Advanced Engineered Structures for High Performance Direct Air Capture System
Contract No. FE0032260

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Carbon Management Review Meeting

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Project Team and Objectives

- To design and construct an engineered sorbent structure for capturing CO_2 from ambient air via a temperature swing adsorption (TSA)
- The unit cell will be a tube-in-plate heat exchanger, coated with an active sorbent phase that has very high CO_2 uptake
- The new contactor will provide:
  - Low pressure drop
  - Enhanced heat transfer for rapid cycling of sorbent to ensure high CO_2 productivity in the TSA cycle (i.e., kg CO_2 removed per kg sorbent per unit time)

Project Duration

- **Start Date = August 28, 2023**
- **End Date = August 27, 2025**

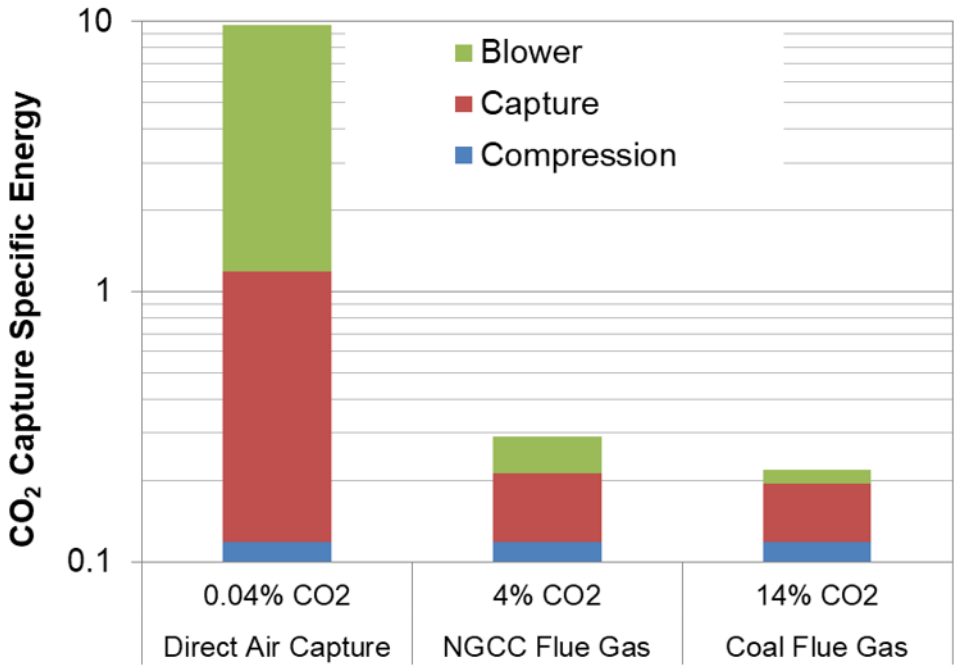
Budget

- **Project Cost = $1,974,000**
- **DOE Share = $1,500,000**
- **TDA & GE = $474,000**

BP	Period	Main Activity
1	Year 1	Material synthesis
		Optimization of coating properties
		Screening based on physical properties and chemical activity
2	Year 2	Bench-scale evaluations
		Long-term cycling
		Techno-economic Assessment
		Life Cycle Analysis

Introduction

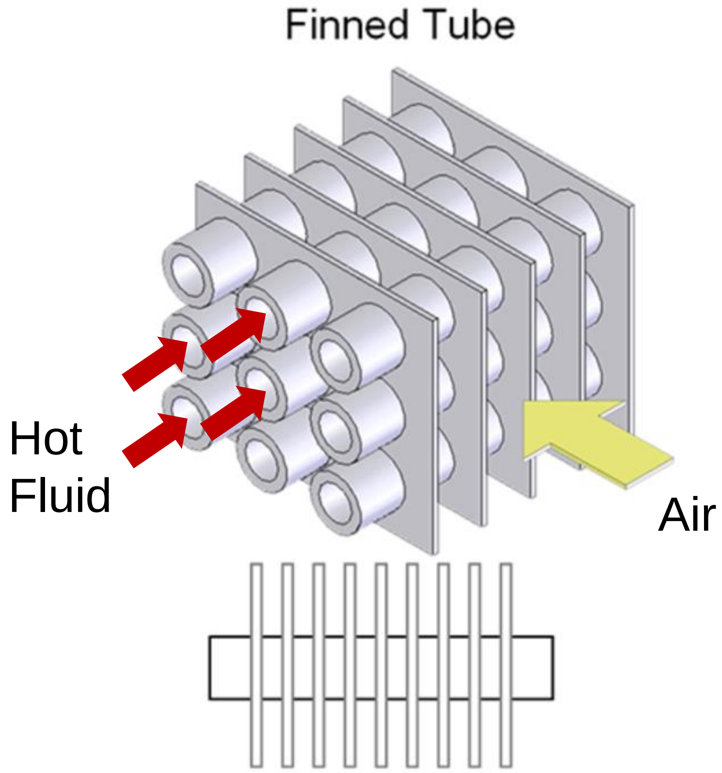
- **The sorbent-based Direct Air Capture systems have to address two key challenges that stems from the low concentration (400-500 ppm) of CO_2 in the air:**
  - **The need to circulate large volumes of air**
  - **A rapid cycle sequence that reduces that increases the CO_2 productivity (ton CO_2 removed per ton sorbent per hr)**

