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EXPERIMENTAL EQUIPMENTS USED IN THE STUDY OF CARBON DIOXIDE ABSORPTION (II)

BY

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Abstract. Carbon dioxide is a component of industrial gaseous fluxes and is frequently removed to improve gas quality or to prevent catalyst poisoning. It is obvious that CO_2 emissions play a primary role in global warming. There are several ways to remove CO_2 - absorption, adsorption, cryogenic separation, permeation through membranes and chemical conversion. The industrial plant for absorption consists of the absorption unit, the regeneration unit and auxiliary equipment. Over time, the absorption process investigations were carried out using innovative equipment, which would improve the performance of this process.

Keywords: absorption; carbon dioxide; experimental devices; solvents.

1. Introduction

Every combustion process of fossil fuels and several different industrial processes produces flue gases, which are a mixture of carbon dioxide (CO_2), water vapour and other gases. In order to avoid CO_2 emissions to the atmosphere, CO_2 must be separated from the other gases. Absorption processes

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with chemical solvents are currently the most used technology for post-combustion CO_2 capture, because are the most efficient systems compared to other post-combustion capture processes (Mangalapally and Hasse, 2011; Hu *et al*., 2018).

The absorption installation is based on the use of two columns: one absorption column, to separate the CO_2 with a solvent and a regeneration column for recovering CO_2 in gaseous form and regenerate the solvent (Mangalapally and Hasse, 2011; Tătaru-Fărmuș and Harja, 2017; Liang *et al*., 2016). Removal performances for gas absorbers depend on each gas - solvent system and with the type of absorber used. Most absorbers have removal efficiencies up than 90%. Industrial equipments used frequently in industrial absorption processes include packed towers, plate columns, venturi scrubbers, spray chambers, etc.

2. Experimental Equipments

Over time, original laboratory equipment has been developed to measure the rate of carbon dioxide absorption at different temperatures, using various solvents. Chronologically, the experimental devices are as follows:

2002.

⇨ Liao (Liao and Li, 2002) investigated the kinetics of the absorption of CO_2 into monoethanolamine + N – methyldiethanolamine aqueous solutions, using a laboratory wetted wall column. The liquid flowed through an annular distributor cap and distributed uniformly as a thin film on the outside of the cylinder. The gas flow rate was measured by a soap film meter. The CO_2 absorption rate was measured from the product of the liquid flow rate. The apparatus and the experimental procedure are the same as those described by Shen (Shen *et al*., 1991).

⇨ A wetted-wall column, presented in Fig. 1, was used by Cullinane and Rochelle (Cullinane and Rochelle, 2004) as the gas–liquid contactor to study the equilibrium and rate experiments for carbon dioxide absorption with aqueous potassium carbonate promoted by piperazine The contactor is the same equipment used in the work of Bishnoi (Bishnoi, 2000) and Dang (Dang and Rochelle, 2001). The wet wall is a tube, which connects the liquid supply line with the column housing. The solvent solution is introduced through the inside of the tube, and is distributed on the outer surface of the tube. The liquid, collected at the base of the column, is pumped back into a liquid reservoir. The gas enters at the base of the column, flowing counter current with the fluid. The gas-liquid contact surface is closed by a thick-walled glass tube. The outer region of the column is the circulating bath of paraffin oil.

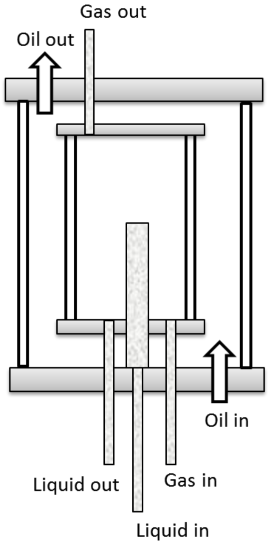

Fig. 1 – Gas–liquid contactor used by Cullinane and Rochelle.

2003.

⇨ A laminar jet apparatus (Fig. 2) was used by Aboudheir (Aboudheir *et al.*, 2003) to generate kinetics data for the absorption of CO_2 into high CO_2-loaded and concentrated solutions of monoethanolamine.

A jet of liquid from a circular nozzle circulates downward and is collected in a capillary hole. To measure the length and the diameter of the liquid jet, a two-dimensional microscope was used. The fluid flow rate was determined by weighing the liquid collected in a timed interval during each experiment. The volumetric technique was used to measure the gas absorption rates in the liquid.

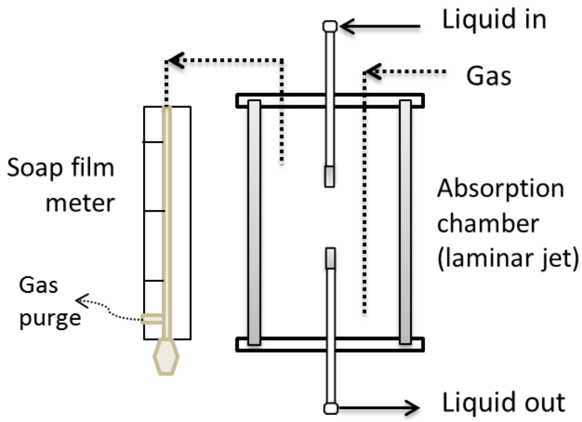

Fig. 2 – The laminar jet apparatus used by Aboudheir (2003).

