

CO₂ CAPTURE. EXPERIMENTAL ACHIEVEMENTS AND PERSPECTIVES

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REZUMAT. În această lucrare, este descris procesul de captare a dioxidului de carbon din gazele de ardere prin intermediul unui solvent chimic. A fost selectată o soluție apoasă monoetanolamina, cu o concentrație de 30% în greutate, pentru a absorbi CO₂ chimic. Rezultatele experimentale au arătat că poate fi atinsă o eficiență de îndepărtare de CO₂ de aproximativ 66%.

Cuvinte cheie: dioxid de carbon, monoetanolamina, gaz de ardere

ABSTRACT. In this paper, the process of capturing carbon dioxide from the flue gas by means of a chemical solvent is described. An aqueous monoethanolamine solution, with a concentration of 30 wt%, was selected to chemically absorb the CO₂. The experimental results have shown that a CO₂ removal efficiency of about 66% can be achieved.

Keywords: carbon dioxide, monoethanolamine, flue gas

1. INTRODUCTION

Fossil fuel combustion releases large amounts of carbon dioxide into the atmosphere (more than 29 billion tonnes of CO₂ in 2008) [1]. It is known that carbon dioxide is a major greenhouse gas, which contributes to global climate change [2]. The energy sector, represented largely by coal- and natural gas-based power plants, is responsible for about 41% of the total CO₂ emissions [3].

There are three main options for CO₂ capture from fossil fuels-based power plants [4,5], namely:

- post-combustion capture, in which the CO₂ is separated from the flue gas;
- oxy-fuel combustion, the fuel is burned in an enriched oxygen medium, producing a flue gas that consists mainly of CO₂ and water vapour; and
- pre-combustion capture (or fuel decarbonization process), the CO₂ is removed from the fuel before combustion.

Post-combustion capture is designed to extract the CO₂ that is diluted in the combustion flue gas. It can be integrated into existing power plants without demanding any major modifications to the power plant itself. Chemical absorption of CO₂ using an amine solvent (e.g., monoethanolamine) is currently the most developed post-combustion CO₂ capture process. At present, there are three commercially available post-combustion technologies:

- the Kerr-McGee/ABB Lummus Crest process, which uses an aqueous monoethanolamine solution with a concentration of 15-20 wt%;

- the Fluor Daniel Econamine process, which is also an amine-based process, employing 30 wt% of MEA; and
- a process based on sterically-hindered amines developed by Mitsubishi Heavy Industries in cooperation with Kansai Electric Power.

In pre-combustion capture, the goal is to trap the carbon prior to combustion. In this process, the fuel is reacted with air or oxygen to produce a synthesis gas, a mixture of carbon monoxide and hydrogen. This is then reacted with steam in a shift reactor to form CO₂ and more hydrogen. The CO₂ gas is separated by means of a physical absorption solvent and the H₂ rich gas is used as the fuel in a boiler or gas turbine to produce energy. Pre-combustion CO₂ capture can be applied both in natural gas and coal based plants. When the primary fuel is a solid fuel (e.g., coal or biomass) then the process is more complex, which includes fuel gasification and synthesis gas purification, in order to remove sulfur compounds, particulates and other impurities from the gaseous stream before CO₂ separation.

The technology of oxy-fuel combustion is not CO₂ capture in the true sense of the term. Here, the process is applied at the input as opposed to the output stage: the objective is to obtain a flue gas with a high concentration of CO₂ by performing combustion in the presence of pure oxygen. Because it recycles part of the CO₂ as a substitute for the nitrogen in air, oxy-combustion is particularly well suited when an existing facility is being retrofitted. However, separating out the oxygen from air,

performed mainly using the cryogenic principle, is both costly and energy-consuming.

2. CO₂ CAPTURE FROM FLUE GAS. EXPERIMENTAL SETUP

The absorber (Figure 1) is a stainless steel column having an inner diameter and height of 0.2 m and 0.8 m, respectively. Before the tests, the

column was randomly filled with ceramic Raschig rings forming a bed of about 0.2 m above the supporting grid. The packing bed would significantly increase the contact between the gas and liquid phases in the absorber. The absorber has been designed to operate at approximately atmospheric flue gas pressure and temperature up to 65°C. An aqueous MEA solution with a concentration of 30 wt% has been selected.