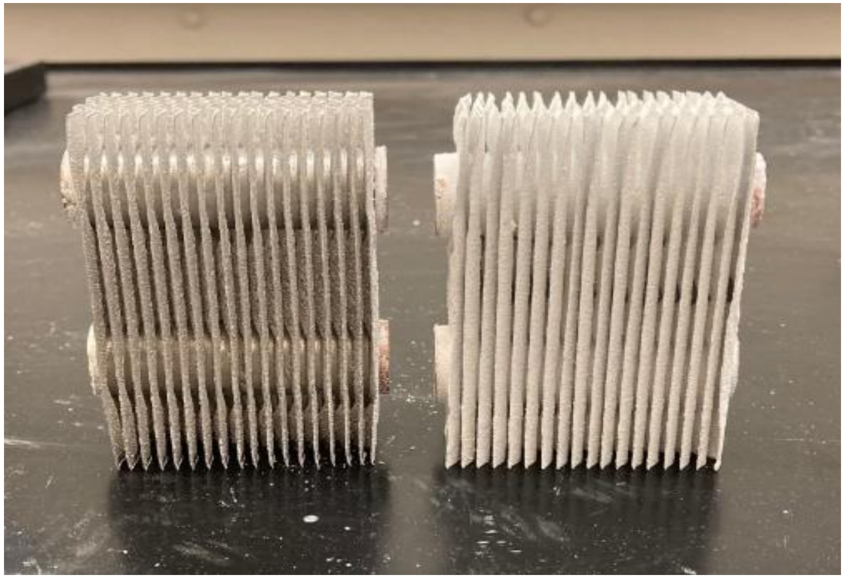


Note: A fixed pressure drop is assumed in all contactors

- **A cost-effective gas-solid contactor must achieve a low pressure drop**
- **An effective heat integration/management system is needed to ensure a rapid cycle to reduce the sorbent inventory**

Project Team's Approach



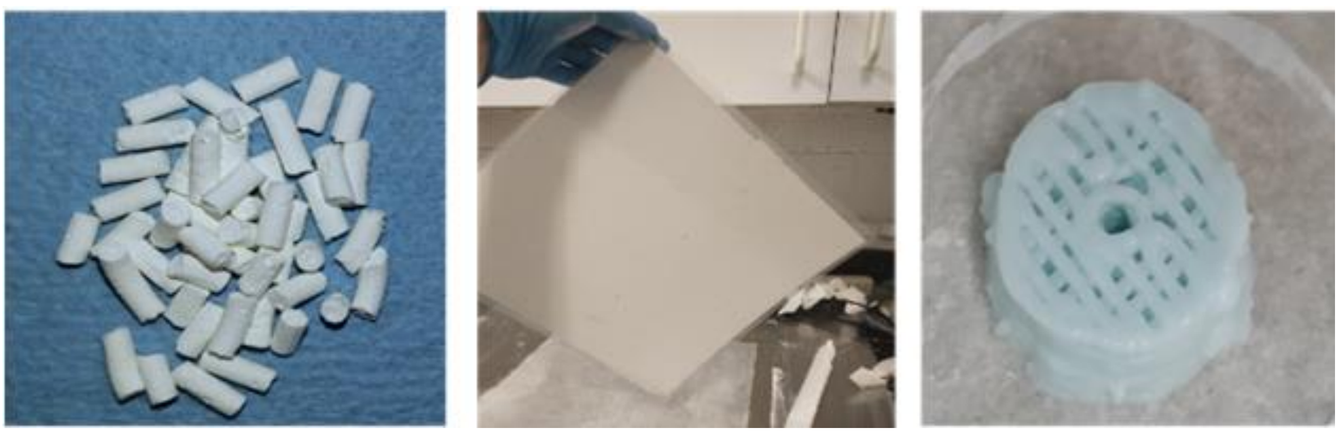


Source: GE Research, 2022

- **A new gas-solid contactor will be designed where the CO_2 sorbent is coated on the surface of the fins of a tube-in-plate heat exchanger**
- **The flow channels in these HEXs allows low pressure drop**
- **The intimate contact between the hot surface and the sorbent material increases the heat transfer rates and ensures rapid heating**