⇨ A schematic diagram of experimental apparatus used by Yoon (Yoon *et al*., 2003) is shown in Fig. 3. The kinetics of CO_2 absorption in aqueous 2-amino-2-methyl-1, 3-propanediol (APMD) solutions was measured using a wetted-wall column absorber. The APMD solution is distributed uniformly as a thin film on the outside of the cylinder and the gas absorption rates were measured. The composition of the output gas was determined by a gas chromatograph. Absorption rates of CO_2 was measured by a soap-film meter.

⇨ Mandal (Mandal *et al*., 2003) studied the absorption of pure CO_2 into aqueous blends of diethanolamine (DEA) and 2-amino-2-methyl-1-propanol (AMP) using a wetted wall contactor. The wetted wall contactor used was similar to the one used by Saha *et al*. (1995).

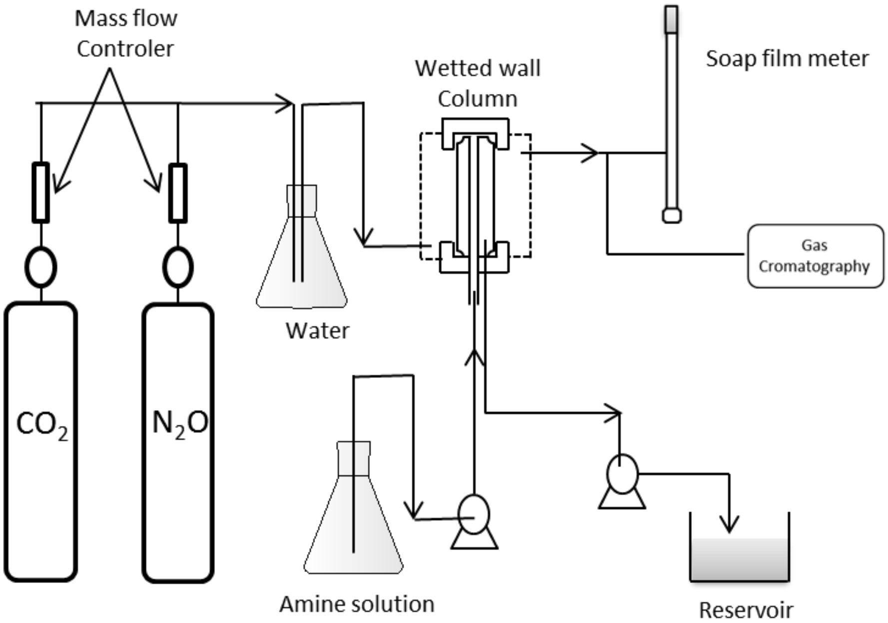

Fig. 3 – The schematic experimental equipment used by Yoon (2003).

2004.

⇨ The rate of reaction between CO_2 and amine was measured by Ali (Ali, 2004) using a standard stopped-flow apparatus (Fig. 4). This principle of this method is to track the evolution of the conductivity of the blends in time. In each experiment, equals volumes of the solutions and carbon dioxide were mixed in the stopped-flow apparatus. A conductivity cell was used to monitor ion formation, as a function of time. Previous work of Ali (Ali *et al*., 2000; Ali *et al*., 2002) has validating this technique.

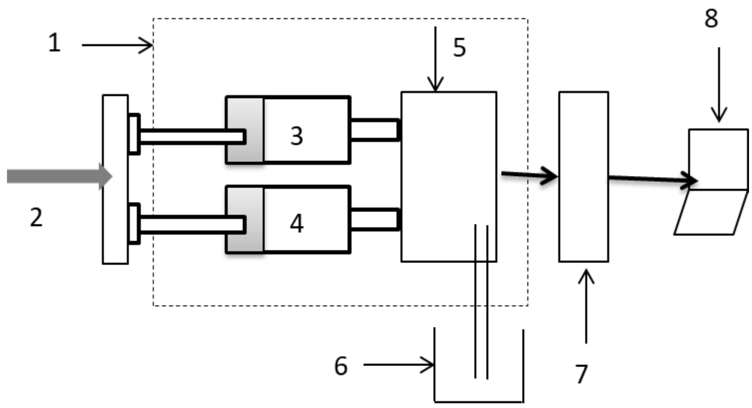

Fig. 4 – Ali experimental apparatus
1 – thermostat; 2 – pneumatic plate; 3 – CO_2 solution; 4 – amine solution;
5 – mixer; 6 – waste; 7 – conductometer; 8 – computer.

2005.

