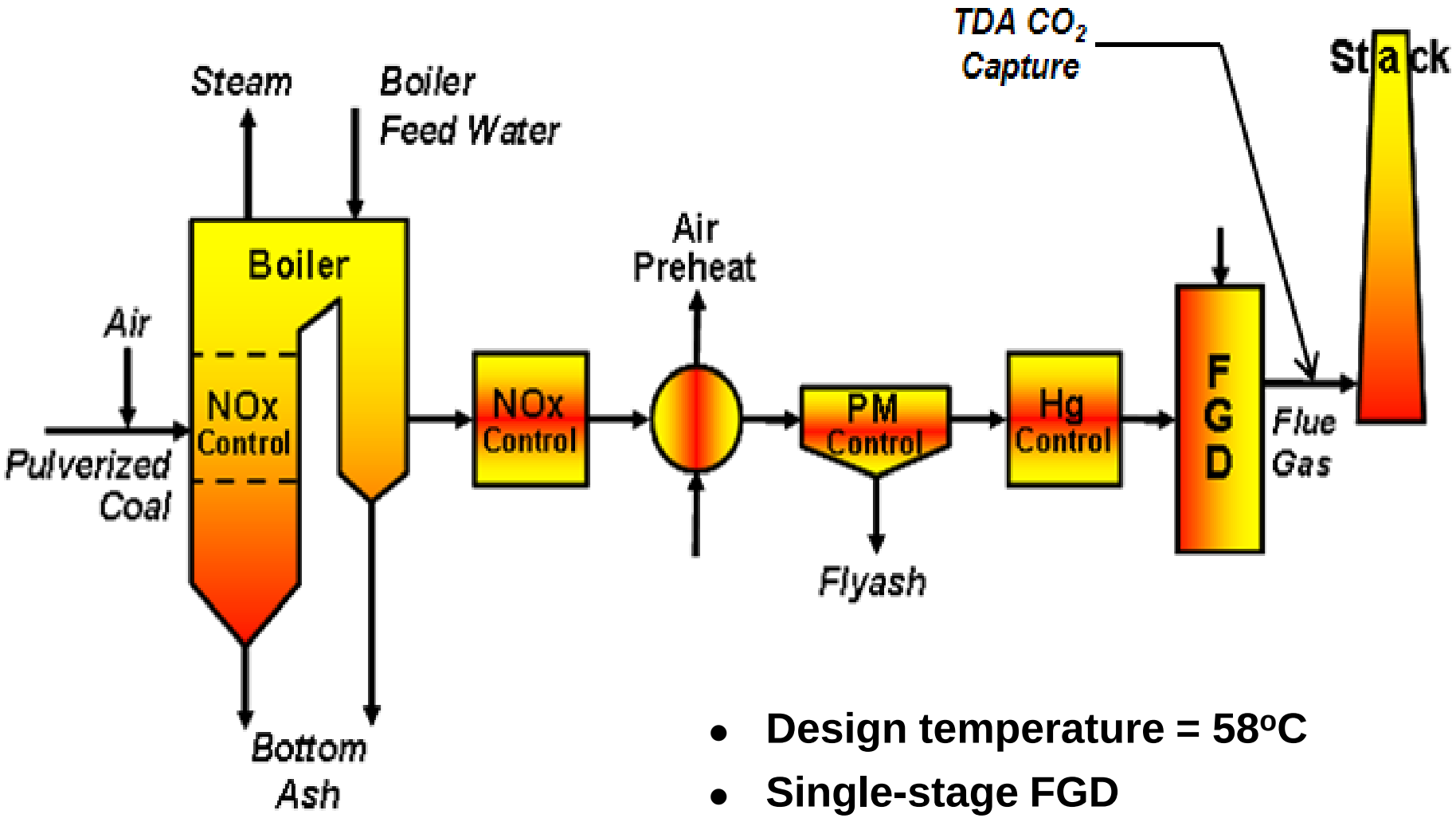
Budget

- **Project Budget = $3,375,000**
- **DOE Share = $2,700,000**
- **TDA/Partners Share = $675,000**

TDA's Approach

- The sorbent consists of a carbon material modified with surface functional groups that remove CO_2 via physical adsorption
  - CO_2-surface interaction is strong enough to allow operation at target temperature range
  - Because CO_2 does not covalently bonded to the surface, the energy input requirement for regeneration process is low
- Heat of adsorption of CO_2 is measured as **3.9-4.8 kcal/mol** for TDA sorbent
  - Selexol ~4 kcal/mol
  - Amine solvents ~14.4 kcal/mol
  - Chemical absorbents 20-40 kcal/mol
    - $Na_2CO_3 + CO_{2(g)} + H_2O_{(g)} \rightarrow 2NaHCO_3$ (ΔH = -30 kcal/mol)
- The net energy loss in sorbent regeneration is expected to be much lower than amine scrubbers
  - Higher process efficiency