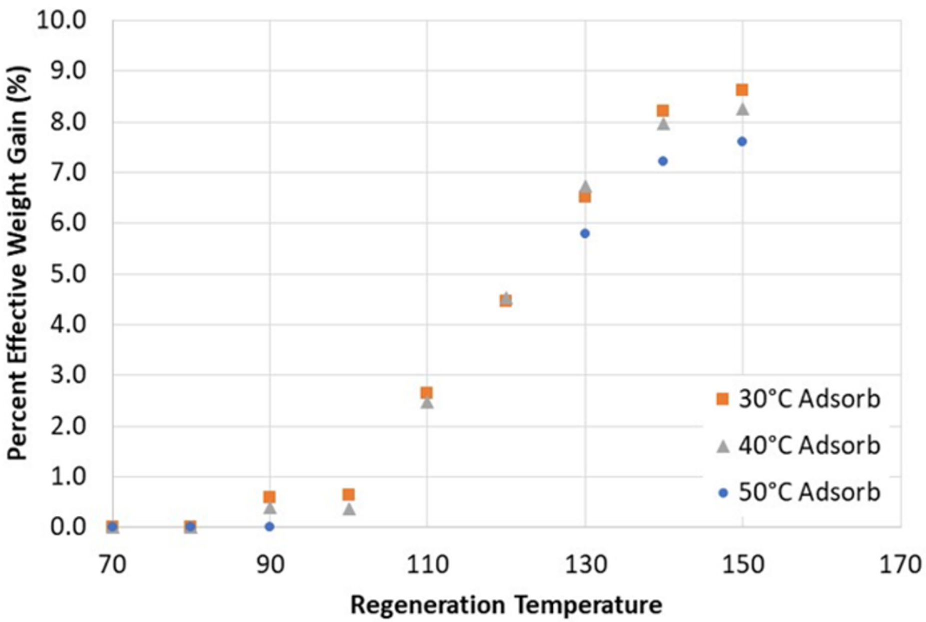
TDA's Sorbent for DAC

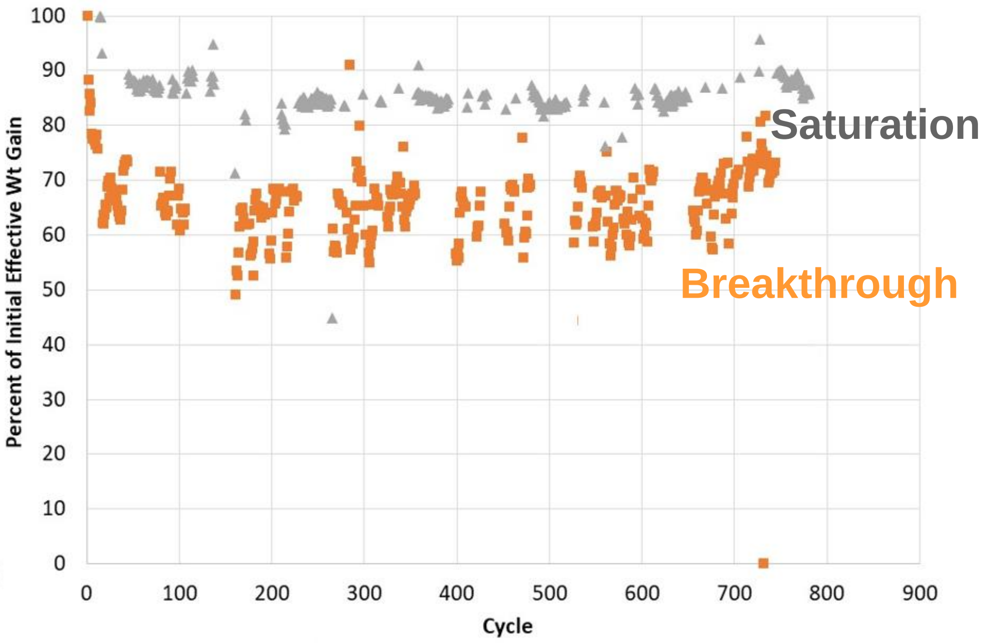
- **TDA has been developing a new polymer sorbent for DAC and life support applications (DE-SC-00020846, 80NSSC18C0135, N00178-18-C-8009)**
  - **Sorbent has very high CO_2 uptake in dilute gas streams (e.g., 400 ppm CO_2 in air; 2,500 ppm spacecraft cabin; up to 5,000 ppm in submarines)**
  - **The sorbent maintains its stability at high temperatures (up to $150^{o}C$)**
- **The sorbent has been prepared in the form of pellets, laminates and 3D printed monoliths; in this project it will be applied as a coating onto metal structures**
  - **GE Research will take the lead on the coating work**



