Analysis of the CO_2 Separation Process from Natural Gas Streams by Absorption with MEA using Aspen HYSYS

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The increasing concern for environmental preservation and efforts to mitigate global warming has intensified studies on process decarbonization. Simultaneously, natural gas (NG) consumption has been rising due to its lower environmental impact than other fossil fuels. To meet commercial standards, natural gas undergoes a CO_2 separation stage, with amine absorption technology being the most widely used due to its industrial applicability. This study aims to organize a test spreadsheet to initiate a sensitivity analysis of the CO_2 absorption process in natural gas streams based on simulations conducted using Aspen HYSYS. The analysis identifies combinations of process parameters that optimize separation results.
Keywords: CO_2 Separation. Absorption. Amines, Aspen HYSYS.

Natural gas consists of various chemical compounds, predominantly hydrocarbons, with methane (CH_4) as its main component. Natural gas is classified into three types:

Dry Gas: Primarily sold as compressed natural gas (CNG) or liquefied natural gas (LNG).

Wet Gas: Contains higher quantities of ethane, propane, and butane, commonly referred to as liquefied petroleum gas (LPG).

Gas Condensate: Comprises heavier fractions of natural gas, such as naphtha [1].

The growing demand for sustainable energy and reduced greenhouse gas (GHG) emissions have increased the appeal of natural gas as a cleaner energy source [1]. However, to meet market requirements, natural gas must have a CO_2 concentration of no more than 3% v/v, as carbon dioxide is a contaminant affecting the gas's characteristics [2].

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CO_2 is typically removed from natural gas streams through amine absorption [3], a widely used technology known for its high absorption efficiency at low concentrations and ease of solvent recovery. However, the energy-intensive nature of the absorption process has prompted research into optimization through simulation tools. This study focuses on organizing a test spreadsheet for sensitivity analysis using Aspen HYSYS, enabling the identification of optimal process configurations.

Materials and Methods

This project began with a literature review to examine the importance of CO_2 removal from natural gas streams. It focused on current methods and the role of amines in this process.

The review included a qualitative bibliographic survey using keywords such as "CO^2 separation," "alkanol amines," and "natural gas." The study highlighted monoethanolamine (MEA) as the primary solvent due to its high CO^2 absorption capacity at low concentrations and efficient recovery.

Using Aspen HYSYS V12.1, a simulation model of the CO_2 capture process with MEA was developed. A test spreadsheet was then organized to initiate sensitivity analysis, targeting key process parameters.

Theoretical Foundation

Absorption is an industrial process used to recover high-value compounds. It is categorized into three types:

Physical Absorption

Chemical absorption with irreversible reaction Chemical absorption with reversible reaction The absorption process relies on mass transfer between a gaseous solute and a liquid solvent in a countercurrent distillation column. The column contains trays or packing material to enhance contact between phases, enabling the solvent to absorb the gaseous solute [4].

This project used Aspen HYSYS to simulate a chemical absorption process with a reversible reaction. CO_2 (the gaseous solute) was separated from the natural gas stream using MEA as the liquid solvent. The primary equipment involved includes an absorber column, a distillation column, a heat exchanger, and auxiliary equipment like pumps and valves [5].

Process Flow (Figure 1)

Natural gas enters the absorber at the column's bottom, while the MEA solution enters at the top. The amine absorbs CO2, exiting as a rich solvent at the column's bottom. The purified gas exits at the top.

The CO_2-rich solvent is heated in a heat exchanger using a hot stream from the bottom of the distillation column.

The heated solvent enters the distillation column's top. The distillation column separates CO_2 from the MEA using steam generated by a reboiler

The CO_2 exits the column's top for collection, while the lean solvent is recycled back to the absorption column after cooling and replenishing with MEA and water. Input and output parameters such as temperature, pressure, flow rate, and CO_2 concentration were collected for sensitivity

Figure 1. Flowchart of the CO_2 absorption process from natural gas stream simulated in the Aspen HYSYS [6].

