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Detailed Estimation of Heat Losses from a Laboratory Pilot Plant for CO_2 Absorption

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1. Abstract

A laboratory scale pilot plant was designed and constructed to study the post-combustion CO_2 capture from for example power plant flue gases. All small scale pilot plants will have relatively large heat losses compared to an industrial plant. In this study all the components of the pilot plant have been analyzed and those being major sources of heat loss were identified.

2. Introduction

One way to reduce emissions of the greenhouse gas carbon dioxide is post combustion capture by absorption with amine as solvent. The aqueous amine solution undergoes a reversible exothermic chemical reaction with CO_2 at a relatively low temperature (about 40-60 °C) in an absorption column filled with a special packing material. The CO_2-rich solvent from the bottom of the absorber column is first heated against the hot stream of CO_2-lean regenerated solvent coming from the reboiler and then enters the top of a desorber column. The CO_2 is continuously transferred and separated from the liquid solvent phase to the gas (steam) phase generated from the reboiler. It exits from the top of the desorber column saturated with water vapor. The water vapor/steam is condensed and piped directly back to the reboiler. The lean solvent flows downward in the desorber and to the reboiler from the bottom (sump). The lean solution from the reboiler is then cooled against the cold stream of CO_2-rich solvent coming from the absorber and enters the top of the absorber column. The CO_2 can be compressed in a multi-stage process and be transported in high density liquid and/or supercritical form.

Today, the post combustion capture technology of CO_2 from power plant flue gases is deemed the most effective and feasible method. A major challenge with this technology is minimizing the operational costs and/or the energy input into the system. Generally, the heat losses due to natural convective and radiative heat transfer from the surface exposed to the surroundings leads to increased energy required for a CO_2 removal plant. Therefore, it has to be minimized. Identification and quantification of the components that are the major sources of heat losses is the first step to reach this goal.

3. Results

The CO_2 laboratory pilot plant is an integrated absorption/desorption system [1]. The packing heights of the absorber and the desorber are 4.36 m and 3.89 m, respectively. The internal diameter of the absorber column is 0.15 m and the thickness of the steal pipe is 2 mm. The internal diameter of the desorber is 0.1 m and the thickness of the steal pipe is also 2 mm. The stainless steel absorber and the desorber are isolated by insulation material with a thermal conductivity of about 0.037 W/m.K. The thickness of the insulation around the absorber and the desorber is about 6.3 cm and 6.5 cm, respectively. In an earlier study [2] the laboratory pilot plant was run with distilled water. The total heat losses from this plant were estimated at water flow rates between 3 l/min and 8 l/min and at reboiler duties between 3.2 kW and 16.1 kW. One conclusion was that the heat losses increased with increasing water mass flow rates, but were independent of reboiler duty. In another study [3], the heat loss of the desorber and reboiler of this laboratory pilot plant was estimated by measuring the surface temperature of the insulation material to be less than 0.5 kW. In the present study, the CO_2 laboratory pilot plant was run with distilled water during a ten-week campaign. The heat losses of individual components of the pilot plant (the desorber column, the reboiler, the mixer tank, the circulation pumps, the heat exchangers, the water wash system and specially the absorber column) were determined for different reboiler pressures (between 0.5 to 2 bars), reboiler duties (between 3.2 kW to 18 kW) and water mass flow circulation rates (between 3 l/min and 10 l/min).

4. References

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