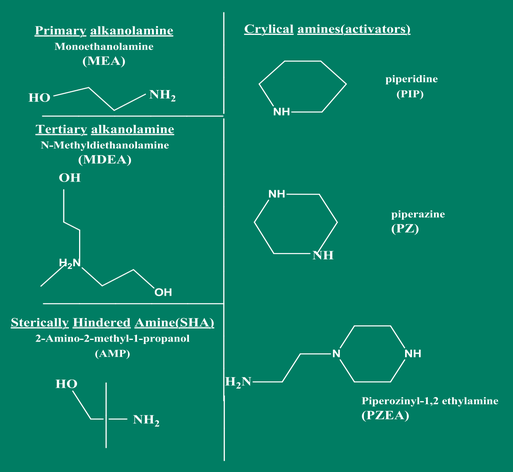
Novel technologies for integrated biogas separation and compression

ESR:4.2: Jing-xiao Liang (Leanne) QUB

Supervisor: Pro. David Rooney Dr. Geoffrey McCullough Dr. Beatrice Smith

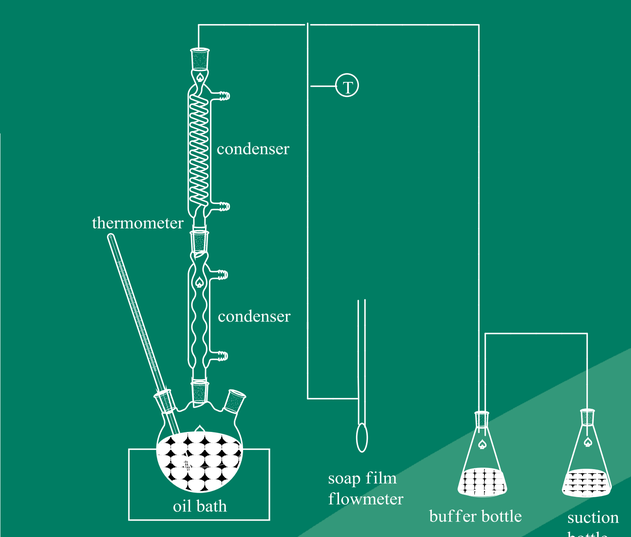
Funded by the European Union

Aqueous alkanolamine solutions are widely used for the removal of acid gases such as CO_2 and H_2S from biogas. Methyldiethanolamine (MDEA) is one of the industrially important alkanolamines used for this purpose. MDEA is characterized by a slow reaction rate with CO_2 compared with primary and secondary amines.



To improve the CO_2 absorption rates of tertiary amines, small amounts of absorption activators (cyclical amines in most cases) can be added to the tertiary amines in order to reach sufficient absorption performances the absorption capacities of the solutions remaining high.

CO_2 Regeneration experiments below is experimental apparatus for regeneration, the whole regeneration experiment was accomplished at atmospheric pressure.



1. Two condensers were placed over the bottle to minimize the evaporation loss of water
2. The released gas was eventually led to a suction bottle in which saturated calcium hydroxide was applied to detect CO_2
3. The flow rate of the released gas was measured using a soap-film meter
4. Before the soap-film meter, the gas temperature was measured, thus the amount of released gas could be calculated as the amount of water in the gas being excluded

This apparatus including an absorption column under elevated pressure and a regeneration column under normal pressure is established to mimic the industrial installation of CO_2 removal both of the columns were in adiabatic state.

