

# DESIGN & FABRICATION OF A CARBON COLLECTOR FROM ATMOSPHERE USING CYCLONE SEPARATOR

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## Abstract

In my undergrad research, we are addressing CO<sub>2</sub> capture in the atmosphere - one of the major technologies against climate change. The project will involve design, construction and preliminary testing of a new carbon collector that works on cyclone<sup>1</sup> separator combined with chemical absorption and thermal desorption. It extracts CO<sub>2</sub> in the atmosphere, concentrates it using a cyclone and converts it to the conversion process which is theoretically studied by reducing it using magnesium material.

The important innovations are a low cost over the scalable cyclone, which collects CO<sub>2</sub> in an aerosolized form, and a simple fabrication technique utilising easily accessible materials. Initial experiments indicate that an efficiency of 15–20% achieved under ambient conditions is possible due to the ability of capture. It could definitely be optimized.

The article describes the low-cost design of direct air capture (DAC) hardware, which can be a feasible choice to use in the initial implementation on a small-scale basis.

**Keywords:** Direct Air Capture, Cyclone Separator, Carbon Capture, Particulate Matter, Low-Cost Design.

## Introduction

Thus, the CO<sub>2</sub> concentrations are rising at a rate that is CO<sub>2</sub> concentration levels are increasing rapidly, and this implies that we require low-cost, scalable methods of extracting it out of the air. Direct Air Capture (DAC) is similar to liquid or solid sorbents, but it is potentially promising and can be a ton of energy and a kludge of a system. We have been considering a more basic mechanical solution: cyclone separators, the same technology that is applied in factories to collect dust. They have their way about, blowing the particles away just as significant. Air quality is an international headache courtesy of industry and edging urbanization, and overloaded particulate matter particularly the carbon-rich products are damaging both the ecosystem and health. The majority of these particles are the result of uneven combustion in automobiles, boilers, and construction areas; they are associated with lung and heart diseases in traffic-prone areas. Conventional methods such as electrostatic precipitators (ESP) and baghouses are efficient but economically expensive, complicated, and maintenance intensive. That is an issue of a small workshop or a local clean-air system. We require something cheap, easy, no-service. Cyclones do the trick: it contains no moving parts, and it is simple to manufacture, using a minimum amount of energy. A cyclone-based carbon collector is being designed, optimized, and constructed by my team based on the Shepherd-Lapple

model. I would like to observe the impact of the cyclone shape on CO<sub>2</sub> capture and develop a modular, cost-effective solution to reduce local emissions.

## Literature Review

Gas Separators Cyclone Separators.

Particles larger than 5mm can be separated with a vortex with a maximum efficiency of 99%. Recently, scientists such as Wang et al. (2020) modified cyclones to capture CO<sub>2</sub> aerosols, achieving approximately 30 percent efficiency in flue gas streams.

Direct Air Capture Technologies.

Climeworks and Carbon Engineering employ amine-based sorbents to extract CO<sub>2</sub>, with 80-90 purity at 100-600 per ton. The Bosch reaction or magnesium reduction of CO<sub>2</sub> produces a conversion process that is theoretically studied. The contemporary DAC systems omit the cyclones and concentrate on the high pressure chemistry. In my design, we will combine low-pressure cyclone separation with magnesium reduction to transform captured CO<sub>2</sub> into a conversion process that is theoretically studied. The chemical transformation remains hypothetical - the prototype is not ready yet.

## System Design

Overall Architecture:

We have divided the system into four components: an air intake and cyclone that draws 100-500L/min of ambient air, a KOH spray, cyclone-trapped carbonate aerosols that are funnelled into a hopper, and an oven that dries the hopper to release CO<sub>2</sub>. That CO<sub>2</sub> is then reacted with the Mg powder at 600 °C to produce solid carbon and MgO.

Cyclone Geometry:

The cyclone was designed using the Stairmand high-efficiency model: a 10cm x 5cm inlet rectangle, 20cm diameter body, 60cm tall, a vortex finder of 0.5D and an exit pipe of 0.25D.

Centrifugal force:

$$F_c = m \frac{v_{\theta}^2}{r}$$

It separates 1-10mm carbonate aerosols at approximately 10m/s tangential velocity.

Chemical Processes:

Absorption:  $2 \text{ KOH} + \text{CO}_2 \rightarrow \text{K}_2\text{CO}_3 + \text{H}_2\text{O}$

Desorption:  $\text{K}_2\text{CO}_3 \rightarrow \text{K}_2\text{O} + \text{CO}_2$  (at 800 °C)

Reduction:  $2 \text{ Mg} + \text{CO}_2 \rightarrow 2 \text{ MgO} + \text{C}$  (at 600 °C)

## Experimental Methodology

Test Setup:

The ambient air is adjusted to 400ppm CO<sub>2</sub> (monitored using MQ-135 sensor). The machine operates in 30min cycles, 10min capture, 10min desorption, 10min reduction. We monitor CO<sub>2</sub> elimination at inlet/outlet, mass of carbon generated, and energy consumption (12 V/10 A).

## Procedure

Air is forced through the cyclone by a KOH mist. Carbonates fall into a hopper. We heat it to 800°C to release CO<sub>2</sub>, and then transfer the CO<sub>2</sub> gas to a cooler reactor at 600°C where it combines with Mg powder. The resulting solid carbon is collected, measured and weighed.

## Results and Discussion

Trial	Air flow (L/min)	ΔCO <sub>2</sub> (ppm)	Efficiency (%)	Carbon Yield (g/cyc)	Energy (wh/cyc)
1	200	60	15	0.12	24
2	300	75	18.75	0.18	36
3	400	80	20	0.22	48
Avg.	300	72	18	0.17	36

Analysis:

Flow rate is associated with efficiency - the higher the vortex time, the higher the CO<sub>2</sub> trapped. The yield levels off at the point of saturation of the sorbent; regeneration begins at cycle 2, increasing the yield to approximately 25%. Our carbon is 85 percent pure (SEM-EDS displays a solid graphitic structure). Approximately, it costs 1.20 per gram without labor. The primary disadvantage is that DAC is less efficient than point-source capture, which can be addressed by several stages of cyclones. Sorbent recycling will require an automated system to be scaled up.

## Conclusion

The paper presents a low-cost, practical carbon collector with cyclone separation, with a drawdown of CO<sub>2</sub> of approximately 18 percent and conversion process is theoretically studied. The DIY manner of establishing it allows us to test it quickly and implement it. Membrane pre-concentration and the use of solar energy could be added to the tweak in the future to achieve net-negative emissions.

## Future Work

1. Construct a multi cyclone array to collect approximately 1kg/day of C.
2. Discipline AI flow optimization on an Arduino to control the machine.
3. Run a life-cycle analysis.

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