Carbon Capture and Storage

Technical Design and Analysis of Industrial Emission Mitigation

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Introduction to Carbon Capture Technology

Definition

Capturing CO_2 from large point sources or directly from the air.

Primary Goal

Prevent CO_2 release to the atmosphere to mitigate greenhouse effects.

Process Overview

CO_2 is compressed, transported, then utilized or stored geologically.

Significance

Key for net-zero in hard-to-electrify industries.

"Capturing CO_2 before it reaches the atmosphere to tackle emissions at the source."

Selecting Optimal Amine-Based Solvents

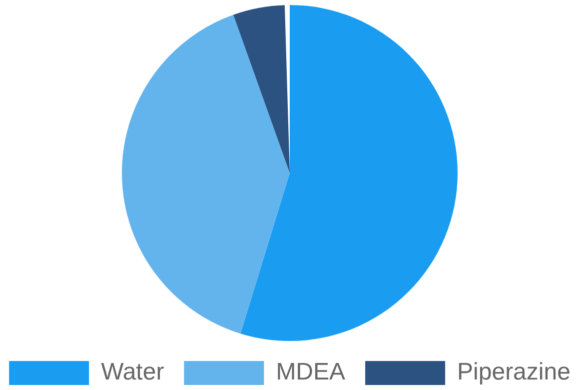
Solvent Analysis

- **MDEA vs. AMP:** Amine-based solvents are standard for chemical absorption.
- **Why MDEA?** Lower volatility reduces solvent loss.
- **High Capacity:** Superior CO_2 absorption vs. AMP.
- **Stability:** Lower corrosion rates reduce maintenance.

20°C
TEMPERATURE

2408 KPa
PRESSURE

Optimized MDEA Blend



- **Water (55%):** Primary carrier.
- **MDEA (40%):** Main CO_2 capture agent.
- **Piperazine (5%):** Enhances reaction kinetics.

Solvent Property Analysis: MDEA vs. AMP

Properties	MDEA	AMP
Boiling Points	247°C	165.5°C
Dynamic Viscosity (20°C)	0.101 Pa.s	0.015 - 0.025 Pa.s
Corrosion Rate (5M)	0.825 µm/day	0.95 µm/day
CO_2 Absorption Capacity	Higher Capacity	Lower Capacity
Foaming Tendency	Higher Tendency	Lower Tendency

MDEA demonstrates superior thermal stability and lower corrosion rates, making it the preferred choice for long-term industrial applications despite its higher foaming tendency.

Evaluating Distillation Column Configurations

Tray Columns

Utilize a series of physical trays or plates to facilitate contact between the rising gas and falling liquid phases. Ideal for large-scale operations with varying flow rates and where periodic cleaning is required.

Packed Columns

Use specialized packing material (random or structured) to provide a large surface area for mass transfer. Typically offer lower pressure drops but can be more expensive and harder to maintain at very large diameters.

KEY SELECTION FACTORS: **Pressure Drop** **Efficiency** **Column Diameter** **Capital Cost**

Technical Comparison: Tray vs. Packed Bed

SELECTED DESIGN

Tray Column

Diameter	5.49 m
Efficiency	71.9%
Height	10.3 m
Pressure Drop	960.2 Pa/tray

- Superior handling of varying gas and liquid flow rates.
- Easier maintenance and cleaning of internal components.
- More cost-effective for large-diameter industrial applications.

Packed Bed

Diameter	6.13 m
Efficiency	Variable
Height	1.09 m
Pressure Drop	143.2 Pa/m

- Lower overall pressure drop per unit height.
- Compact height requirement for specific purities.
- **Limitation:**Excessive diameter required for high-capacity CO_2 capture.

Economic and Cost Analysis

Capital & Operating Costs

Capital Expenditure (CAPEX)

Initial investment for the absorption column, solvent inventory, and auxiliary heat exchangers.

Operating Expenditure (OPEX)

Ongoing costs driven by energy for solvent regeneration, pumping power, and solvent make-up.

Efficiency Impact

Higher capture efficiency directly reduces the long-term cost per ton of CO_2 captured.

Financial Viability

Scaling Potential

Economic viability improves significantly with larger scale operations due to economies of scale.

Strategic Insight

The selection of MDEA and Tray Columns optimizes the balance between initial CAPEX and long-term OPEX, ensuring the most sustainable financial model for industrial carbon capture.

Strategic Conclusions and Recommendations

Solvent Selection

MDEA-based blends provide the optimal balance of high CO_2 absorption capacity, low volatility, and minimal corrosion for industrial-scale carbon capture operations.

Equipment Choice

Tray columns are the preferred design for large-scale absorption, offering superior operational flexibility and easier maintenance compared to packed bed alternatives.

Future Outlook

Continued research into hybrid solvents and advanced packing materials will further reduce capture costs and improve the overall efficiency of the CCS value chain.

Implementation

Prioritize integration with existing high-emission industrial sites to maximize environmental impact and leverage existing infrastructure for transport and storage.

The proposed technical design offers a robust, efficient, and economically viable solution for industrial carbon mitigation.

Academic References

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