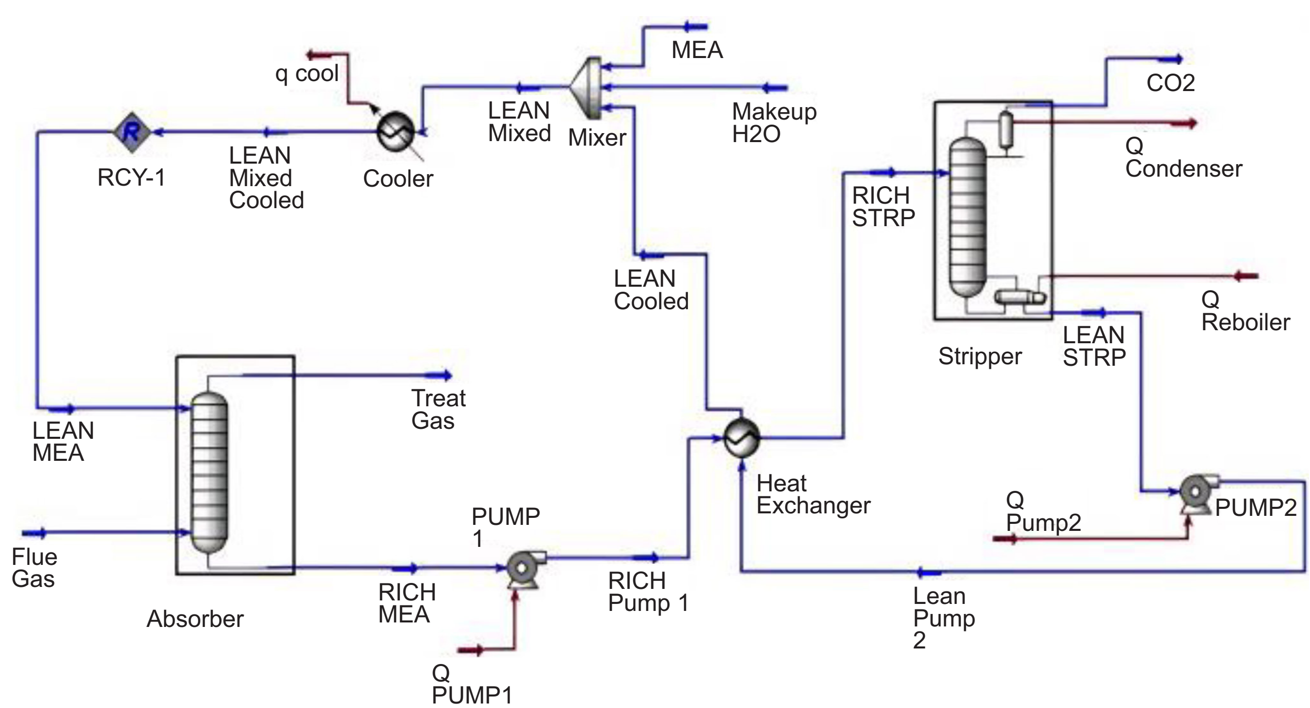

Table 1. Test table for sensitivity analysis.

Test	Current	Stream Modified Parameter
1	Pump	Temperature
2	MEA Makeup	Flow Rate
3	MEA Makeup	Composition
4	Heat Exchanger	Temperature
5	Gas Supply	Temperature
6	Gas Supply	Flow Rate
7	Gas Supply	Composition

analysis.Seven scenarios were constructed for a test table (Table 1) to evaluate the influence of variable modifications on process efficiency.

The sensitivity analysis aims to identify the best process configurations for efficient CO_2 separation.

Conclusion

The CO_2 absorption process from natural gas streams is of significant environmental relevance. Given its energy demands, continuous research and development are essential. Simulation tools like Aspen HYSYS facilitate the exploration of alternative process routes and improve efficiency.

Future studies should focus on enhancing solvent recovery, reducing energy consumption, and exploring alternative technologies to further optimize the CO_2 separation process.

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References

1. Moholt B. Simulering av CO_2-fjerning med aminer. Master Thesis, Telemark University College, 2005.
2. Santos DS. Análise comparativa de tecnologias de separação de CO_2 no processamento de gás natural. Dissertação (mestrado) – Universidade Federal do Rio de Janeiro, 2014.
3. Teixeira WD, Santana MLA, Lima YS. Avaliação do processo de degradação da MEA no sistema de absorção de CO_2 em gás de queima. Revistas UNIFACS 2016;10(1).
4. Oleiveira LTP. Estudo da remoção do CO_2 por absorção utilizando MEA a partir de simulações no Aspen HYSYS. Monografia (graduação) – Universidade Federal Rural do Semi-Árido, Mossoró – RN, 2017.
5. Lima BC. Avaliação de configurações de remoção de CO2 por absorção utilizando MEA a partir de simulações de processo. Monografia (graduação) - Universidade Federal Rural do Semi-Árido, Mossoró – RN, 2019.
6. Pan M, Agulonu A, Gharaie M, Perry S, Zhang N, Bulatov I, Smith R. Optimal design technologies for integration of combined cycle gas turbine power plant with CO_2 capture. Chemical Engineering Tansactions 2014;39.