Integrated CO_2 Capture System



- Design temperature = 58°C
- Single-stage FGD

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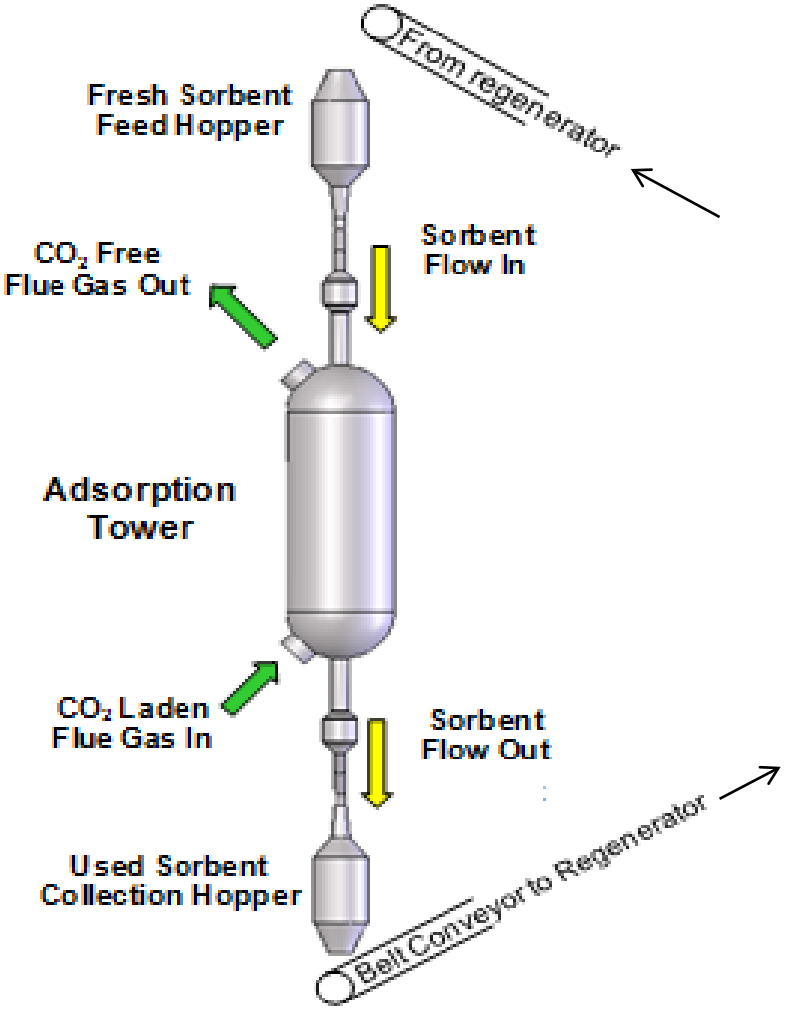
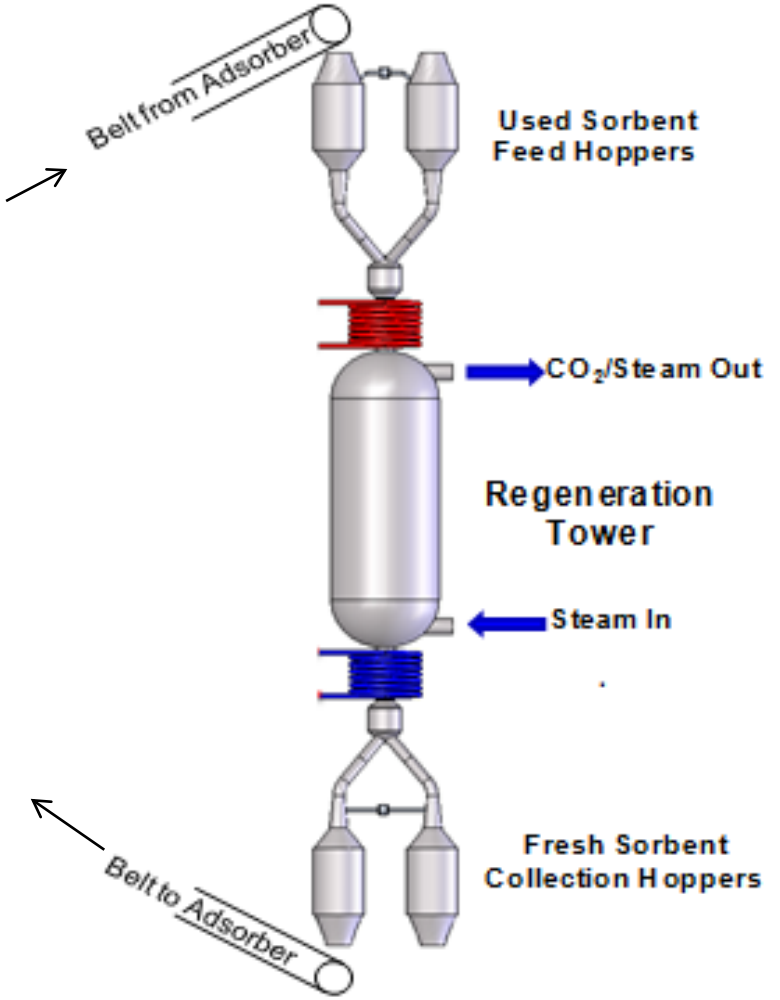
TDA's CO_2 Capture System



