SRI International

Carbon Capture from Natural Gas:
SRI's perspective on current technologies & future needs

United States Energy Association Workshop on Technology Pathways Forward for CCS on Natural Gas Power Systems

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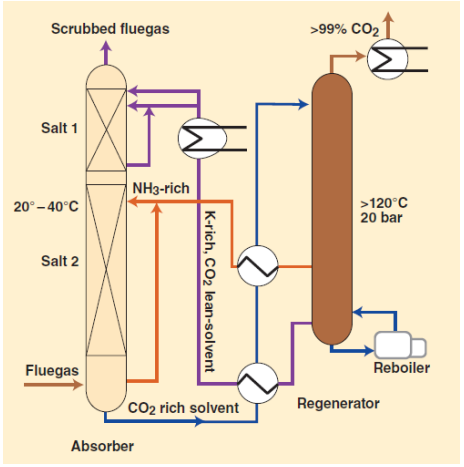
Who We Are

SRI is a world-leading R&D organization with a strong carbon capture program

- An independent, nonprofit corporation founded in 1946
  - 2013 revenues: approximately $540 million
  - 2,500 employees at 20 locations worldwide
- Development and scale-up carbon of capture technologies since 2006
  - Post-combustion, pre-combustion and novel solutions, such as capture from air
  - Flexible business model
    - Demonstrate and scale-up technologies brought to us by commercial clients
    - Collaborative research to develop new solutions
    - Original research
- Three new DOE awards in 2013 totaling about $15M over 3 years



Lessons Learned at Coal-Fired Power Plants Apply to Natural Gas-Fueled Plants

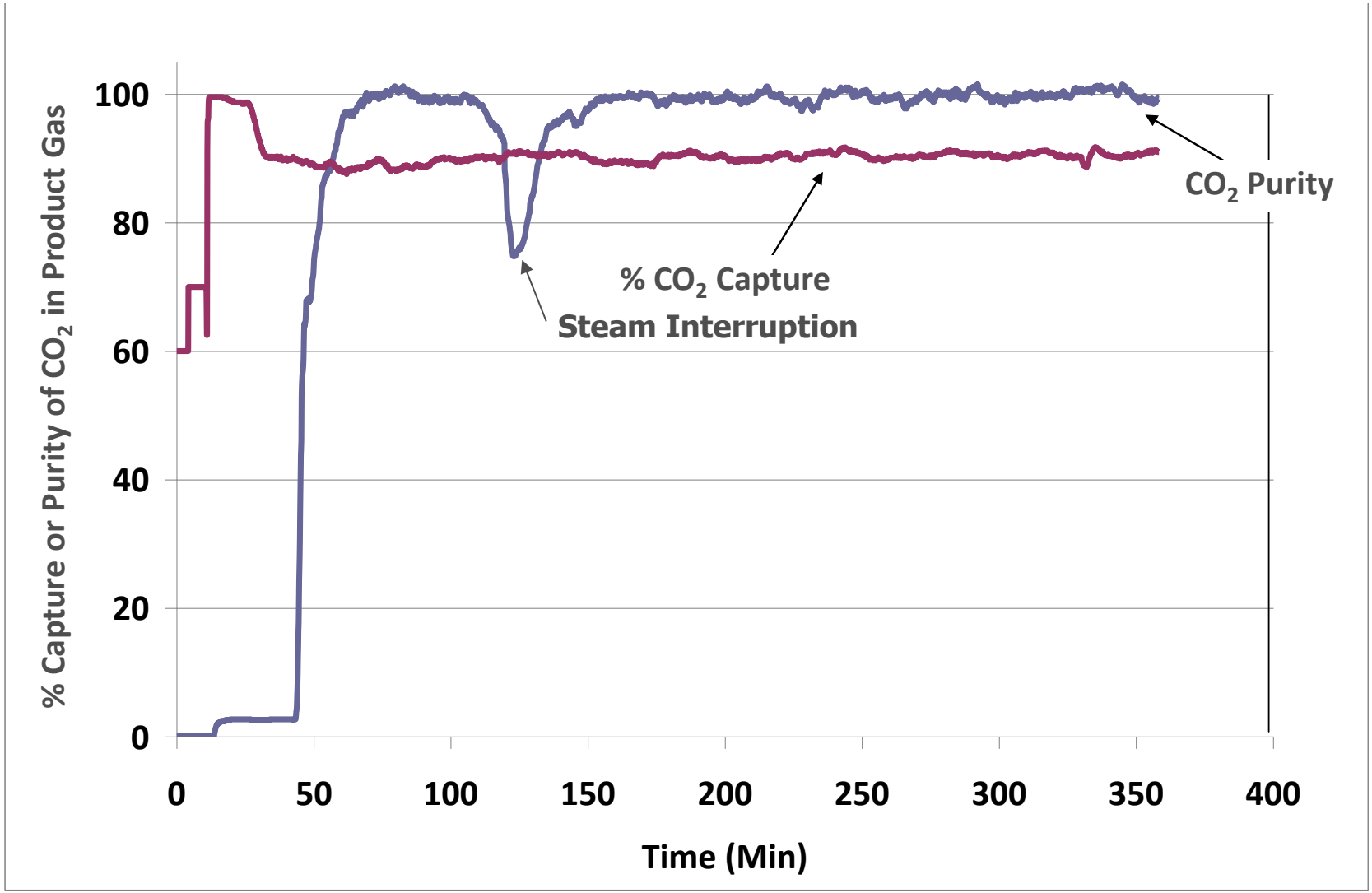
- General lessons
  - Multiple solutions will be needed; economics may vary with
    - Type of fuel (coal or natural gas)
    - Plant size/scale
    - Retro-fit vs. greenfield
    - Space constraints
    - Corporate financial models (e.g., cost of capital vs. operating expenses)
    - Regional issues (e.g., environmental regulations or local CO_2 markets)
  - Scale-up is an art, not a science, and must be done in increments
  - Demonstration using real streams is essential
  - Experience at scale is required to drive down costs
- SRI approaches that show promise:
  - SRI's falling bead reactor using carbon sorbent from ATMI
  - Mixed salt solvents

