Generating Pressurized but CO_2-free Steam via Direct Contact Steam Generation Process

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Motivation

- To use aqueous sodium hydroxide (NaOH) solution for capturing CO_2 generated during direct contact combustion-based steam generation approaches.

Project Objectives

- To design and use open experimental setups for producing Na_2CO_3 precipitate via neutralization of 4% (wt) aqueous NaOH solution via CO_2.
- To use direct contact heat transfer mechanism along with the implementation of pure CO_2 stream into the vortex/ cavity created in the NaOH solution through use of magnetic stirrer for producing Na_2CO_3 precipitate and while generating water vapors (i.e., steam).

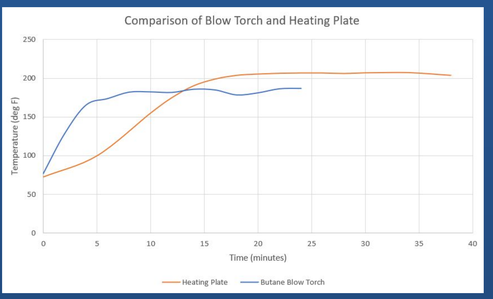
Testing Approaches

- We tested feasibility of direct contact heat transfer mechanism to neutralize aqueous NaOH solution with CO_2 and compared its efficacy in producing Na_2CO_3 precipitate and evaporating aqueous phase (i.e., generation of steam). The following experimental approaches were used:
  - Use a magnetic stirrer plate placed underneath beaker containing 4% (wt) aqueous NaOH solution for aqueous vortex created in beaker.
  - Use of blow torch inserted into vortex created in beaker for facilitating direct contact heat transfer between flame and aqueous solution
  - Use of cyclone separator for separating solids (e.g., Na_2CO_3 precipitate) from aqueous solution.

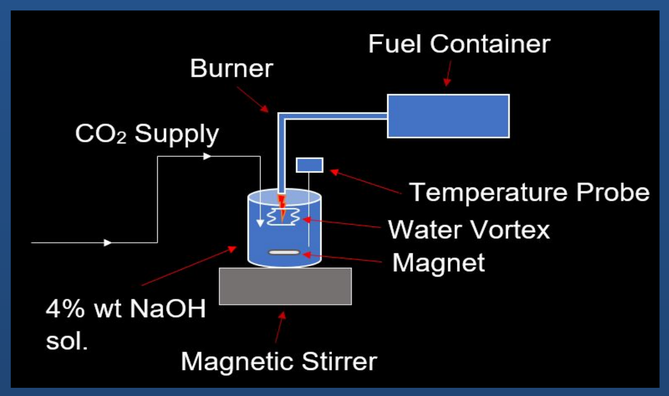
Experimental Observations

Experiment Type	Volume of evaporated water (cc)	Time Taken (mins)	Energy Consumed (W-h/g)
Water evaporation via the use of heating plate (i.e., indirect heat transfer)	30	34	14
Water evaporation via the use of butane blow torch (i.e., direct contact heat transfer)	30	28	3.25

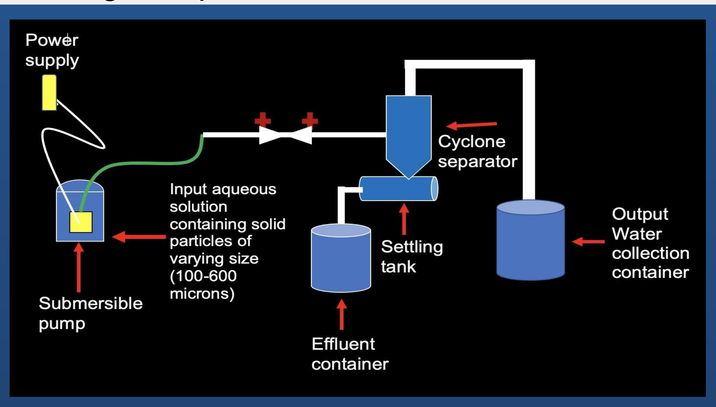
- Based on the experimental observations, it can be said that the direct contact heat transfer-based evaporation of aqueous solutions is much more efficient compared to conventional heating plate-based method.



Experimental Testing Setups



Conversion of aqueous NaOH solution into Na_2CO3 precipitate and steam via utilization of available CO_2 and direct contact heat transfer mechanism

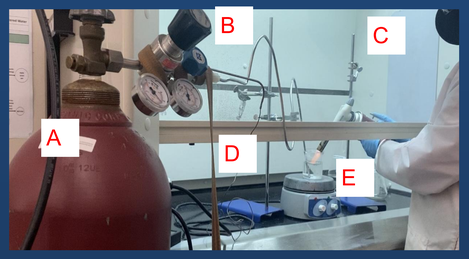


Cyclone separation-based decantation of solid particles from aqueous solutions

Aqueous NaOH Solution

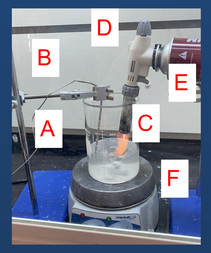
Precipitated Na_2CO_3

Dried Na_2CO_3



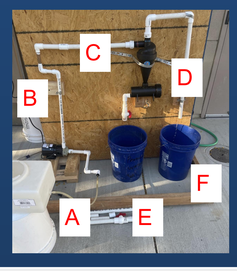
Direct contact steam generation process for generating CO_2-free steam

A. CO_2 tank w. pressure gauge
B. steel tubing connecting pure CO_2 to beaker
C. Butane can with blow torch burner for generating flame
D. 150 mL beaker containing aqueous NaOH solution
E. magnetic stirrer for genating vortex in the aqueous phase



Use of butane torch for direct contact heat transfer

A. 150mL beaker containing aqueous NaOH solution;
B. thermocouple;
C. flame;
D. burner;
E. fuel (butane) can;
F. magnetic stirrer



Cyclone separator system

A. feeding tank (input)
B. pump
C. cyclone separator
D. settling tank
E. effluent container
F. water collection(output)

Mole Basis	$2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$ $2*40gm + 44gm \rightarrow 106gm + 18gm$
For 1000 cc Solution	$40gm + 22gm \rightarrow 53gm + 9gm$
For 400 cc Solution	$16gm + 8.8gm \rightarrow 21.2gm + 3.6gm$

Summary

- Use of analogous open system experiments for using direct contact steam generation approach to test its efficacy to achieve specific project objectives.
- Use of cyclone separator with various aqueous solutions to observe decantation of solid particles from aqueous phase.
- The project results provide us with optimism to capture CO_2 in the form of Na_2CO_3 while using salty water sources to generate CO_2-free steam via direct contact steam generation approach.
- Direct contact heat transfer approach was successfully used to precipitate out Na_2CO_3 from aqueous 4% (wt) NaOH solution while capturing almost all of the supplied CO_2 and transforming aqueous phase into steam.
- In proxy separation experiments (where dust and silicon carbide were used in place of recovered Na_2CO_3solid particles), the cyclone separation process resulted in varying recovery (50% to 80%) of solid particles present in input aqueous solutions.

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Project Team