Adsorption



Regeneration

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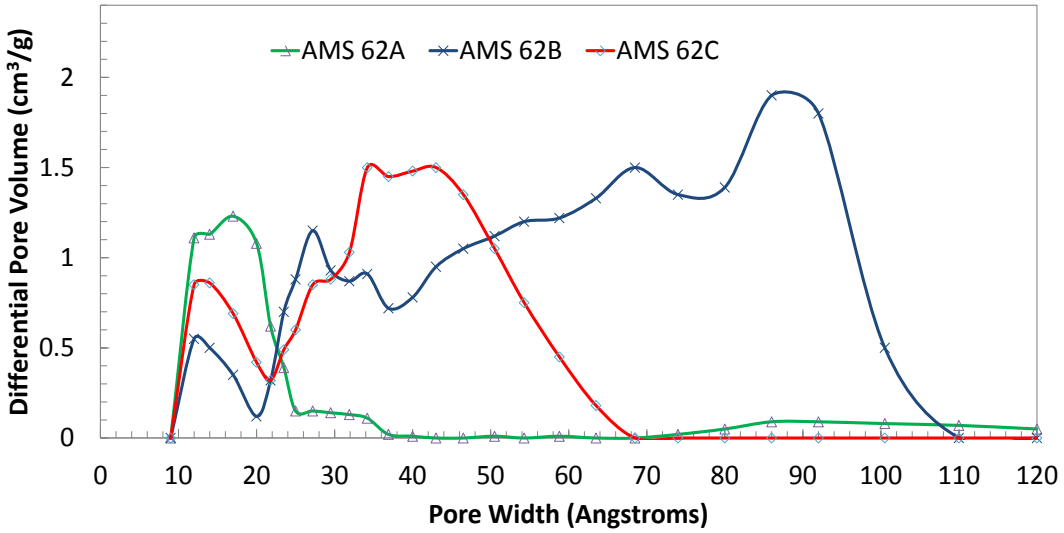
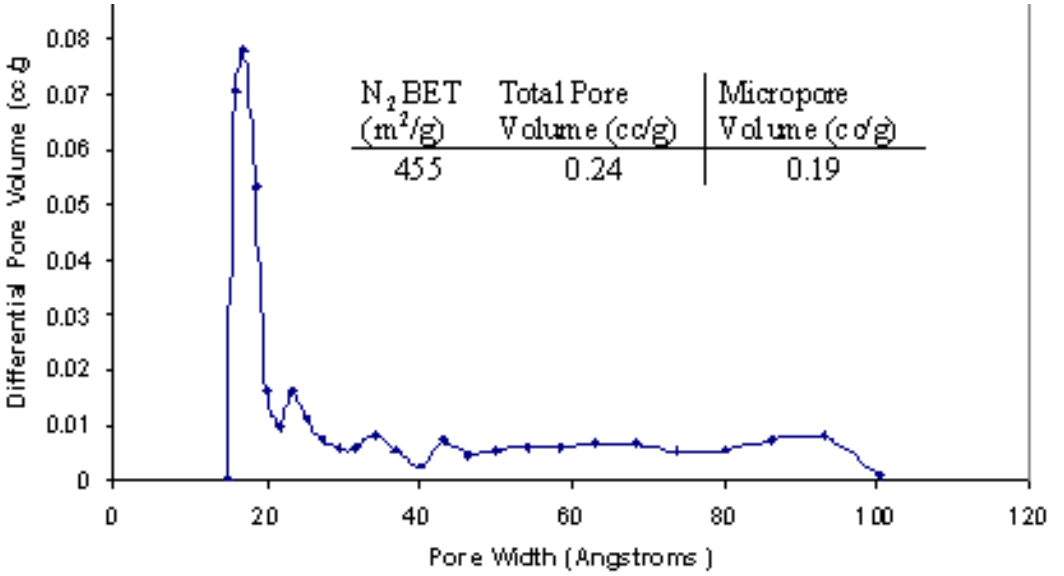
TDA's Sorbent

- **A mesoporous carbon is used to disperse the active sorbent phase**
  - **The preparation process enables us to introduce surface groups active for CO_2 removal**
- **The carbon support is previously developed for ultra-capacitors, large pores to achieve liquid transport**
  - **Successfully demonstrated for pre-combustion carbon capture (DE-FE0000469)**
  - **T= 260°C, 12,000+ cycles**





