Development of Life Support Adsorption Technologies for Future Exploration Spacecraft

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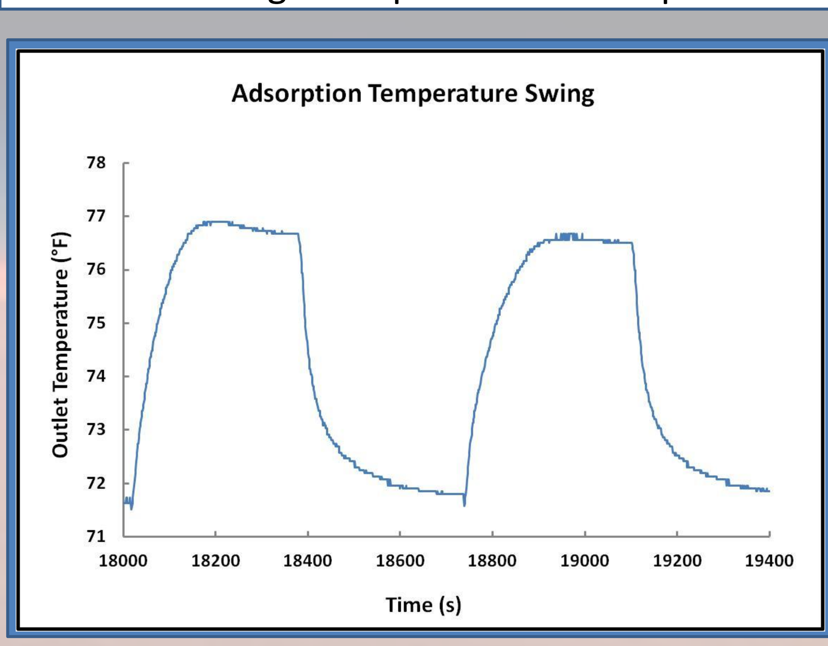
Introduction

The removal of humidity from manned spacecraft is critical to the success of long-term missions. High humidity levels yield condensation inside the spacecraft, damaging its critical systems. The moisture collected can also be recycled, reducing the frequency of resupply. Currently utilized by the International Space Station, the Environmental Control and Life Support System (ECLSS), recycles H_2O using packed beds of adsorbent molecular sieves. Although these molecular sieves effectively adsorb H_2O, increased efficiency is necessary if a closed-loop life support system is to be developed. This work tests adsorbent materials for resistance to attrition for future life support systems. This work tests a new packed bed design that exploits the temperature swing of sorbent materials during adsorption and desorption.



Adsorption

- Removes H_2O from air
- Releases heat into system
- Adsorption rate is inversely proportional to temperature

Desorption

- Releases H_2O from packed bed of adsorbents
- Removes heat from system
- Desorption rate is directly proportional to temperature

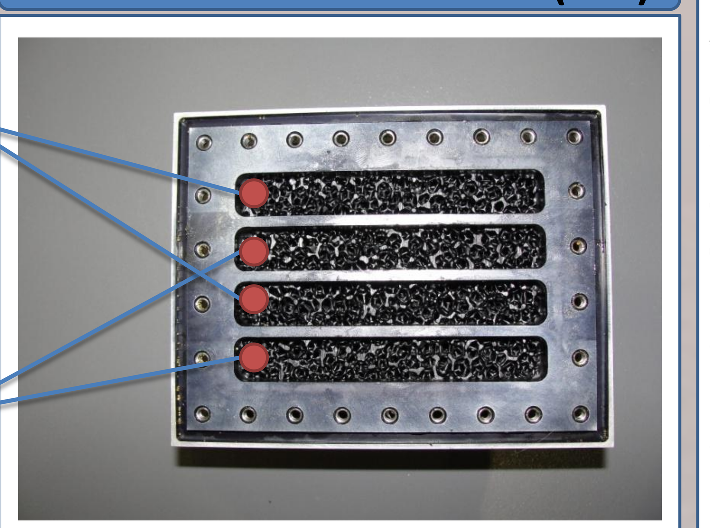
Efficiency of humidity removal increases if air heat can be added or removed from system