Various forms of polymer sorbent: (left) pellets (middle) laminate and (right) 3D printed monolith

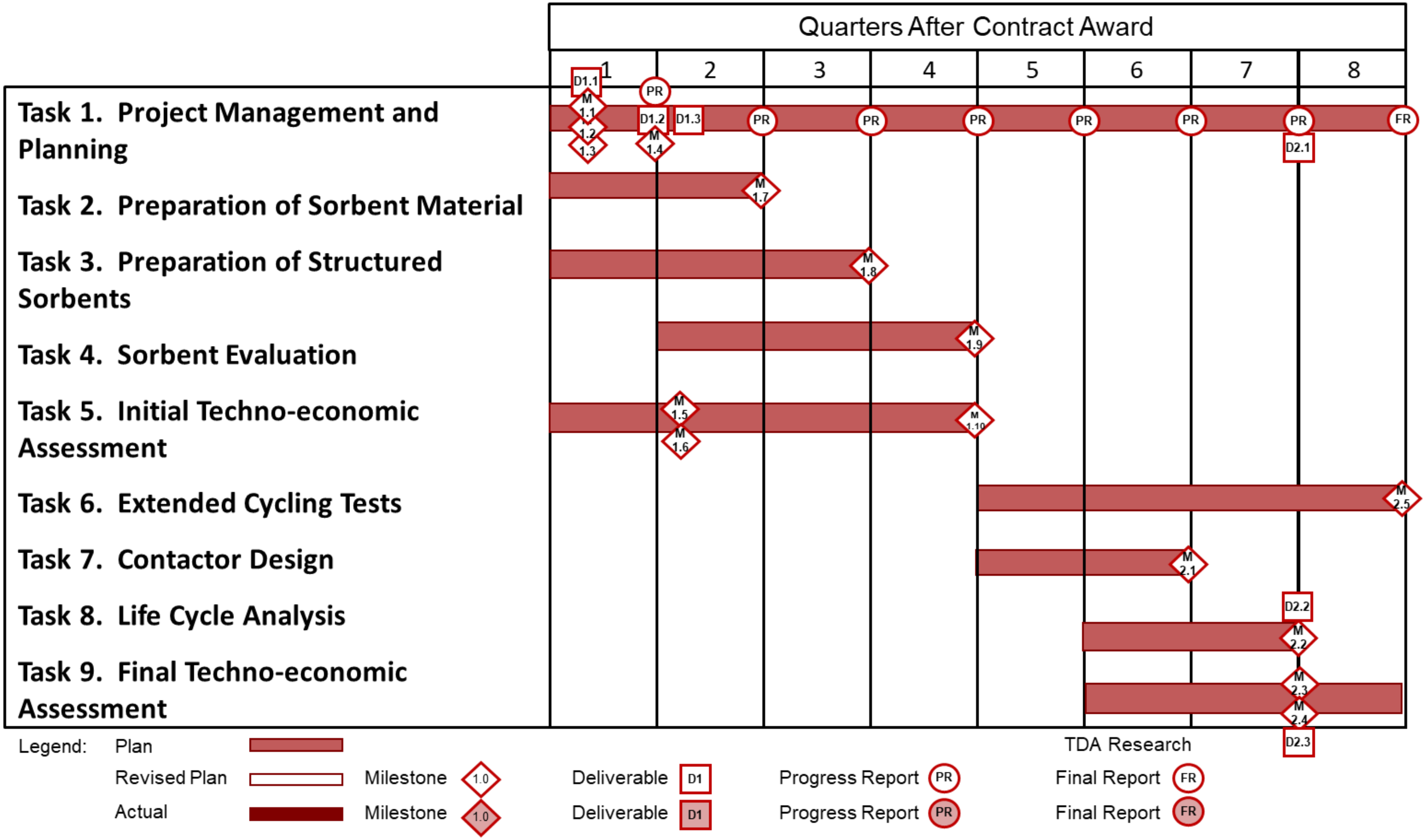
High Temperature Stability





- High stability under TSA/VTSA cycling
- No release of by-products at temperatures up to 150ºC
- High working capacity
  - Up to 9% wt. CO_2 uptake
- Stable operation for ~800 cycles under DAC conditions (over 10,000 cycles has been demonstrated for the Navy application)

