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Crossflow Absorption for Post Combustion CO_2 capture: Solvent Performance Comparison

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Abstract

This paper presents crossflow absorber designs to remove 90% of the CO_2 in a flue gas from a 110 MW Natural Gas Combined Cycle (NGCC) source using 7 molal (mol/kg solvent) monoethanolamine (MEA) (30 wt%). This application included a height limitation of 7 meters for the CO_2 capture process. In traditional countercurrent design, due to the 80% flooding design constraint, only the height of the unit can be used to increase the packing volume. When height constraints are at play, countercurrent columns will lead to a capital-intensive design with multiple contactors in series. However, in crossflow contacting, the length and width of the unit can be used to increase the total packing volume to meet a given CO_2 removal while respecting the height constraint.
In this application, the flue gas was fed to the capture train at 164 °C, 10.6 mol % water, and 3.88 mol % CO_2. Two crossflow train configurations were studied. The first configuration, shown in Figure 1, included a pre-quench to cool the gas to 75 °C, followed by a crossflow direct contact cooler (DCC), a simple absorber, and a crossflow water wash (WW). The WW was designed to ensure water balance around the absorber, and no consideration was given to volatile amine removal. The DCC was designed to achieve a water content of 4.7 mol % in the outlet gas stream, which corresponds to flue gas saturated to water at 33 °C and ensures a 5 °C temperature driving force in the water wash. Three absorber designs were studied, each fixing two physical dimensions and using the remaining to vary the packing volume, as shown in Figure 2.

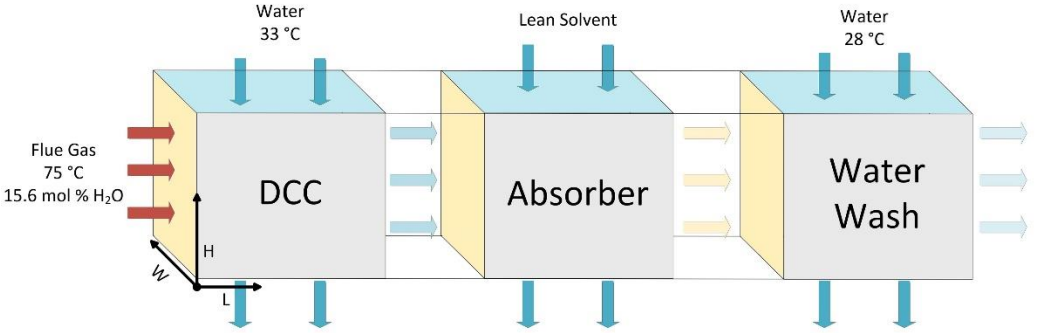

Figure 1: Simple crossflow absorber train

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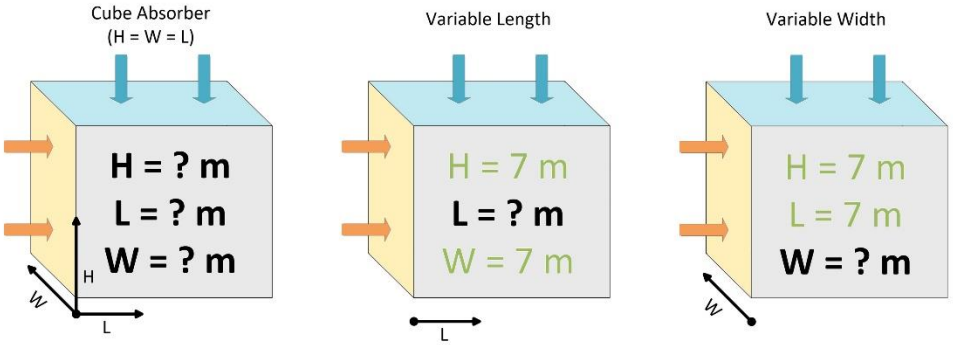

Figure 2: Simple crossflow absorber configurations

The second configuration was the crossflow absorber train with pump-around intercooling (PA IC), shown in Figure 3. In this configuration, the flue gas was pre-quenched and was fed directly to the absorber. The solvent contacting section was split into two cubes with equal dimensions, and a portion of the first cube was used for the PA IC loop. This configuration emulates the traditional countercurrent PA IC design, where a section of packing with a high liquid flux cools the flue gas instead of the DCC. This design was optimized by varying the liquid rate and the amount of packing in the PA IC loop.

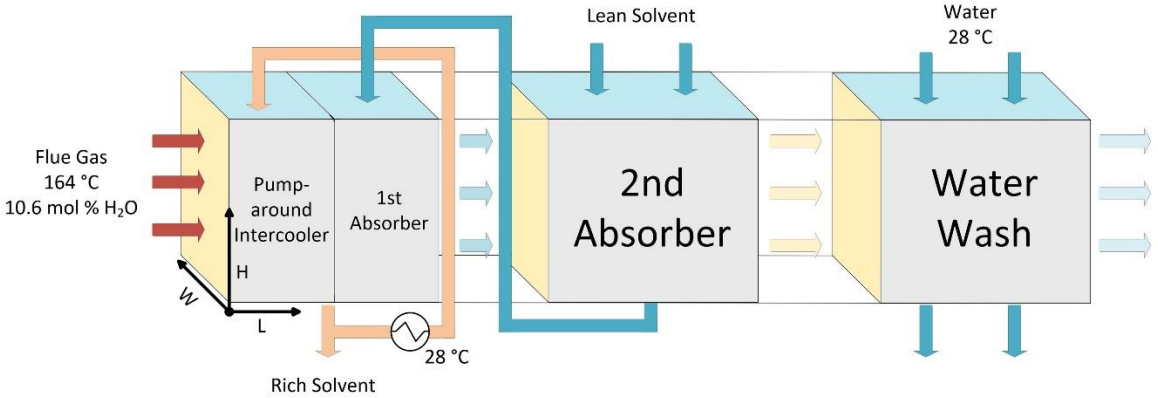

Figure 3: Simple crossflow absorber configurations

Abreu [1] has proposed several crossflow designs for this system using 5 molal piperazine (PZ) (30 wt%) to identify the key differences between countercurrent and crossflow contacting. This work will expand on that comparison by applying the same design philosophy to 7 molal MEA. While 5 molal PZ has various technical advantages over MEA such as a faster reaction rate, lower volatility, and higher thermal degradation resistance [2], the latter is an "open source" solvent with publicly available solvent models and a wealth of existing research. The goal of this work is to qualify the potential of crossflow contacting for gas turbine applications using a first-generation solvent and establish a design case for solvent comparison that can be used with other "open source" solvents such as CESAR-1. The crossflow units were modeled using the countercurrent crossflow slab method developed by Gao [3]. The golden standard MEA solvent model (version 3.2.1) developed for the DOE Carbon Capture Simulation Initiative (CCSI) toolset was used to estimate thermodynamic and physical properties, and reaction kinetics for the capture solvent [4].

References

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Keywords: CO_2 absorption; monoethanolamine; crossflow contacting.