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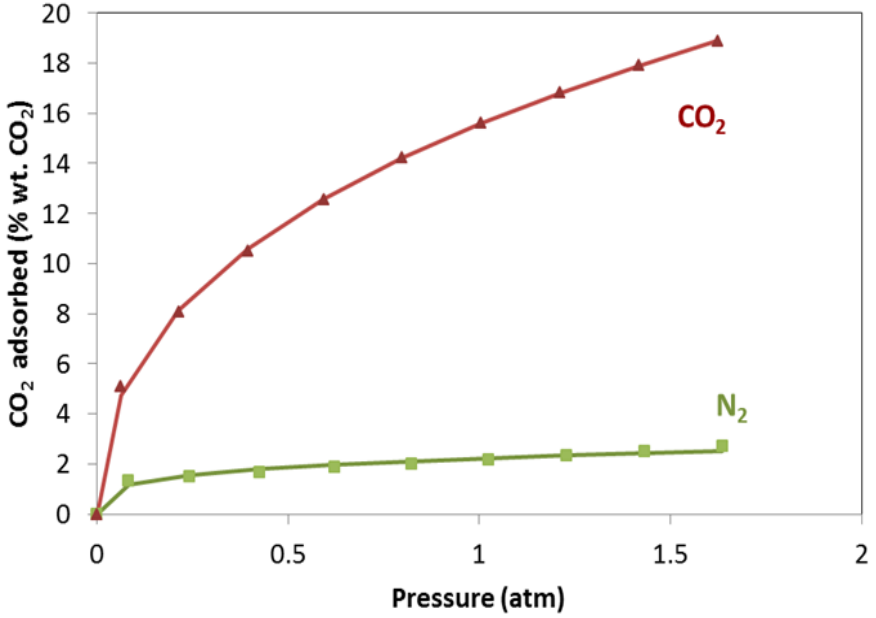
Adsorption Isotherms

Langmuir-Freundlich Isotherm Model

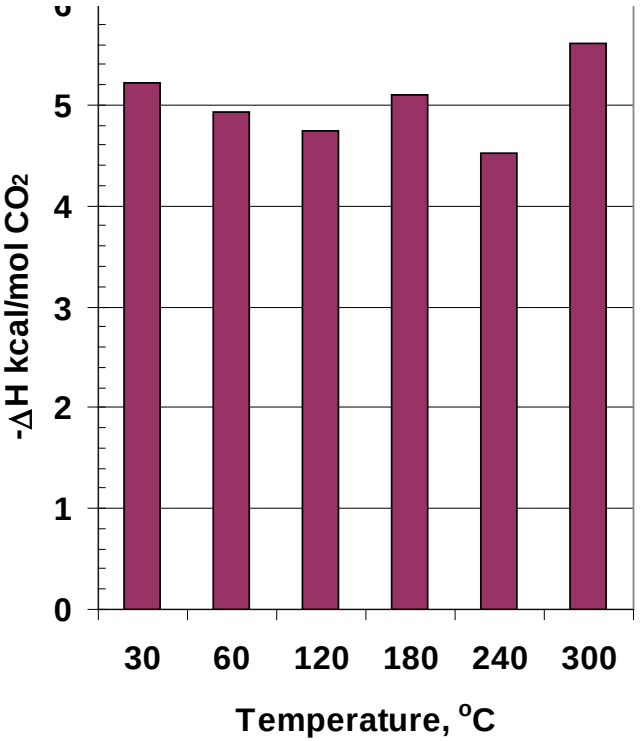


$$q = \frac{q_s B P^n}{1 + B P^n} \qquad q_s = k_1 e^{k_2/T} \qquad B = k_3 e^{k_4/T}$$

	k_1	k_2	k_3	k_4	n	$-\Delta H$ (kcal/mol)
CO_2	28.0	1.63E-08	6.11E-04	1613.4	0.46	3.87
N_2	317.0	6.43E+02	6.37E-05	439.6	0.25	1.53

$-\Delta H_{CO2}$ = 3.9 kcal/mol $-\Delta H_{N2}$ = 1.5 kcal/mol

Calorimetry Measurements



$-\Delta H_{ads}$ = 4.9 0.4 kcal/mol

- **Isosteric heat of adsorption calculations and DSC experiments confirm the low heat of adsorption**