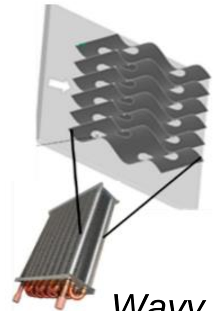
Project Tasks and Schedule



Preparation of Test Articles

- **Develop structured sorbents by applying sorbent/binder composites onto surfaces of heat exchanger plates**
- **Optimize binder formulation, sorbent coating thickness and porosity to improve CO_2 capacity/uptake kinetics and the adhesion and heat transfer performance**
- **Explore different methods for coating (e.g., spraying, dip coating)**
- **Evaluate different types of enhanced performance tube-in-plate structures: wavy fins, off-set fins, and grooved fins**
- **Coat coupons for bench scale performance testing**

Fin Types



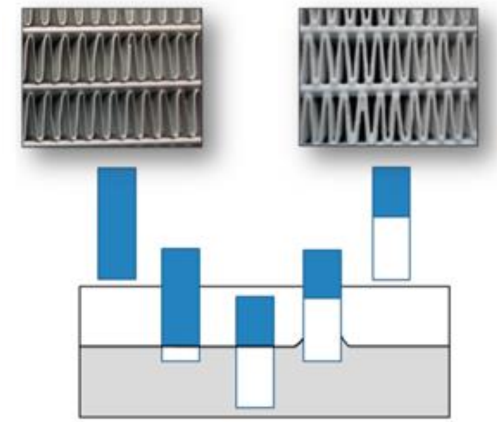
Wavy Fin

Off-set Fin

Grooved Fin

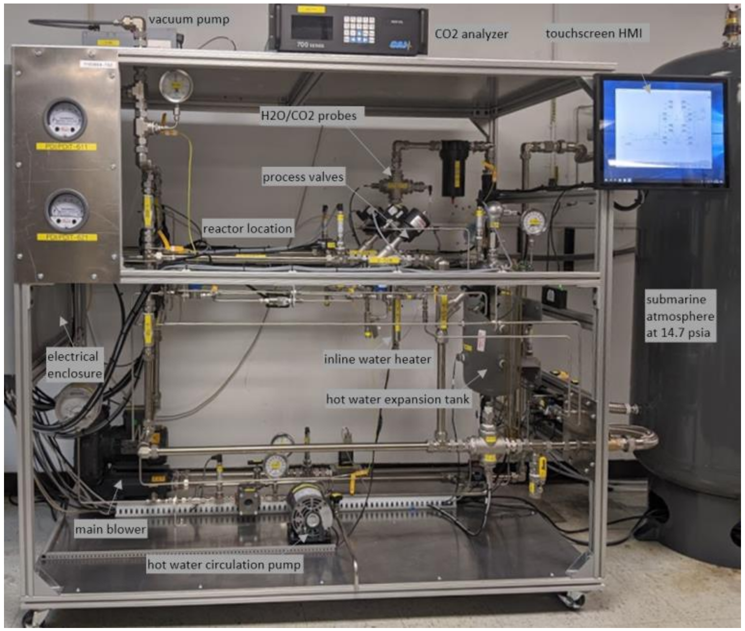
Coating Methods

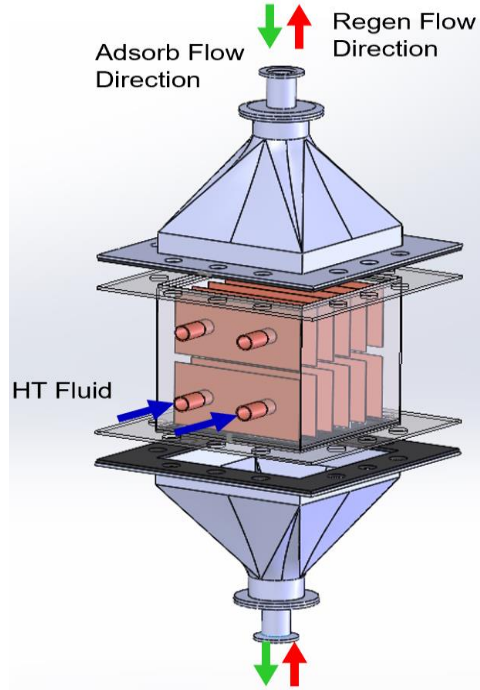
Dip coating

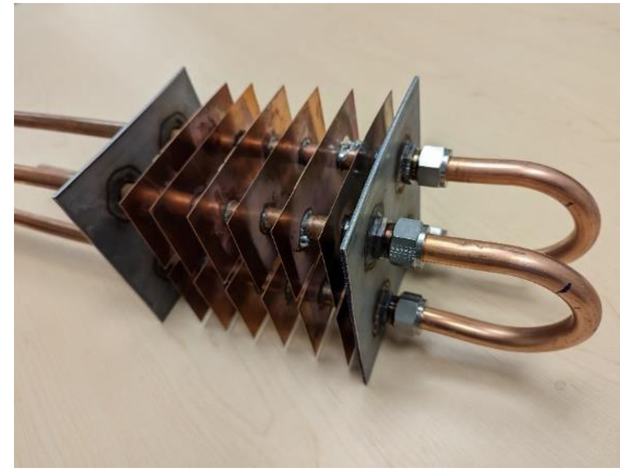


Spray coating

Evaluation of Coupons / Assemblies





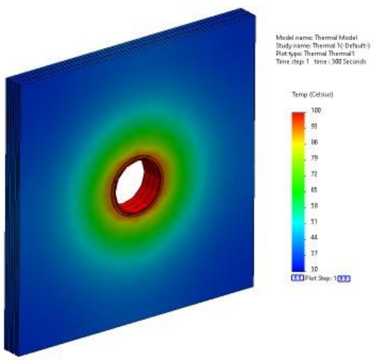


- **Initial tests will be carried out using isotherm equipment and thermogravimetric analyzer**
- **Testing of single/multiple coated coupons at bench-scale under representative conditions**
