Sixth Annual Conference on Carbon Capture & Sequestration

Capture - Advanced Concepts

PC FLUE GAS: IMPACT ON THE CO2 PERMEATOR

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The Carbozyme Permeation Process: Gas Separation by Catalyzed Reaction-Diffusion







Comparison of Experimental and Modeled Performance

- Celgard X40-200 micro-porous hollow fiber
- # of feed fibers = # of sweep fibers
- nominal porosity = 30%

Carbozyme

- Total membrane surface area = 0.19 m^2
- Effective membrane area = 0.076 m^2
- No CLM pumping

In the simulation $kcat = 1E6 (s^{-1})$





5-Day Permeate gas composition



Mass Transfer Permeator Module Designs



Long-Term Stability - 50-Day Run with temperature-based condensation



c.

Spiral Wound Hollow Fiber 1/4" PVC Permeator







Evaporation Control Heating

Carbozyme



Composition of Various Flue Gases

Carbozyme

| Flue Gas | Carbon | Carbon | NOx | Nitrogen | Nitrous | Sulfur | Mercury | Oxygen | Nitrogen | Particulates | Hydrocarbons |
|---------------|---------|----------|-------|----------|---------|---------|---------|--------|----------|--------------|--------------|
| | Dioxide | Monoxide | | Oxide | Oxide | Dioxide | | | | (Ash) | |
| | CO2 | CO | | NO | NO2 | SO2 | Hg | 02 | N2 | | |
| | g/MJ | mg/MJ | mg/MJ | | | mg/MJ | | | | mg/MJ | mg/MJ |
| Natural Gas | 56 | 9.4 | 47.2 | | | 0.3 | | | | 0.6 | 3.8 |
| Propane | | | | | | | | | | | |
| Fuel Oil | 75 | 13.9 | 236.4 | | | 426.7 | | | | 50.4 | 9.7 |
| Coke | 92 | 1717.6 | 57.3 | | | 398.9 | | | | 309.2 | 381.7 |
| Subbituminous | | | | | | | | | | | |
| Lignite | 111 | 3146.9 | 209.8 | | | 1129.4 | | | | 608.4 | 699.3 |



Base Flue Gas Composition

| Component | | Composition | Composition | Composition | Composition |
|--------------------|--------|-----------------|-------------|-------------|-------------|
| | | (mol at 100 mol | water added | (%) Wet Gas | (%) Dry Gas |
| | | basis) | | | |
| Water ¹ | H_2O | 7.71 | 12.58 | 12.00 | 0% |
| Nitrogen | N_2 | 74 | 74 | 70.56 | 80.18 |
| Carbon dioxide | CO_2 | 14.3 | 14.3 | 13.64 | 15.49 |
| Oxygen | O_2 | 3 | 3 | 2.86 | 3.25 |
| Argon | Ar | 0.93 | 0.93 | 0.89 | 1.01 |
| Nitric oxide | NO | 0.04 | 0.04 | 0.03 | 0.04 |
| Sulfur dioxide | SO_2 | 0.026 | 0.026 | 0.025 | 0.029 |
| Hydrogen chloride | HCl | 3.00E-04 | 3.00E-04 | 2.86E-04 | 3.25E-04 |
| Hydrogen fluoride | HF | 1.00E-05 | 1.00E-05 | 9.54E-06 | 1.08E-05 |
| Mercury | Hg | 2.00E-07 | 2.00E-07 | 1.91E-07 | 2.17E-07 |
| TOTAL | | 100 | 104.87 | 100 | |

Amount of water in Flue Gas was adjusted to provide sufficient humidity so that the aqueous phase would not dry out at high Flue Gas to CLM ratios.



Possible Modes of Contaminant Operation

- Decrease in CLM pH below 7.5
- Loading of inhibitory anions above the *Ki* value
- Loading of inhibitory cations above the Ki value



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Contaminants Acceptance Concentration

Carbozyme

| CONTAMINANT | ACCEPTANCE |
|------------------|----------------|
| | CONCENTRATION |
| | IN CLM |
| | <u>Ki</u> (mM) |
| Cŀ | 200 |
| F | 200 |
| SO4 ⁼ | 200 |
| NO3 ⁻ | 35 |
| рН | 7.5* |

*pH criteria are very conservative.

Flue Gas Contaminant Experiment

- Hollow fiber contactor (25°C water jacketed)
- 1 M NaHCO₃ (38 mL) recirculate constant volume
- Gas containing:
 - 79% N₂, 15% CO₂, 5% O₂, 0.3% Ar, 0.0288 % SO₂, 0.044 % NO, 0.003 % NO₂
- Gas flow at 75 to 80ccm for 65 hr, then 200 to 250ccm for 167 hr
- Measure
 - solution pH (in-line probe recorded every 5 min)
 - feed gas concentration and flow rate
 - outlet gas concentration and flow rate
- Simulations done using OLI Systems StreamAnalyzer® software
- Target: 2500h continuous operation under oxidizing or non-oxidizing post-combustion conditions







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Cost Comparisons



The Carbozyme Benefit