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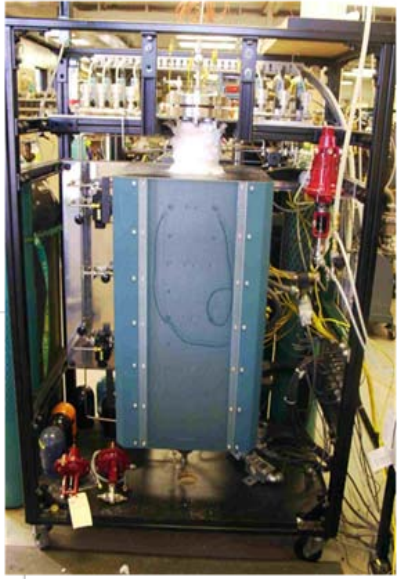
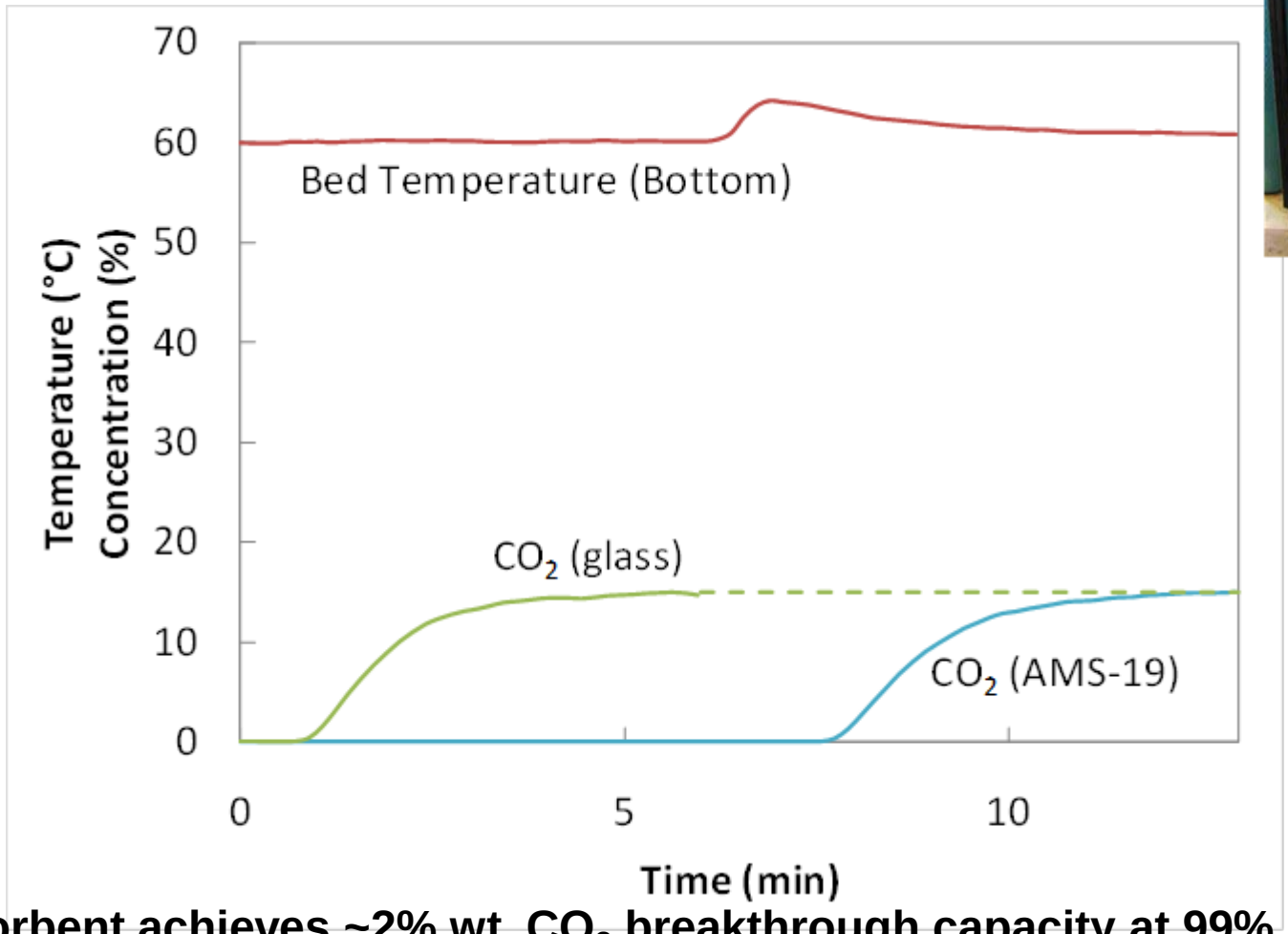
Typical CO_2 Breakthrough Profile



T=60°C, P= 17 psia, simulated flue gas, 15% vol. CO_2



- **Sorbent achieves ~2% wt. CO_2 breakthrough capacity at 99% CO_2 removal efficiency**

