CO_2 CAPTURE FROM FLUE GAS BY PHASE TRANSITIONAL ABSORPTION

primary project goals

Hampton University set out to conduct the kinetic study for its novel technology, phase transitional absorption, which has the potential to reduce operation costs by at least half (possibly by 80%) and significantly cut capital investment (compared with current monoethanolamine [MEA]-carbon dioxide [CO_2] absorption technologies).

technical goals

To understand the mechanisms of phase transitional absorption by measuring absorption kinetics, regeneration rate, and loading capacity, as well as to further compare with other methods, such as the state-of-art MEA absorption.

technical content

The phase transitional absorption process is radically different from the conventional absorption processes. It uses an activated agent, which, when mixed with a special solvent, forms a special phase transitional absorbent for CO_2 capture. The absorbent, after absorbing CO_2 from flue gas in an absorber, flows into a settler where it is separated into two phases: a CO_2-rich phase and a CO_2-lean phase. The CO_2-rich solvent is then sent to a regenerator for regeneration. After regeneration, the solvent is cooled and mixed with the CO_2-lean phase and sent to an absorber to complete the cycle.

A schematic diagram of the process is shown in Figure 1. It may be noted that the process is similar to a conventional MEA process, except that a settler is added for separating the two phases.

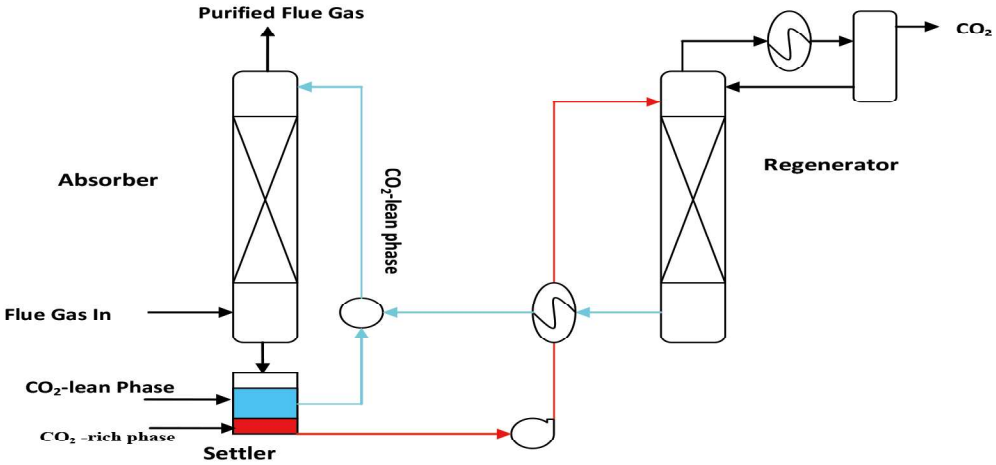

Figure 1: Concept Flow Diagram of Phase Transitional Absorption

In the conventional absorption process, such as an MEA process, the entire solvent is sent to the regenerator for regeneration, which necessitates a large circulation pump and a large amount of regeneration energy. In contrast, in the phase transitional absorption process, the

technology maturity:

Laboratory-Scale, Using Simulated Flue Gas

project focus:

Phase Transitional Absorption

participant:

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project number:

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None

performance period:

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absorbent separates into two phases, and only the CO_2-rich phase needs to be regenerated. The CO_2-rich phase is only approximately 20 percent of the total absorbent. Thus, the pumping and heating requirements are significantly less compared to the MEA process.

Another important feature of the phase transitional absorption is that the absorption rate of CO_2 will be enhanced by selecting the proper solvent, as shown in Figure 2.

