InnoSepra

Process for CO_2 Capture from Low Concentration Streams

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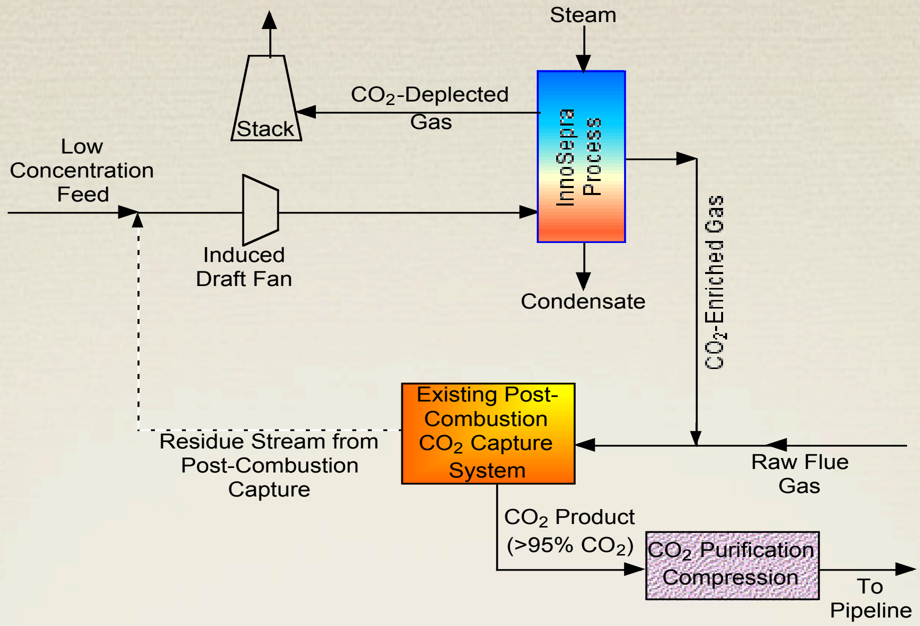
Executive Summary

- Cost effective CO_2 capture from low concentration sources
  - Residue stream after 90% capture, 1-1.5% CO_2 or other low concentration source such as the NGCC flue gas
  - Physical sorbents in structured forms with very high CO_2 capacities at low CO_2 concentrations
  - CO_2 enrichment by a factor of 5-10
  - Recycle to a new or an existing post-combustion capture process
- Significantly lower cost compared to other options
  - ~$46/tonne enrichment cost for a dry residue stream
  - ~$72/tonne enrichment cost for a saturated residue stream
  - For an existing post-combustion capture system 99% capture is possible with <10% increase in the capture cost

Process Overview



- A two-stage process with structured sorbents to minimize pressure drop for very high flows associated with low concentration sources
- Moisture removal in the first stage for feeds containing moisture
- The CO_2 adsorption in the second stage
- A CO_2 enriched stream (10-15% CO_2) produced during regeneration, recycled as feed to a new or an existing post-combustion CO_2 capture system

Key Features

- Structured sorbents in a rotating wheel or fixed bed configuration for ***optional*** moisture removal and CO_2 adsorption
- CO_2 adsorption on sorbents with very high capacities at low CO_2 concentrations, direct thermal regeneration to produce a CO_2-enriched stream
- Recycle of CO_2-enriched stream to a post-combustion capture system utilizing sorbents, solvents, or membranes
- >99% CO_2 capture with a <10% increase in the capture cost (over the cost of 90% capture)

Why Structured Sorbents

Advantages

- Very high surface area to volume ratio (>10x10^6 m^2/m^3) for sorbents, much higher than amines (~1,000 m^2/m^3) and membranes (250-5,000 m^2/m^3)
- 40-55% lower heat requirement for regeneration compared to amines, 75-80% lower power loss compared to amines due to steam extraction (much lower steam extraction temperature)
- Very low pressure drops (1/5th to 1/10th of particulate sorbents), not subject to fluidization constraints, commercially available