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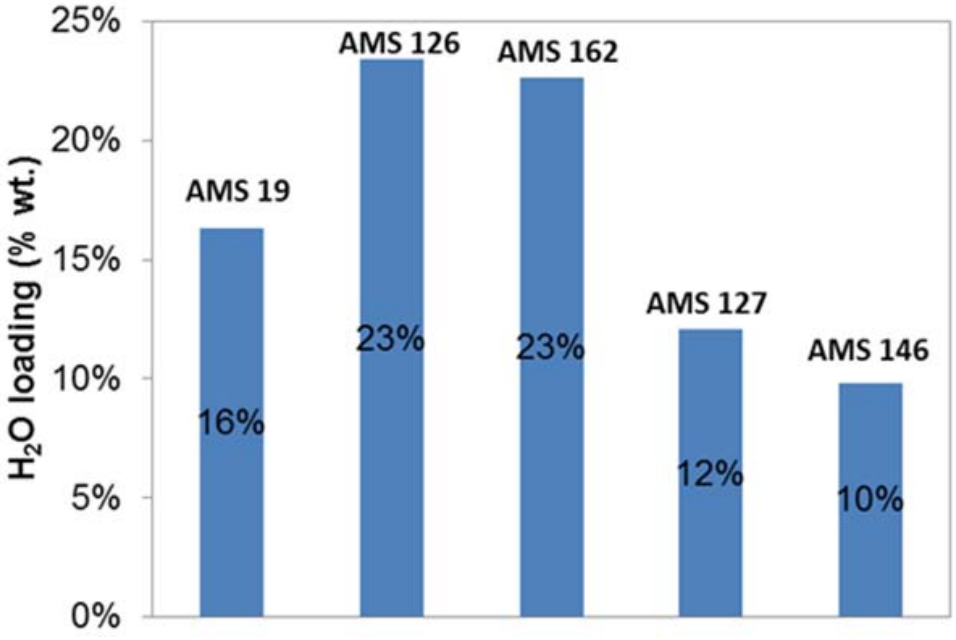
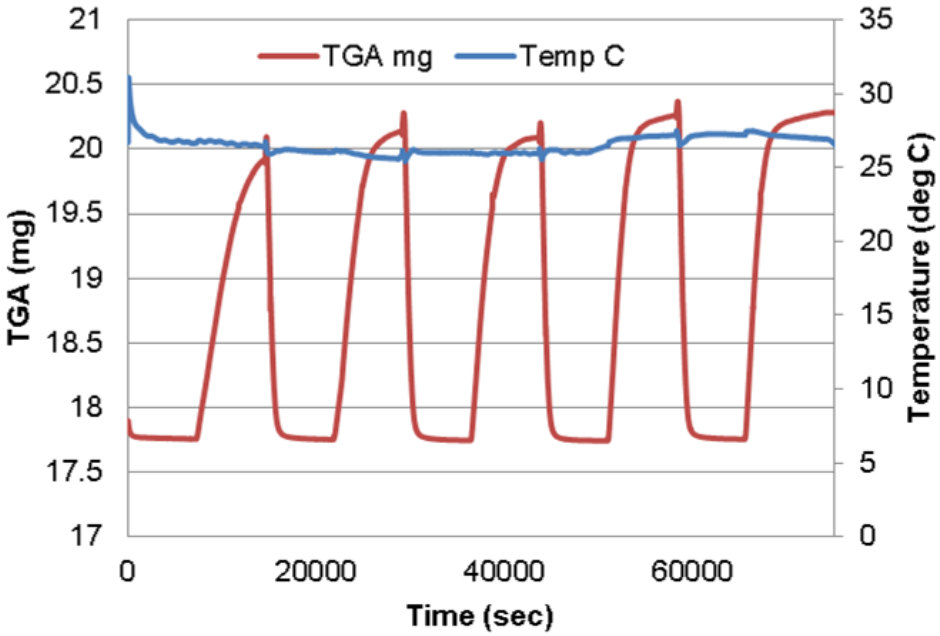
Water Adsorption

T = 26°C; H_2O = 2.4% vol.



