TEAM 022

Small-Scale CO2 Capture–Release (NaOH-Based)

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EE ISE 4 CHE ME

Problem statment

The project addresses the need for a small-scale chemical system capable of capturing CO_2 from gas streams using NaOH absorption and releasing it through thermal regeneration. The core problem is achieving efficient CO_2 removal, partial regeneration, and safe temporary storage, while meeting constraints related to corrosion resistance, energy usage, cost, and prototype manufacturability.

Constrains

- compact Setup (1-2sq m) to fit labs
- Operates at 1 atm pressure
- Temperature < 100 C
- Maximum initial cost < 5000 SAR

Specifications

- Absorption column must hold pH 14 without degradation
- Safety risk score (based on FMEA <3
- Data logging interval Every 10 seconds
- Sensor Temp range 0-120 C

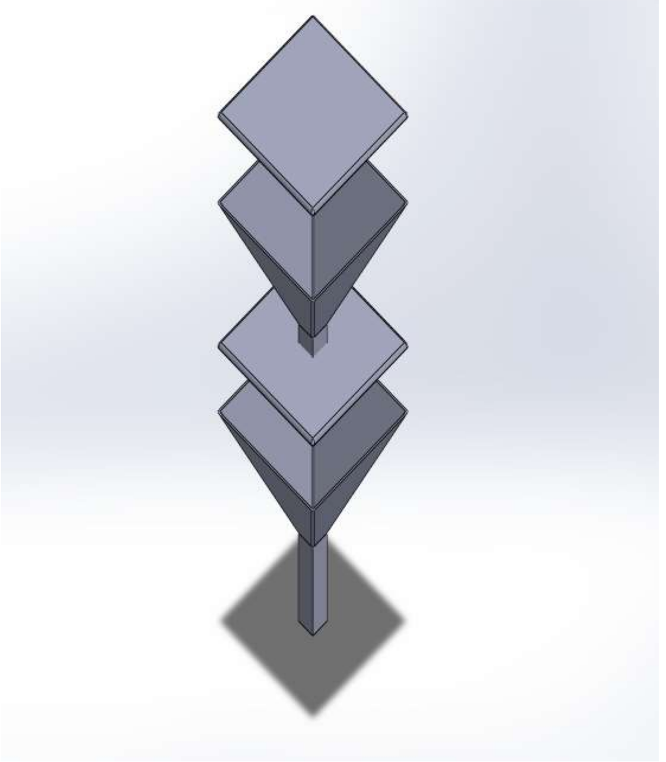
Prototype Design

CHE
Selected 0.5 M NaOH for efficient CO_2 absorption and low-energy regeneration, operating at safe conditions of 1 atm and below 95° C.

ME
Constructed absorber and regenerator from SS316 (1 mm) for corrosion resistance, using a gravity-feed design to simplify liquid transfer.

EE
Implemented Arduino-based control with pH, temperature, and flow sensors, including automatic shutdowns when pH < 8 or temperature > 95° C.

ISE
Used Response Surface Methodology to define optimal operation (pH 12.3, 91° C) and applied FMEA and SPC to enhance safety and process reliability.



Testing & Validation

- pH & Temperature Optimization Output"We identified the optimal pH and regeneration temperature that maximize CO_2 capture efficiency. These optimized parameters significantly improved overall system performance and ensured consistent, reliable operation."

Optimal pH : 12.31
Optimal Temp (C) : 91.35
Pred. Efficiency : 57.34 %

-) Thickness Optimization Output
- "We optimized the absorber wall thickness to achieve maximum structural safety at minimum material cost, resulting in a final design that maintains stability under operating conditions. This optimization ensured an efficient and lightweight prototype without compromising safety margins."

Results

	Thickness_mm	Mass_kg	Energy_Wh_per_cycle	Cost_SAR	Lifetime_years
0	0.8	3.525	185.936	308.618	3
1	1.0	4.406	194.503	348.273	5
2	1.2	5.287	203.071	387.927	7

	Feasible	Cost_norm	Weight_norm	Objective
0	False	0.796	0.667	0.731
1	True	0.898	0.833	0.866
2	True	1.000	1.000	1.000

Best Option:

	Thickness_mm	Mass_kg	Energy_Wh_per_cycle	Cost_SAR	Lifetime_years
1	1.0	4.406	194.503	348.273	5

	Feasible	Cost_norm	Weight_norm	Objective
1	True	0.898	0.833	0.866

Conclusion

The project successfully delivered a compact CO_2 capture system using NaOH absorption. By integrating CHE, ME, EE, and ISE disciplines, the team achieved a safe, automated prototype operating at atmospheric pressure. Experimental results validated by ISE models confirmed an optimal capture efficiency of 57.34% at pH 12.3 and 91°C. The design meets the critical need for affordable, small-scale carbon management in research and agricultural sectors.

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