Limitations

- Continuous processes with short residence times are difficult
- Typical cycle times are 1-2 mins (O_2 VSA, Inventys/ Questair) to 4-10 mins (InnoSepra)
- Some of the surface area to volume advantage lost due to the use of a cyclic process

Prior Work

- DOE SBIR (Phase I and II) for post-combustion CO_2 capture using structured sorbents
  - Moisture removal capacities of up to 30-wt% in breakthrough tests at 25-35^oC, moisture removal to below 10-ppm in cyclic tests
  - CO_2 removal capacities of up to 10-wt% at 25^0C and up to 6-wt% at 35^oC, lower than particulate sorbents
  - Both CO_2 recovery and purities lower than particulate sorbents

Project Goals

- Fabricate adsorption test modules for CO_2 and moisture adsorption, modify the process units
- Semi-bench scale testing for moisture removal
- Lab and semi-bench scale testing for CO_2 adsorption
- Engineering design for a full-sized plant
- Techno-economic analysis for a 1,000,000 scfm feed

Photograph of Fixed Bed Test Unit

Testing of Structured Sorbents for Moisture Removal

Progress

- Testing carried out in both fixed bed and rotating bed units
- Better performance and more process flexibility with fixed bed units

Moisture Removal Tests with the Rotating Bed

Feed Temperature	Feed Air Flow	Regen Air Flow	Feed Moisture	Process Outlet Moisture	Moisture Removal
(degC)	(slpm)	(slpm)	(ppm)	(ppm)	%
25.1	160	145	32,500	1,250	96.2
25.4	160	145	33,200	1,890	94.3
26.1	240	215	36,913	2,388	93.5
25.3	240	215	33,010	2,346	92.9
28.2	158	144	39,217	1,310	96.7
27.5	158	144	37,592	1,350	96.4
27.6	239	214	37,630	1,410	96.3
27.7	239	214	38,050	1,390	96.3
34.0	161	143	56,220	1,620	97.1
34.1	160	144	57,020	1,810	96.8
32.3	242	212	50,118	1,725	96.6
32.0	240	213	49,235	1,460	97.0

Moisture Removal Tests with the Fixed Bed

Feed Temperature	Feed Air Flow	Regen Air Flow	Feed Moisture	Process Outlet Moisture	Moisture Removal
(degC)	(slpm)	(slpm)	(ppm)	(ppm)	%
25.0	155	140	32,010	400	98.8
22.7	158	141	27,910	425	98.5
24.9	240	215	32,055	450	98.6
24.1	240	215	30,500	505	98.3
27.1	163	147	36,600	492	98.7
27.5	161	145	37,300	601	98.4
27.0	238	213	36,010	545	98.5
27.7	239	214	38,100	560	98.5
32.1	158	142	48,520	490	99.0
34.1	160	144	57,200	553	99.0
32.3	245	215	49,800	510	99.0
32.0	241	214	49,300	525	98.9