Water adsorption- desorption cycles in TGA

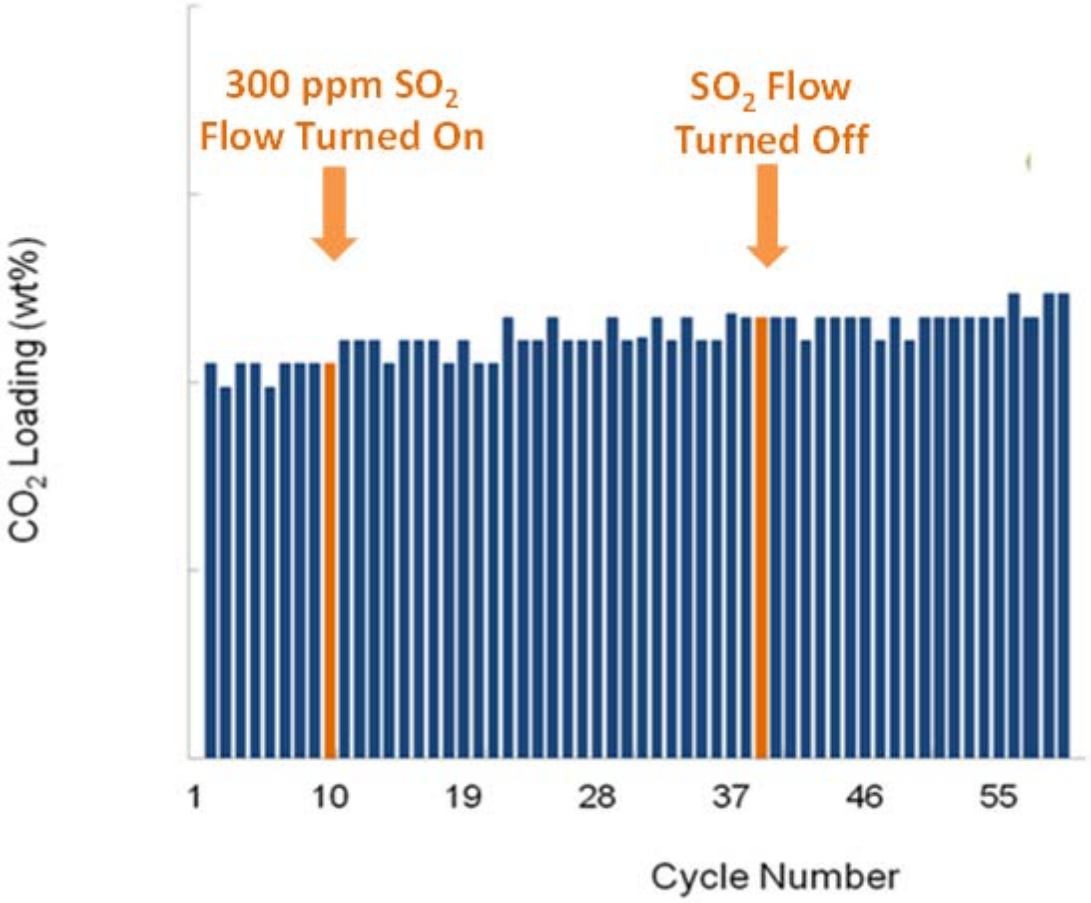


- **Unlike other adsorbents (e.g., molecular sieves) water does not competitively adsorb over CO_2**
- **Under a DOE SBIR project (Contract No. DE-SC0006239) TDA is investigating new adsorbents**

TDA Research

Impact of SO_2 on Sorbent Performance

Adsorption T= 62ºC, 15.2% CO_2, 2.8%O_2, bal N_2, sat. with H_2O, 300 ppmv SO_2

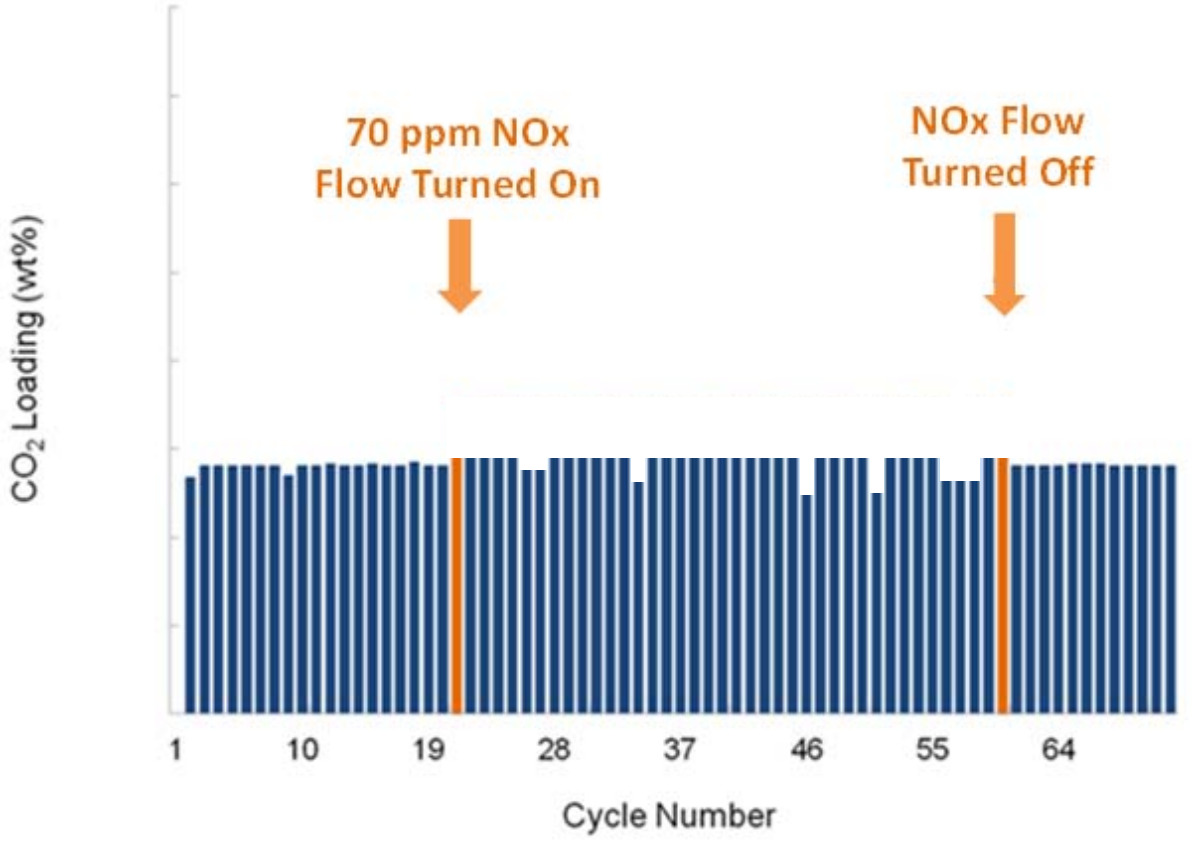


- **Sorbent maintained stable capacity with up to 300 ppmv SO_2**
  - Slightly better performance at lower SO_2 concentration