⇨ An innovative concept for the removal of CO_2 from gas was developed by Zhang (Zhang *et al*., 2005). First, they evaluate the efect of immobilised amines in the CO_2 absorption process with methyldiethanolamine (Schubert *et al*., 2001), using an aerated stirred tank reactor. In order to identify the limiting steps of the new system, experiments with a liquid medium in a fixed-bed reactor (Fig. 5) have been carried out. Two electric conductivity detectors are used before and after the fixed-bed for the rapid qualitative detection of CO_2 concentration variations.

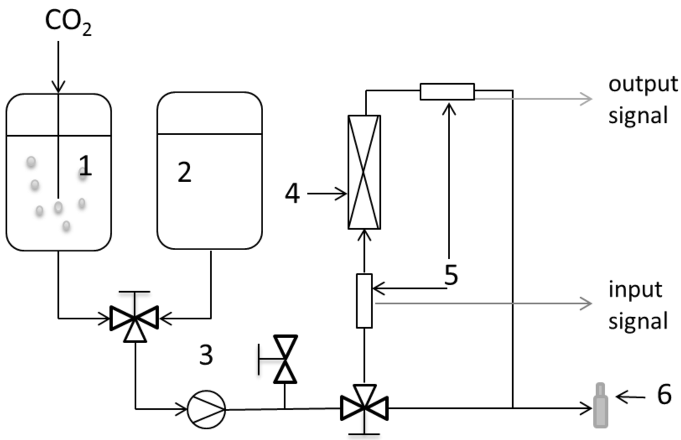

Fig. 5 – Schematic diagram of the equipment (Zhang *et al*., 2005)
1 – CO_2 saturated water feed tank; 2 – amine tank; 3 – pump; 4 – fixed-bed reactor;
5 – electrical conductivity detector; 6 – sample collector.

⇨ In the same year, Siminiceanu (Siminiceanu *et al*., 2005) used a gas–liquid reactor to measure the absorption rate for carbon dioxide absorption, (Fig. 6). The device is composed of a Lewis cell with double jacket (which allows the circulation of a fluid, regulating in temperature inside the cell) provided with a Rushton turbine in its lower part (liquid phase), a propeller in its upper part (gas phase) and four PTFE counter blades to avoid deformation of the gas-liquid interface area by a vortex and also to maintain a stable horizontal ring. The experimental issue is the same used by Pani (Pani *et al.*, 1997) and Cadours (Cadours *et al*., 1997; Cadours, 1998).

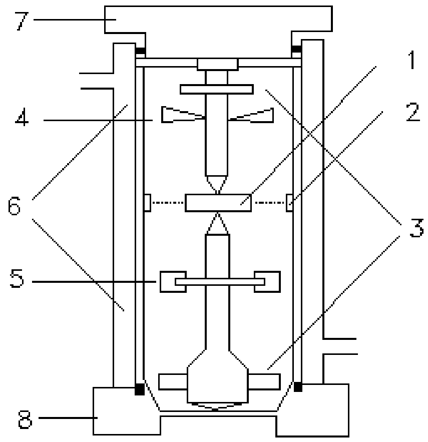

Fig. 6 – Gas – liquid reactor used by Siminiceanu (2005)
1 – central teflon cylinder; 2 – teflon ring; 3 – magnetic bars; 4 – propeller;
5 – Rushton turbine; 6 – baffles; 7 – upper flange; 8 – lower flange.

3. Conclusions

With the increasing number of disasters related to climate change, it is important to consolidate all available information to reduce CO_2 emissions into the atmosphere, to minimize the effect of global warming. Although new CO_2 elimination technologies are emerging, it is unanimously accepted and recognized that the absorption process is the most popular method of separating CO_2 from gas or natural gas streams.

The performance of the CO_2 absorption process is influenced by the type of reactor used. Currently, due to the research carried out, there are data needed to design and design a large number of types of gas - liquid contactors.

It was hoped that, with the studies conducted worldwide, the challenges related to the absorption process could be overcome and several CO_2 capture projects could be integrated and materialized in the industrial process.

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ECHIPAMENTE EXPERIMENTALE UTILIZATE ÎN STUDIUL ABSORBȚIEI DIOXIDULUI DE CARBON (II)

(Rezumat)

Dioxidul de carbon este o componentă a fluxurilor gazoase industriale și este îndepărtat frecvent pentru a îmbunătăți calitatea gazelor sau pentru a preveni otrăvirea catalizatorilor. Este evident, de asemenea, că emisiile de CO_2 joacă un rol primordial în încălzirea globală. Există mai multe moduri de a elimina absorbția CO_2 într-un solvent lichid, adsorbția, separarea criogenică, separarea prin membrane și transformarea în alți compuși. Instalația industrială de absorbție constă din unitatea de absorbție, unitatea de regenerare și toate echipamentele și utilajele auxiliare necesare. De-a lungul timpului, investigațiile procesului de absorbție au fost efectuate folosind echipamente inovatoare, care ar îmbunătăți performanța acestui proces. Această lucrare prezintă a doua parte a cronologiei experimentelor efectuate în studiul absorbției dioxidului de carbon, concentrându-se pe echipamentele experimentale dezvoltate în cercetările de laborator între anii 2000 și 2005.