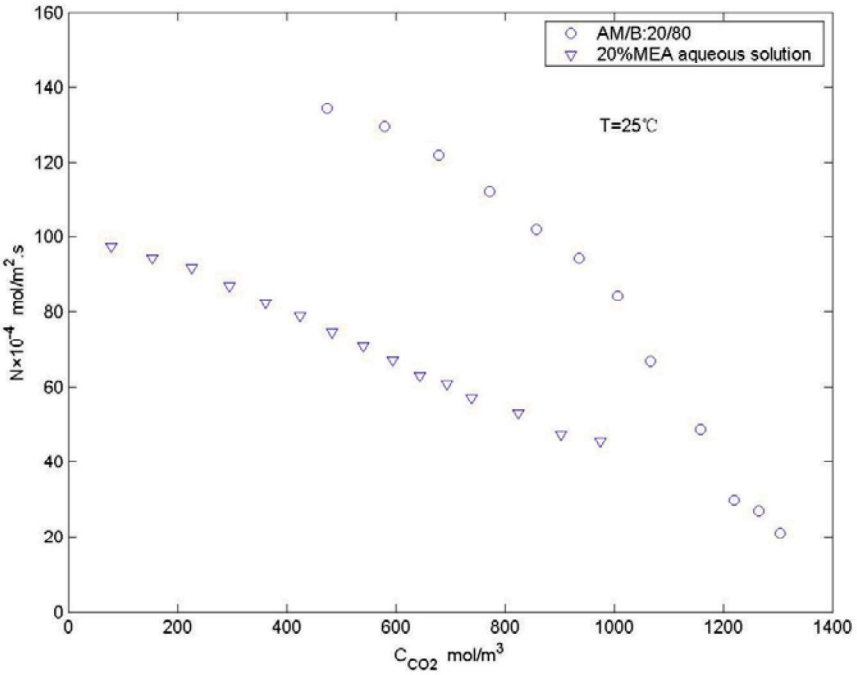

Figure 2: Absorption Rate Comparison (Phase Transitional Absorption vs. MEA Technology)

T = 25°C; P_{CO2} = 1 atm; N=60 rpm; VL = 900 ml.
Phase Transitional Absorption: activated agent: AM 20 percent by volume; solvent: B 80 percent.
MEA Technology: 20 percent (by volume) MEA aqueous solution.

Experimental results also showed that the temperature did not have strong impact on the absorption rate for the several absorbents studied. The small effect on the absorption rate by temperature could be attributed to the much smaller reaction heat.

The highest absorption rate is found when the activated agent was in the range of 30 to 40 percent by volume. The range may vary if the different activated agents and solvents are used. The range of activated agents with the highest absorption rate is highly related to the physical and chemical properties of the absorbent (i.e., activated agents and solvents), as well as the combination.

It was determined from these results that the mechanism of the absorption is a fast chemical reaction controlled by the liquid-side mass transfer. Therefore, an absorber with large gas-liquid interface and sufficient liquid turbulence is recommended in order to have a higher absorption rate, such as a packed column.

TABLE 1: PARAMETERS FOR PHASE TRANSITIONAL ABSORPTION PROCESSES

	Units	Current R&D Value	Target R&D Value
Pure Solvent			
Molecular Weight	mol^{-1}	varies	
Normal Boiling Point	°C	varies	
Normal Freezing Point	°C	N/A	
Vapor Pressure @ 15°C	bar	N/A	
Manufacturing Cost for Solvent	$/kg	N/A	

TABLE 1: PARAMETERS FOR PHASE TRANSITIONAL ABSORPTION PROCESSES

	Units	Current R&D Value	Target R&D Value
Working Solution			
Concentration	kg/kg	20/80 by volume	
Specific Gravity (15°C/15°C)	-	N/A	
Specific Heat Capacity @ STP	kJ/kg-K	N/A	
Viscosity @ STP	cP	N/A	
Absorption			
Pressure	bar	1	
Temperature	°C	25-50	
Equilibrium CO_2 Loading	mol/mol	0.4 – 0.5	
Heat of Absorption	kJ/mol CO_2	N/A	
Solution Viscosity	cP	N/A	
Desorption			
Pressure	bar	1	
Temperature	°C	90-120	
Equilibrium CO_2 Loading	mol/mol	≈ 0	
Heat of Desorption	kJ/mol CO_2	N/A	
Proposed Module Design		*(for equipment developers)*	
Flue Gas Flowrate	kg/hr	N/A	
CO_2 Recovery, Purity, and Pressure	% / % / bar	N/A	
Adsorber Pressure Drop	bar	N/A	
Estimated Absorber/Stripper Cost of Manufacturing and Installation	$ / kg/hr	N/A	

Definitions:

STP – Standard Temperature and Pressure (15°C, 1 atm).