Testing of Structured Sorbents for CO_2 Enrichment

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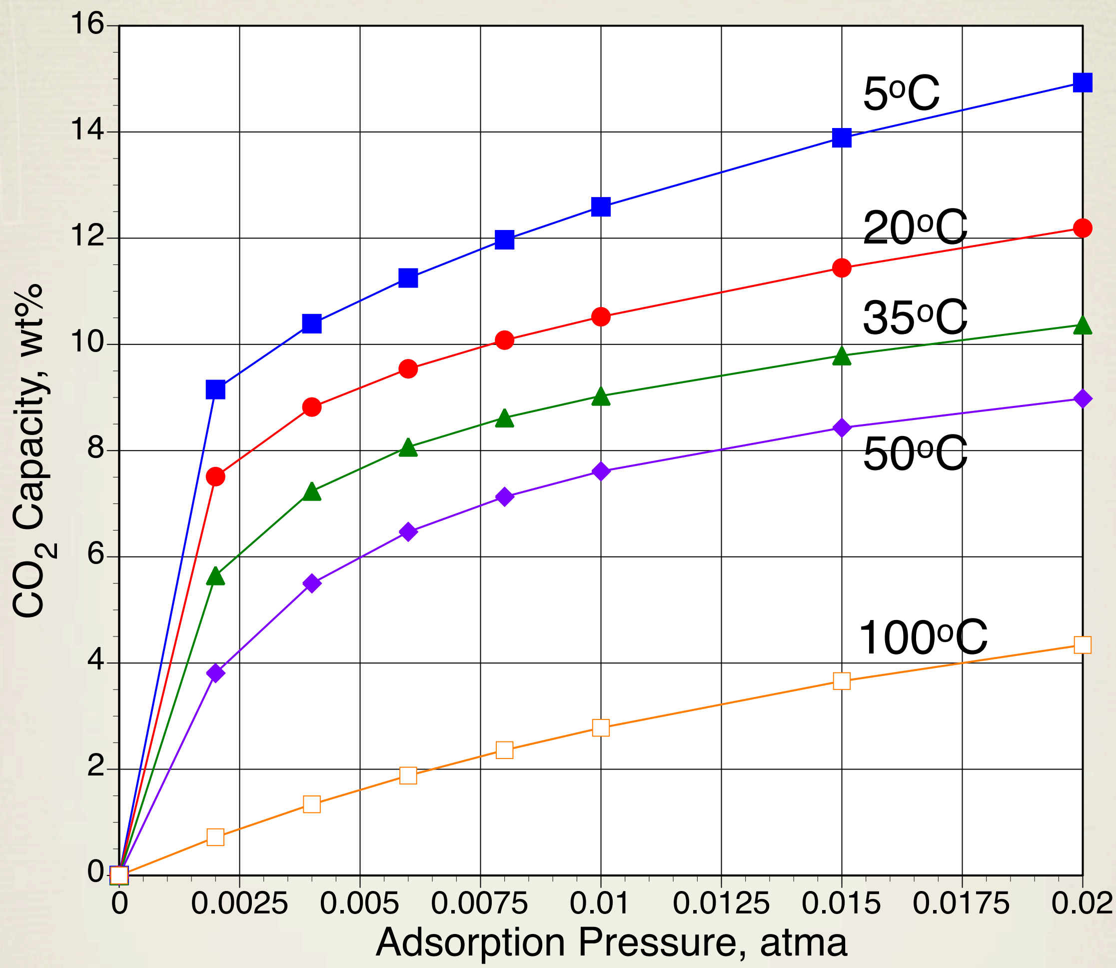
- Sorption isotherms at low CO_2 concentrations



- Breakthrough and cyclic tests with preferred sorbents at 25-35^{0}C (0.5-2.0% CO_2 in the feed)
  - Breakthrough capacities of 5.0-8.5-wt% at 25^{o}C, and 4.0-7.0-wt% at 35^{o}C
  - Cyclic capacities >90% of breakthrough capacities
  - CO_2 enrichment by a factor of 5-10 depending on feed CO_2 concentration, regeneration temperature, and cycle time

Techno-Economic Analyis

Progress

- Techno-economic analysis carried out for both the wet feed (amines) and dry feed (InnoSepra's sorbent-based process) using the experimental results

CO_2 Enrichment Cost for a Wet Residue Stream (250,000 scfm Flow)

Compression System, $MM	5.04
Adsorption System, $MM	7.05
Total Capital, $MM	**12.1**
Electrical Power, MW	2.5
Power Equivalent of Steam, MW	1.0
Total Power, MW	**3.5**
Total Annual Cost, $MM	3.77
CO_2 Enrichment Cost, $/tonne	**71.8**

CO_2 Enrichment Cost for a Dry Residue Stream (250,000 scfm Flow)

Compression System, $MM	2.25
Adsorption System, $MM	4.55
Total Capital, $MM	**6.80**
Electrical Power, MW	0.9
Power Equivalent of Steam, MW	1.0
Total Power, MW	**1.9**
Total Annual Cost, $MM	2.42
CO_2 Enrichment Cost, $/tonne	**46.0**