Overview

1. Introduction
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Introduction to Absorbers

- Liquid stream “absorbs” gaseous components from gas stream in absorption unit (pictured)
- Utilizes varying solubilities of gas components to separate components of the gas stream

http://www.croll.com/images/air_library_technicalbulletins5_pic1.jpg
Natural Gas Sweetening

- Natural gas enters “sour,” containing $\text{H}_2\text{S}$ and $\text{CO}_2$
- An amine solution absorbs $\text{H}_2\text{S}$ and $\text{CO}_2$ from the sour gas stream
- “Sweetened” gas and “sour” amine solution leave the absorber
MDEA

The exchange of $\text{H}_2\text{S}$ and $\text{CO}_2$ in the absorber is determined by the solubility of these gases in the liquid amine solution.

Note: MDEA selectively removes $\text{H}_2\text{S}$
H₂S + CH₃N(C₂H₄OH)₂ → HS⁻ + CH₃N(C₂H₄OH)₂H⁺

- Due to MDEA being a tertiary amine, does not react with CO₂ at a reasonable rate
- Cannot form carbamate ion as tertiary
Solubility

Henry’s Law represents the solubility of a dilute gas in liquid.

\[ P_T y = M_{x,y} x \]

Empirical data for Henry’s Law coefficients (solubility) of \( \text{CO}_2 \) and \( \text{H}_2\text{S} \) in MDEA are available which correspond to different flow rates of MDEA-H\(_2\)O solution.
McCabe-Thiele

\[ M_{x,y} = \text{Henry's Coefficient} \]
\[ X = \text{Mol Fraction of Solute in Solvent} \]
\[ Y = \text{Mol Fraction Solute in Carrier Gas} \]
\[ X_1 = \text{Fraction Solute Leaving in Solvent} \]
\[ X_2 = \text{Fraction Solute initially in Solvent} \]
\[ Y_1 = \text{Fraction Solute in Gas Initially} \]
\[ Y_2 = \text{Fraction Solute in Gas Leaving} \]
\[ L = \text{Amount of Liquid Solvent (Mols)} \]
\[ G = \text{Amount of Gas (Mols)} \]

\[ y_1 = \frac{L}{G} (x_1 - x_2) + y_2 \]
McCabe-Thiele

- Useful for calculating stages by ‘stepping off’
- Provides a basis for calculating the Overall Mass Transfer Coefficient of the gas phase
- Can also use as a basis to calculate the height of the column, fraction of absorption, Number of Transfer Units (NTU) and the Overall Height of the Transfer Unit
Mass Transfer - Driving Factors

- The driving force behind mass transfer is the difference in mol fractions of the gas phase.
- This is due to the fact that the solute has a high affinity for the solvent (H2S for MDEA).

\[ N = K_y(y - y^*) \]

\[ K_y = \text{The overall gas phase mass transfer coefficient} \]
Mass Transfer - Height

- By substitution our definition of $N$ with a mass flux equation we arrive at the functional formula for height $(H)$

$$H = \frac{G}{K_y \ast a} \int_{y_2}^{y_1} \frac{dy}{y - y^*}$$

Where:

$$G = \frac{\text{Molar Flowrate of the gas}}{\text{Cross Area}} = \frac{\text{Mol}}{\text{cm}^2 \ast s}$$

$$a = \text{Packing Constant} = \frac{\text{cm}^2}{\text{cm}^3}$$
• Where overall **height of the transfer unit** is a measurement of the efficiency of the packing units
  ○ As HTU decreases, the more efficient the packing

\[
HTU = H_{og} = \frac{G}{K_y \times a}
\]

and

\[
NTU = N_{og} = \int_{y_2}^{y_1} \frac{dy}{y - y^*}
\]
Mass Transfer - NTU

- **Number of transfer units** (NTU) can be simplified to a more useful equation via substitution and integration.
- NTU represents an overall change in solute mole fraction divided by the average mole difference in the gaseous phase.

\[
NTU = \frac{A}{A - 1} \ln \left( \frac{(1 - \alpha)^2}{A} \right)
\]

\[
A = \frac{L}{G \cdot M_{x,y}}
\]

\[
\alpha = \frac{(y_1 - y_2)}{(y_1 - y_2^*)}
\]
Mass Transfer - NTU

- Alpha is the ratio of amount adsorbed to maximum amount absorbed, or the fraction of absorption
- As NTU increases, it indicates a need for a greater packing contact factor
Preliminary Design

Circulation Rate: Flowrate of MDEA/Water solution entering absorber

- Initial estimate required
- Rule of thumb:

\[
GPM = \frac{0.206 \times MM \times (H_2S + CO_2) \times MWT}{ML \times WT}
\]

MM = gas flow (MMSCFD); \( H_2S \) = mol fraction \( H_2S \) removed;
CO\(_2\) = mol fraction \( CO_2 \) removed; \( MWT \) = mol. weight of MDEA;
ML = mol. loading (acid gas/mole) \( WT \) = weight percent MDEA solution