TDA Research

Impact of NO_x on Sorbent Performance

T= 62ºC, 15.2% CO_2, 2.8%O_2, bal N_2, sat. with H_2O, 70 ppm NO_x

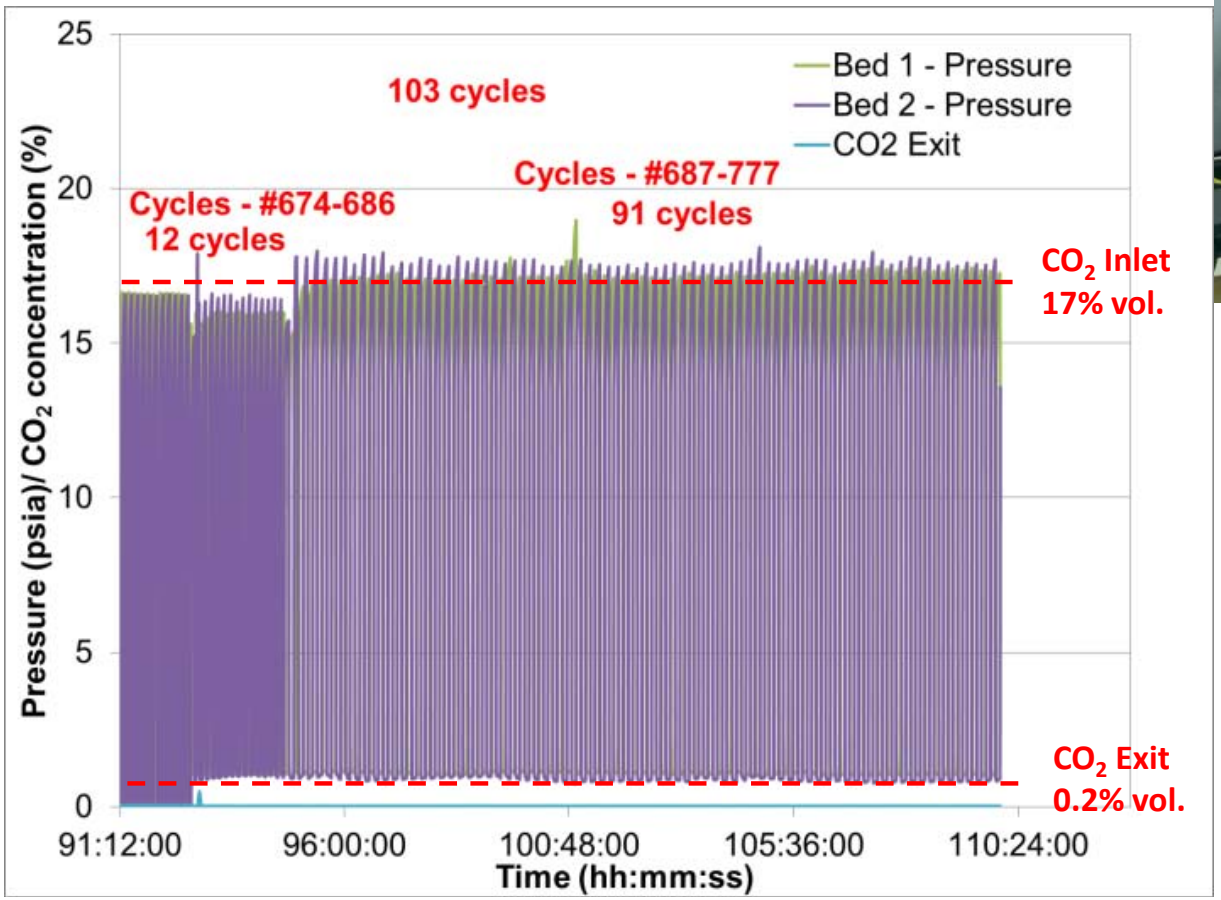


- **Sorbent maintained stable capacity with up to 70 ppmv NO_x**
  - NOx had no impact on sorbent performance

TDA Research

Multiple VSA Cycles

T = 22°C; Half-cycle time = 4-8 min; P_{ads}= 16 psia; P_{des}= 1 psia; simulated flue gas, 17% vol. CO_2, H_2O = 1.2% vol.



- **Sorbent maintained its CO_2 capacity and removal efficiency over 770 cycles**

Preliminary Economic Analysis

- **A comparison against the amine system was carried out based on a 550 MW Plant used as a basis in a previous DOE/NETL analysis**
- **Preliminary results indicate ~120 MW loss (~20% plant efficiency)**
- **MEA has 179 MW loss (more than 32%)**

	kW_e	Net Efficiency (%)
Plant power output without CO_2 Capture	550,000	35.74
Plant power output w/ TDA's CO_2 Capture	430,550	27.97

- **A more detailed analysis supported with Aspen Plus Simulation is under progress**

Acknowledgements

DOE/NETL

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