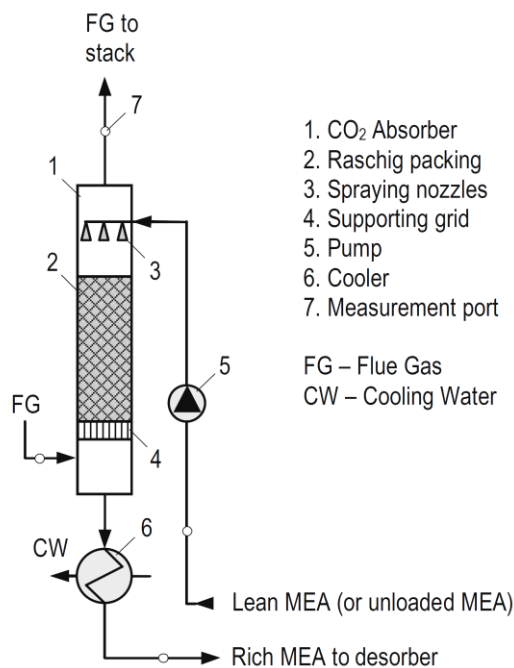
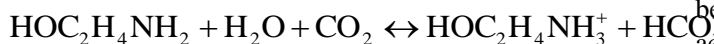


Figure 1. Schematic diagram of the absorption column for CO₂ removal from flue gas

The process of combustion and flue gas cleaning, including ash and SO₂ removal prior to CO₂ absorption has been well described in our previous studies [6-8].

Flue gas with low sulfur content, after the flue gas desulfurization unit, enters the CO₂ absorption column and comes into contact, counter-currently, with a lean solution of MEA, which chemically absorbs the CO₂. The process should occur at low temperatures of about 50-60°C. To reverse the absorption chemistry and so, to regenerate the solvent, the MEA rich in CO₂ must be heated up to 120°C. The fundamental reaction for CO₂/MEA process is [9]:



During the absorption process, the reaction proceeds from left to right. From the absorber bottom, the rich MEA, which contains the chemically bound CO₂, is pumped to the desorber where it is heated by the flue gas stream, in order to be able to release almost pure CO₂.

During regeneration, the reaction proceeds from right to left, thus CO₂ and water evolve

separately from the amine solution. The captured CO₂ leaves through the top of the separation device. The CO₂ should be then dehydrated, compressed and stored. The lean solution of MEA, containing far less CO₂, is cooled down to around 40°C and recycled back to the absorber, for further additional CO₂ capture and continuity of the global process.

3. EXPERIMENTAL RESULTS

The CO₂ absorption process into aqueous MEA solution has been relatively good with an overall absorption efficiency of 66%. The flue gas was produced by burning a low quality coal in fluidized bed. It should be taken into account that the acceptable concentrations' levels of SO₂ and NO_x in the flue gas before the absorber are recommended to be less than 10 and 50 ppm, respectively [10]. In accordance with [8], using a solution of sodium hydroxide (2.5 wt%) it is possible to achieve less than 180 ppm of SO₂ in the flue gas before the absorber. While, spraying aqueous calcium hydroxide (2.5 wt%) into the same SO₂ concentrated flue gas stream removes more than 90% of SO₂ (<125 ppm SO₂ after the scrubber). But, in the case

of NO_x emissions, if they are not controlled, the ability of MEA solvent to capture more CO₂ decreases. During operation has been measured high NO_x level of 280-340 ppm. All these have had a

negative effect on the CO₂ capture process. Figure 2 shows the inlet flue gas CO₂ concentration and the concentration of CO₂ after absorption.

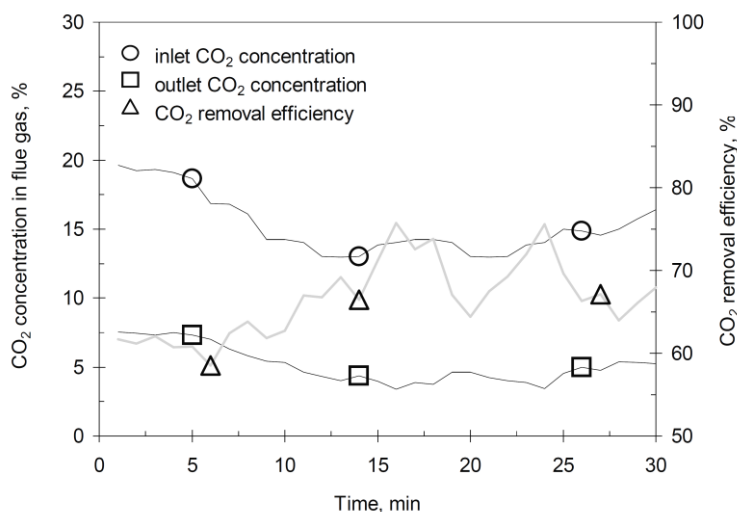


Figure 2. Flue gas CO₂ concentration measured before and after absorption into MEA solution

4. CONCLUSIONS

In order to generate a total CO₂ lean global process by CO₂ absorption (through scrubbing with monoethanolamine), the CO₂ emission might be also reduced and controlled, of course by paying the price for the supplementary technology. The solubility of CO₂ into MEA is mostly influenced by temperature, pressure, and amine solution strength.

The use of MEA to separate CO₂ from the flue gas also removes nearly all of the SO₂ and some of the NO₂. These emissions react with the amine to form stable salts that cannot be regenerated by heating and so represents a loss of solvent from the system. Also, careful attention must be paid to the fly ash and soot present in the flue gas, as they might plug the absorber if contaminants levels are too high.

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