Capture with Solid Sorbents (Carbon Microbeads in a Falling Bed Reactor)

- Adsorption of CO_2 from flue gas on a selective and high-capacity carbon sorbent.
- Ability to achieve rapid adsorption and desorption rates (no solid state diffusion limit).
- Minimize thermal energy requirements (Heat of adsorption: ~25 kJ/mole).
- Ability to produce pure CO_2 stream suitable for compression and pipeline transportation.
- A continuous, falling micro-bead sorbent reactor geometry integrates the adsorber and stripper in a single vertical column.
- Provides a low pressure drop for gas flow and to minimize physical handling of the sorbent.

This material is based upon work supported by the Department of Energy National Energy Technology Laboratory under Award Number DE-NT0005578.

CO_2 Capture with a 4.5% CO_2 Flue Gas



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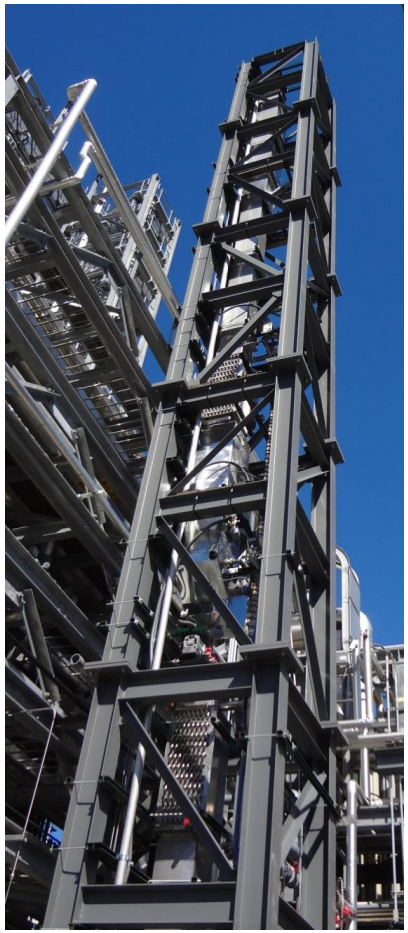
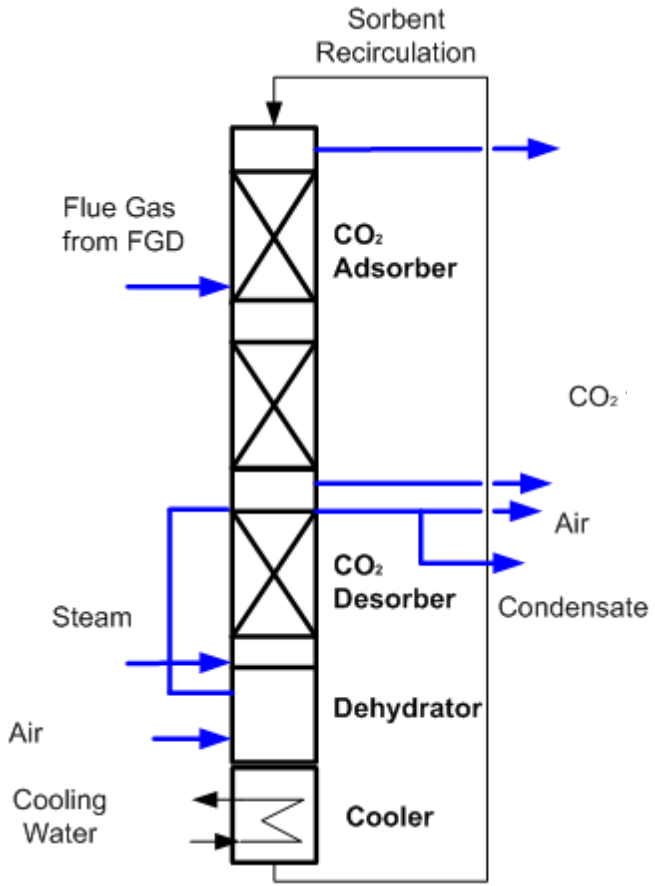
Large Bench-Scale Testing at the National Carbon Capture Center





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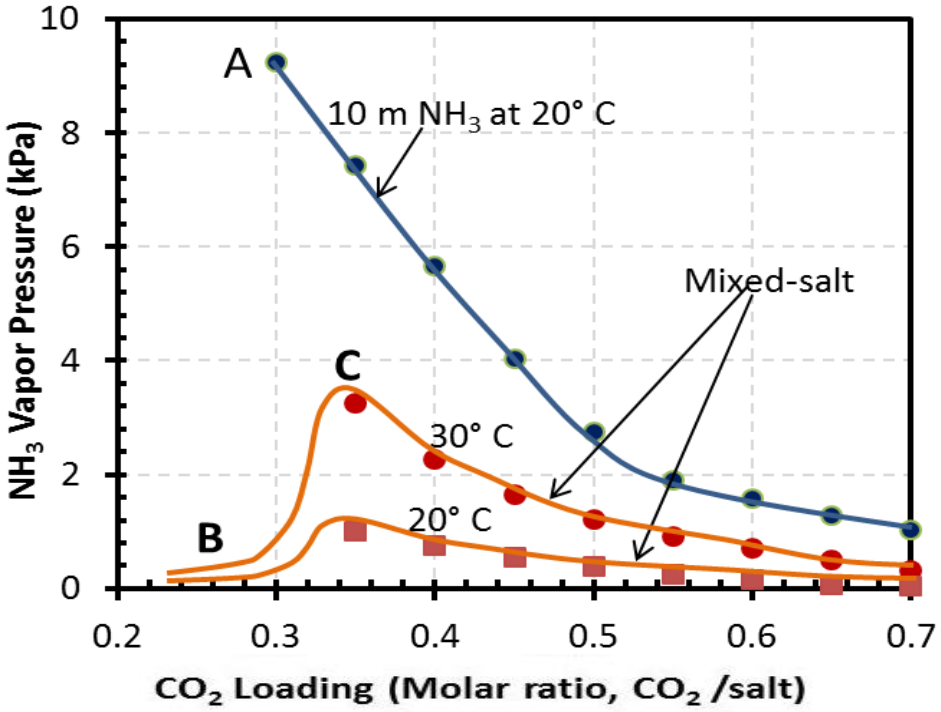
Flue Gas CO_2 Capture with Mixed Salt Solvents