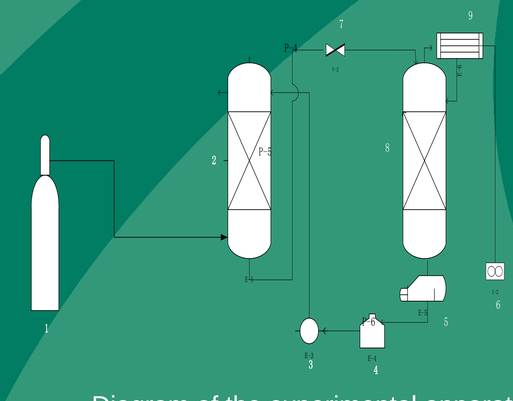
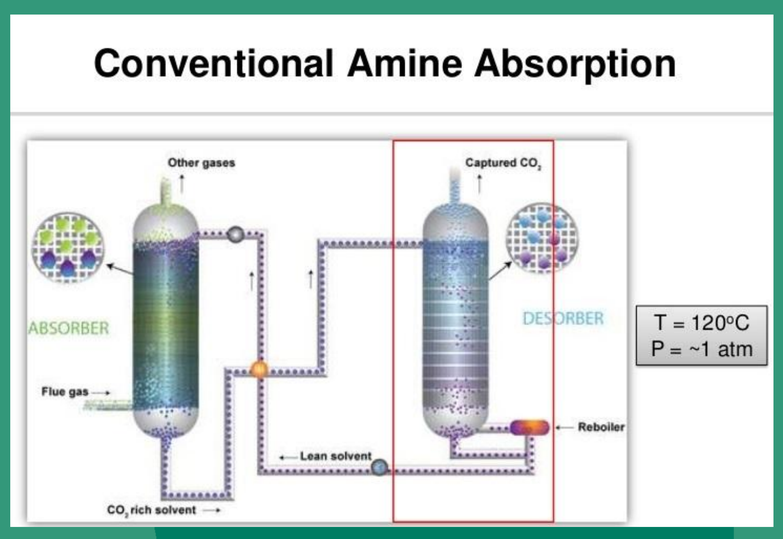


Diagram of the experimental apparatus:
1.CO_2 steel bomb 2.absorption column 3. pump 4.surge tank 5.reboiler6.Wet flow meter 7.flash valve 8.regeneration column 9.condenser

CO_2 was passed through absorption column from its bottom, and tail gas was emitted at the top The rich solution that was drawn from the bottom of the absorption column was flashed and then allowed to flow into regeneration column, where it was stripped by a reboiler. The CO_2 from the stripper was metered and purged. The lean solution drawn from the regeneration column was sent back to the absorption column with a metering pump



Theoretical Analysis

Donaldson and Nguyen (1980) proposed the following reaction mechanism for the reaction of CO_2 with MDEA:

$$R_3N + CO + H_2O = HCO_3^- + R_3NH^+ \quad (1)$$

This reaction mechanism is essentially a base catalysis of the CO_2 hydration reaction and it can be divided into two steps: First, MDEA combines with CO_2 in a liquid film to form an unstable weakly boned CO_2-nitrogen atom complex as follows:

$$R_3N + CO_2 = R_3NCOO \quad (2)$$

Then the hydrolytic reaction of R_3NCOO takes place in the liquid phase in equilibrium as follows:

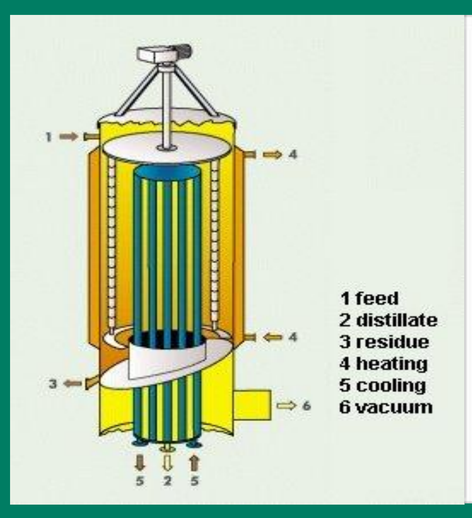
$$R_3NCOO + H_2O = R_3NH^+ + HCO_3^- \quad (3)$$

Because of the concentration of MDEA in bulk phase is high, the concentration of MDEA in liquid film is nearly equal to that of bulk phase if the partial pressure of CO_2 is not very high and the conversion of MDEA is not large. The reaction with respect to MDEA can be regarded as pseudo-first-order and the reaction rate can be expressed as

$$r_m = k_2 C_{am}(P_{CO2} - P_{CO2}^*) \quad (4)$$

am = methyldiethanolamine * = equilibrium at the interface

next step: continuous in-line measurement



Wiped-film evaporator

A single analyzer is now capable of measuring a wider selection of gas components utilizing many different types of sensor technology. Non-dispersive infrared (NDIR) modules are available to measure gas such as CO, CO_2, NO, N_2O, CH_4, SO_2 and others

HORIBA gas analyzer

Permanent gases such as CO, CO_2, O_2, N_2, and methane are common analysis in refinery gases, natural gas, fuel cell gases, and many other industrial processes. Understanding the concentration of these components can be very important for controlling manufacturing processes, and impact the quality and commercial value of end products

Agilent Technologies GC