Transfer heat from adsorption bed to desorption bed

Isothermal Bulk Desiccant (IBD)

Flow Path A

Flow Path B



- Flow path A adsorbs while flow path B desorbs
- Reticulated aluminum foam fills each bed to enhance heat transfer
- Heat transfers between flow paths
- Adsorbent particles packed in the pores of the aluminum foam

Calculations

$$Humidity\left(\frac{g}{m^3}\right) = 216 \times \frac{\left[\left(6.1094 \times e^{\left|\frac{17.625T}{T+243.04}\right|}\right)\left(100 \times \left[\frac{112 - .1T + T_D}{112 + .9T}\right]^8\right)\right]}{T + 273.1}$$

Variables: Dewpoint Temperature-T_D
Air Temperature- T

Used to calculate humidity before and after Adsorbent Bed and determine quantity of adsorbed H_2O

Objectives

Improve the capacity of sorbents and efficiency of adsorption while minimizing system power requirements by utilizing the heat of adsorption.

Demonstrate a proof of concept for the Isothermal Bulk Desiccant, and the zeolite coated Isothermal Bulk Desiccant.

Reduce the total mass of the humidity removal system and improve reliability to reduce future mission cost and risk.

Methodology

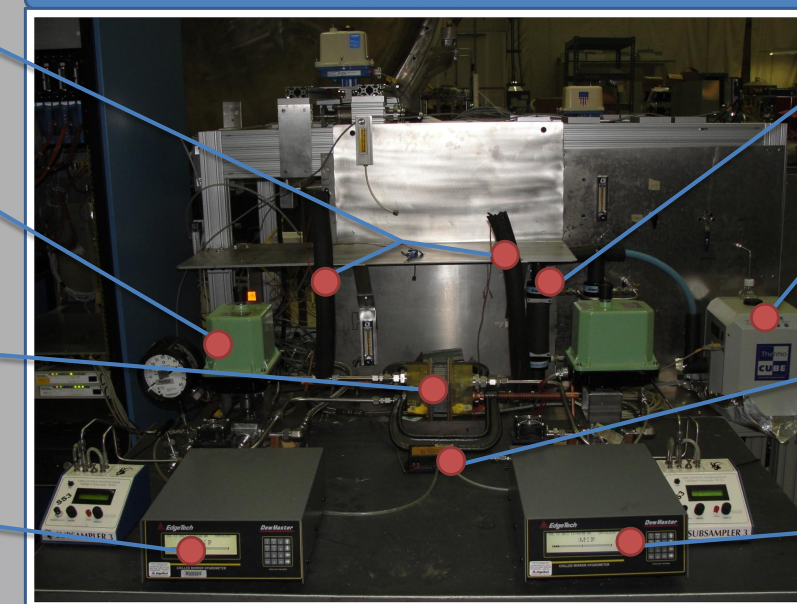
Test Stand

Thermocouples
Measures inlet and outlet temperature of the adsorbent bed

4 way valve
Changes flow path of system

Test Article
Holds bed packed with adsorbents

Dew Point Sensor
Measures dew point of air stream after the packed bed



Membranes
Humidifies inlet air to the system

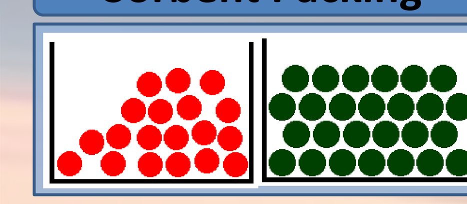
Thermocube
Chills water fed to humidifying membranes.