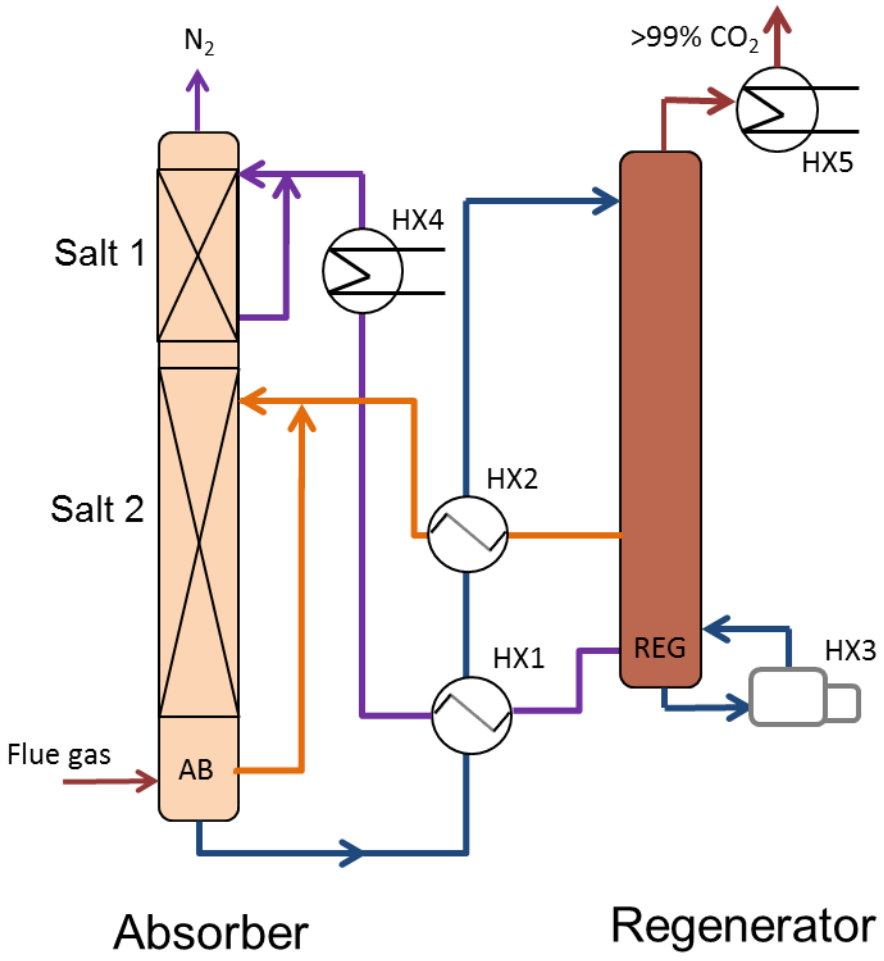


Benefits

- **Ammonia emission reduced by more than an order of magnitude**
- **Absorber-side water use reduced by more than an order of magnitude**

Ammonia vapor pressure as a function of CO_2 loading. A comparison between mixed-salt and 10-m aqueous ammonia at 20°C is shown.

Atmospheric CO_2 Capture – High-Pressure CO_2 Product



Summary

- Good ideas exist, but further investment is needed to get them ready for industry use.
- The concentration of CO_2 in NG-fired plants is lower than corresponding PC-fired plants.
- Flue gas from natural gas-fired gas plants is cleaner than flue gas from coal-fired power plants.
- Process development takes a long time; we need to start now.
- The lessons learned from current development projects provide a good starting point for NG-fired systems.

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