- **Inlet air T= 15-45^{o}C ; RH= 0-90%**
- **Ability to control HT fluid temperature**
- **Ability to run vacuum and steam sweep for regenerations**

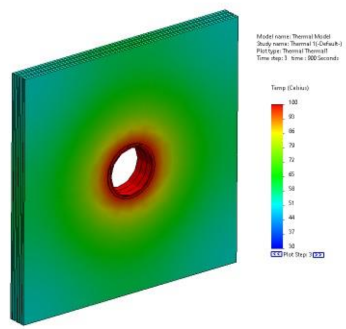
CFD Supported Design

- **Preliminary CFD results show that sorbent coated plates can be cycled in a relatively short duration**

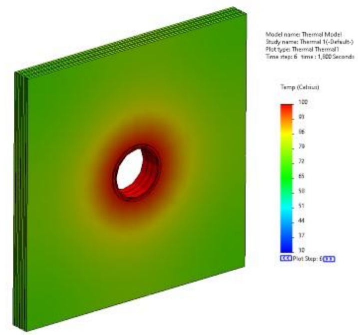
After 5 minutes



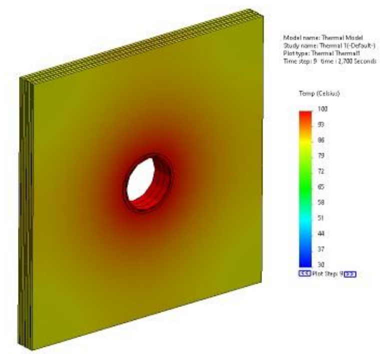
After 15 minutes



After 30 minutes



After 45 minutes



Critical Performance Metrics	Heating time Temperature uniformity Pressure drop Volume of module (bed size) Overall cost
Critical Design Variables	Fin spacing Fin material Fin height Bed height Tube dia – (flow rate of HEX fluid) Heat loss

Contactor Design / Process Design

- **Design of the gas-solid contactor**
  - 1,000,000 MTPY of CO_2 removal
- **Design the DAC process**
  - Operating Temperature
  - Use of vacuum, steam purge
  - Working Capacity of the Sorbent
- **Estimate cost (CAPEX)**
- **Estimate the consumable and utility requirements (OPEX)**
- **Complete a TEA based on DOE Guidelines**
- **Complete Life Cycle Analysis**