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Review article

Amine reclaiming technologies in post-combustion carbon dioxide capture

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ABSTRACT

Amine scrubbing is the most developed technology for carbon dioxide (CO₂) capture. Degradation of amine solvents due to the presence of high levels of oxygen and other impurities in flue gas causes increasing costs and deterioration in long term performance, and therefore purification of the solvents is needed to overcome these problems. This review presents the reclaiming of amine solvents used for post combustion CO₂ capture (PCC). Thermal reclaiming, ion exchange, and electrodialysis, although principally developed for sour gas sweetening, have also been tested for CO₂ capture from flue gas. The three technologies all have their strengths and weaknesses, and further development is needed to reduce energy usage and costs. An expected future trend for amine reclamation is to focus on process integration of the current reclaiming technologies into the PCC process in order to drive down costs.

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Introduction

Carbon capture and storage (CCS) is a means of mitigating the contribution of fossil fuel emissions to global warming, based on capturing CO₂ and storing it away from the atmosphere by different means. Amine scrubbing is currently the most developed technology and is expected to be available commercially within the next decade to enable CO₂ capture from flue gas streams. Alkanolamines such as monoethanolamine (MEA), diethanolamine (DEA), N-methyl-diethanolamine (MDEA), as well as amine blends traditionally have been investigated for this application. Other amines under active consideration for CO₂ capture are sterically hindered amines such as 2-amino-2-methyl-1-propanol (AMP) (Sartori and Savage, 1983; Mimura et al., 2000), and piperazine (PZ) (Rochelle et al., 2011), which is a cyclic diamine. MEA is so far the most studied solvent in this application and MEA based scrubbing is often used as a base case for evaluation of the PCC processes (IEAGHG, 2012; IPCC, 2005).

Fig. 1 illustrates a typical configuration of amine based process for PCC. A flue gas stream containing approximately 10 vol.% CO₂ and 5 vol.% O₂ is counter-currently contacted with the aqueous amine solution in an absorber column, which is operating at 55°C and 1 atmosphere pressure (Rochelle et al., 2001). The CO₂ rich amine solution exits at the bottom of the absorber column and is then sent through a counter-current heat exchanger, where it is pre-heated by the lean amine solution before being sent to the stripper column. The CO₂ is liberated from the amine solution in the stripper, which operates at 120°C and 1 atmosphere pressure. In the stripper, heat is provided by the steam from the reboiler. The gas leaving the stripper is dehydrated and compressed before transport and sequestration. The hot lean amine solvent is passed back through the cross-exchanger and back to the absorber for further CO₂ removal with a slip stream being sent to a reclaimer to remove solvent impurities.

Solvent losses often occur in an amine-based absorption/stripping system due to solvent volatility and degradation. Volatility is the loss of volatile amine off the top of the absorber in the exiting, treated flue gas. A well designed water wash

column can be used to recover the majority of amine losses through volatility.

All amine solvents are subjected to degradation as a result of the impurities either in the feed flue gas or those introduced to the amine system from other sources (ElMoudir et al., 2012). In PCC operations, the solvent degradation depends upon both flue gas composition and the type of pre-treatment operations. As the amine-based process was applied at first to natural gas sweetening, then to gas-fired flue gas, and finally to coal-fired flue gas, the impurities in the flue gas stream become more and more complex (Kohl and Nielsen, 1997; Dumée et al., 2012). Solvent degradation due to the presence of high levels of oxygen, SO_x, NO_x and fly ash in coal-fired flue gas causes increasing deterioration in long term performance.

Amine solutions are degraded with the impurities to form heat-stable salts (HSSs) and amine degradation products. These contaminants cause reduction of CO₂ absorption capacity, corrosion, foaming, fouling, and increase in viscosity and release of pollutants from toxic degradation products (Ciferno et al., 2009; Strazisar et al., 2003). To operate amine processes more effectively and reduce environmental pollution, these problems should be addressed. Maintaining proper amine solution quality in CO₂ capture plants is an important requirement. The solvent management strategies can be divided into two categories: degradation prevention and inhibition and solvent cleaning. Solvent degradation inhibition seems to be one method of protecting solvent (Soria, 1998) and more applications may be seen in the future (ElMoudir et al., 2012) but are beyond the scope of this work, and so solvent cleaning forms the focus of this review.

1. Amine reclaiming technologies

Heat stable salts refer to the salts formed by reactions of amine and its acidic degradation products and impurities. These salts are not regenerated under stripper conditions. Most acids and acidic gases that exhibit a lower pK_a than CO₂ will react irreversibly with amines to form HSSs. These include

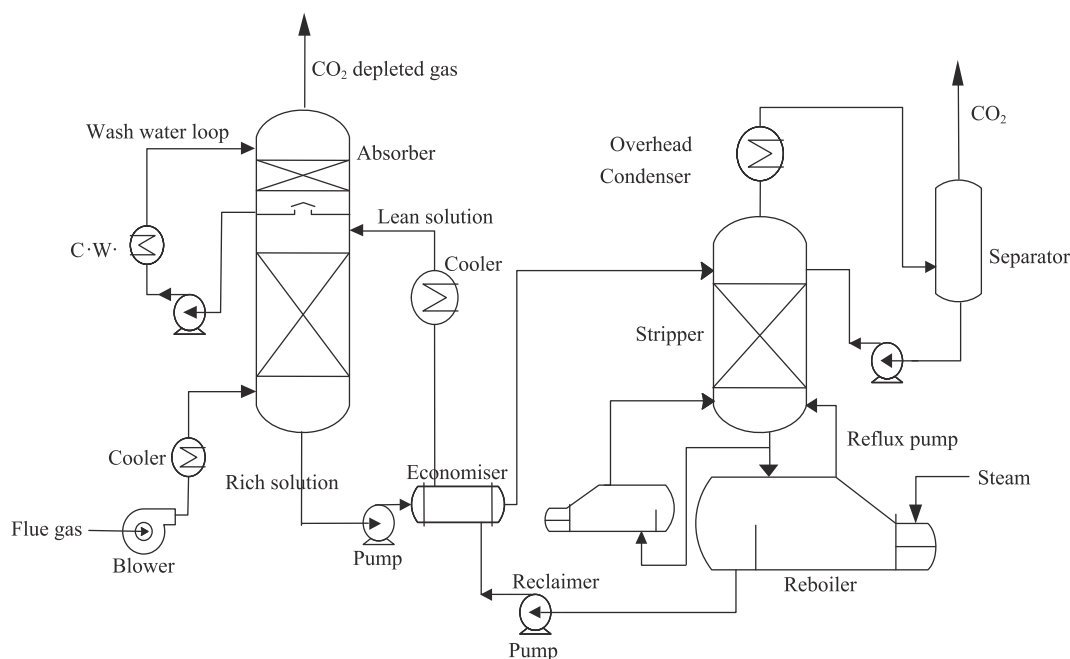


Fig. 1 – Schematic of the typical amine-based absorption-stripping unit for CO₂ removal.

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