Pure Solvent – Chemical agent(s), working alone or as a component of a working solution, responsible for enhanced CO_2 absorption (e.g., the amine MEA in an aqueous solution).

Manufacturing Cost for Solvent – "Current" is market price of chemical, if applicable; "Target" is estimated manufacturing cost for new solvents, or the estimated cost of bulk manufacturing for existing solvents.

Working Solution – The solute-free (i.e., CO_2-free) liquid solution used as the working solvent in the absorption/desorption process (e.g., the liquid mixture of MEA and water).

Absorption – The conditions of interest for absorption are those that prevail at maximum solvent loading, which typically occurs at the bottom of the absorption column. These may be assumed to be 1 atm total flue-gas pressure (corresponding to a CO_2 partial pressure of 0.13 bar) and 40°C; however, measured data at other conditions are preferable to estimated data.

Desorption – The conditions of interest for desorption are those that prevail at minimum solvent loading, which typically occurs at the bottom of the desorption column. Operating pressure and temperature for the desorber/stripper are process-dependent (e.g., an MEA-based absorption system has a typical CO_2 partial pressure of 1.8 bar and a reboiler temperature of 120°C). Measured data at other conditions are preferable to estimated data.

Pressure – The pressure of CO_2 in equilibrium with the solution. If the vapor phase is pure CO_2, this is the total pressure; if it is a mixture of gases, this is the partial pressure of CO_2. Note that for a typical PC power plant, the total pressure of the flue gas is about 1 atm and the concentration of CO_2 is about 13.2 percent. Therefore, the partial pressure of CO_2 is roughly 0.132 atm or 0.130 bar.

Concentration – Mass fraction of pure solvent in working solution.

Loading – The basis for CO_2 loadings is moles of pure solvent.

Estimated Cost – Basis is kg/hr of CO_2 in CO_2-rich product gas; assuming targets are met.

Other Parameter Descriptions:

Chemical/Physical Solvent Mechanism – The mechanism of the absorption is a fast chemical reaction controlled by the liquid-side mass transfer.

technology advantages

- Greatly reducing regeneration energy compared with the MEA process.
- Higher absorption rate, resulting in lower capital investment for absorption equipment.
- Higher CO_2 working capacity, which will reduce sensible heat and solvent volume in circulation.
- Low corrosion rate to carbon steel compared to the MEA process.
- Potentially less solvent loss.
- Non-toxic, environmentally safe.

R&D challenges

- Process exists only at the laboratory scale and needs to be scaled-up.
- Moisture in flue gas may have impact on the process.

results to date/accomplishments

- Measured the absorption rate at 15, 25, 35, 45, and 55 °C.
- Measured the effect of absorbent concentration in solution (from 10 to 50 percent by volume) on absorption rate and loading capacity.
- Measured the effect of solution agitation speed (30, 60, and 90 rpm) on absorption rate.
- Measured the absorption rate at 1 atm of CO_2 partial pressure.
- Conducted the regeneration tests; measured the regeneration rate at different temperature.
- Conducted the corrosion tests for carbon steel coupon.
- Conduct the initial process evaluation based on the lab results and made the comparison with MEA absorption.

next steps

This project ended on June 30, 2009.

available reports/technical papers/presentations

Hu, L., "CO_2 Capture from Flue Gas by Phase Transitional Absorption." Final Report June 2009. *http://www.netl.doe.gov/File%20Library/Research/Coal/ewr/co2/phase-transitional-absorption-final-report-june2009.pdf*.