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Review

Recent progress and new developments in post-combustion carbon-capture technology with amine based solvents

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A B S T R A C T

Currently, post-combustion carbon capture (PCC) is the only industrial CO_2 capture technology that is already demonstrated at full commercial scale in the TMC Mongstad in Norway (300,000 tonnes per year CO_2 captured) and BD3 SaskPower in Canada (1 million tonnes per year CO_2 captured). This paper presents a comprehensive review of the most recent information available on all aspects of the PCC processes. It provides designers and operators of amine solvent-based CO_2 capture plants with an in-depth understanding of the most up-to-date fundamental chemistry and physics of the CO_2 absorption technologies using amine-based reactive solvents. Topics covered include chemical analysis, reaction kinetics, CO_2 solubility, and innovative configurations of absorption and stripping columns as well as information on technology applications. The paper also covers in detail the post build operational issues of corrosion prevention and control, solvent management, solvent stability, solvent recycling and reclaiming, intelligent monitoring and plant control including process automation. In addition, the review discusses the most up-to-date insights related to the theoretical basis of plant operation in terms of thermodynamics, transport phenomena, chemical reaction kinetics/engineering, interfacial phenomena, and materials. The insights will assist engineers, scientists, and decision makers working in academia, industry and government, to gain a better appreciation of the post combustion carbon capture technology.

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1. Introduction and background information

Globally, the capture of CO_2 from industrial flue gases has become a critical environmental issue. The threat of climate change from increased levels of GHGs in the atmosphere is significant. According to the International Energy Agency (2012), under current policies and mitigation strategies, worldwide energy-related CO_2 emissions will reach nearly 45 gigatonnes by 2035, which is correlated with only a 50% probability of limiting the average global temperature increase to 5.6 °C unless strong efforts are made to achieve the target of stabilizing greenhouse gas concentrations at 450 ppm CO_2-e. Mean global temperatures are on the rise, and various regions of the world have been experiencing adverse climate issues. Therefore, the need for research development and demonstration of cost-effective CO_2 capture technologies is urgent.

There are three major process options for CO_2 capture: pre-combustion, post-combustion, and oxyfuel combustion. Depending on the process, various technologies for CO_2 capture can be used, including absorption, adsorption, membranes, and hybrid applications of these three. At the moment, post-combustion carbon capture (PCC) is the only industrial CO_2 capture technology being demonstrated at full commercial scale. The major examples are the TMC Mongstad in Norway (300,000 tonnes per year CO_2 captured) and BD3 SaskPower in Canada (1 million tonnes per year CO_2 captured).

A typical flow sheet of the PCC process is similar to an industrial acid gas removal system utilizing a chemical absorbent is shown in Fig. 1.1. The raw gas, which enters the unit through an inlet separator where entrained liquid and solid particulates are removed, flows from the bottom of the absorber upwards against a counter-current stream of the lean solution. The CO_2 in the flue gas is absorbed and the treated flue gas leaves the top of the absorber. The loaded ("rich") solution flows from the bottom of the absorber and passes through the lean-rich heat exchanger where it is heated by the hot, recycled lean solution. It then enters the top of the stripper column. In some cases, a flash tank is installed upstream of the heat exchanger to desorb and some portions of the absorbed CO_2 by reducing the pressure on the rich stream.

Upon entry into the stripper, some of the absorbed CO_2 is flashed. The solution then flows downward against a counter-current flow of water vapor generated in the reboiler. The stripping vapor removes most of the remaining CO_2 from the rich stream. The overhead mixture leaves the stripper through a condenser where most of the water vapor is condensed and returned to the stripper as reflux. The lean solution, which leaves the bottom of the stripper, exchanges heat with the rich solution in the lean-rich heat exchanger and then passes through a cooler before being pumped back to the absorber.

Over the past ten years, there have been significant new developments in post-combustion capture processes. The IEA sponsored the 2nd Post Combustion Capture Conference (PCCC2, Bergen, Norway in 2013) as well as the 12th International Conference on Greenhouse Gas Control Technologies (GHGT-12, Austin, USA in 2014), the most recent showcases of these new developments in this R&D area. Significant portions of recent information on the subject can be found on the IEAGHG website (www.ieaghg.org).

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