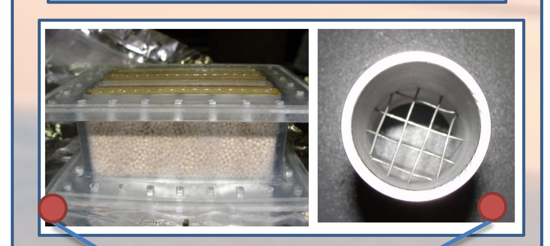
ΔP Sensor
Measures pressure drop across packed bed

Dew Point Sensor
Measures dew point of inlet air stream

Sorbent Packing

Conventional Packing
- Weight of particles on the top prevents efficient settling at the bottom
- Packing density is inconsistent
- Higher attrition to particles during adsorption and expansion





Packed Bed

Snowstorm Apparatus

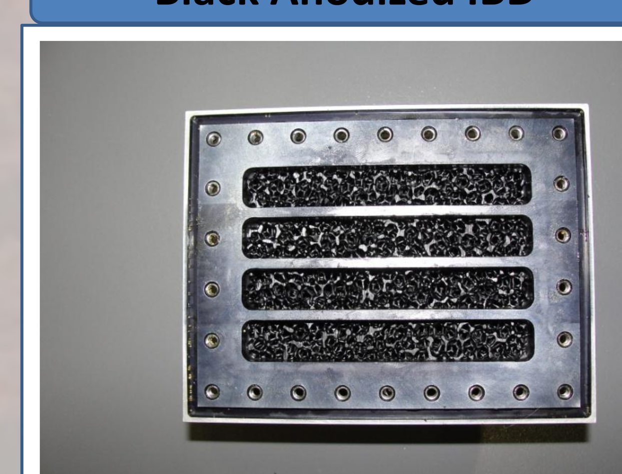
Snowstorm Packing
- Packed slowly on vibration table so that each layer of particles can reach most stable position before covered by particles
- Wires in snowstorm apparatus help to evenly disperse the particles
- Packed beds are more uniform

Isolated Adsorption Bed

- Simulates an isolated adsorption bed without heat transfer between beds.
- Packed with activated zeolite 13x using snowstorm technique.
- Tested in 6 minute Adsorption/Desorption cycles.
- Temperature and Dew point data collected

Black Anodized IBD

- Packed with zeolite 13x using snowstorm technique.
- Tested in 6 minute Adsorption/Desorption cycles.
- Air flow-rates held constant with the control case
- Temperature and Dew point data collected

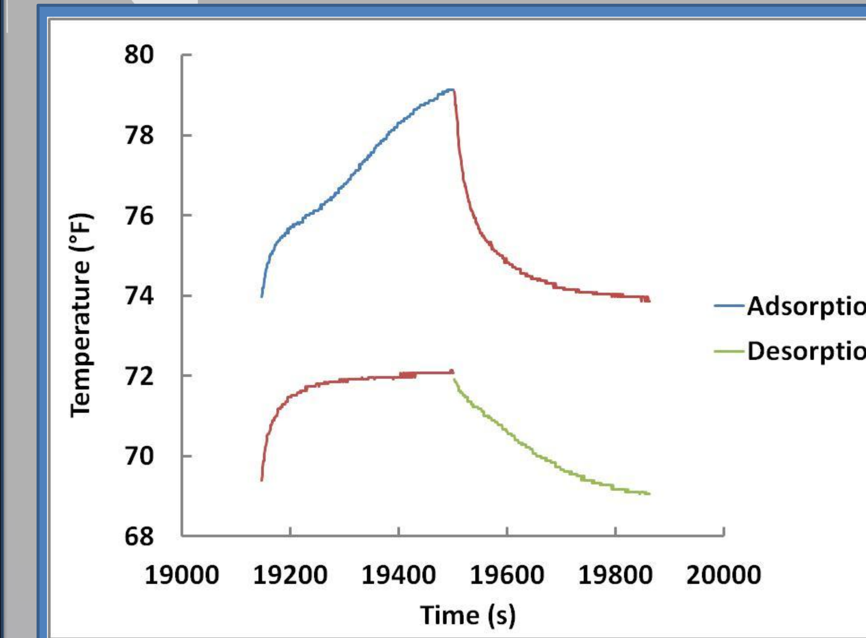


Zeolite Coated IBD

- Reticulated aluminum foam fills each bed
- Aluminum foam is coated with zeolite 13x
- Tested in 6 minute adsorption/desorption cycles.
- Air flow-rates held constant with the control case
- Temperature and dew point data collected.

Results

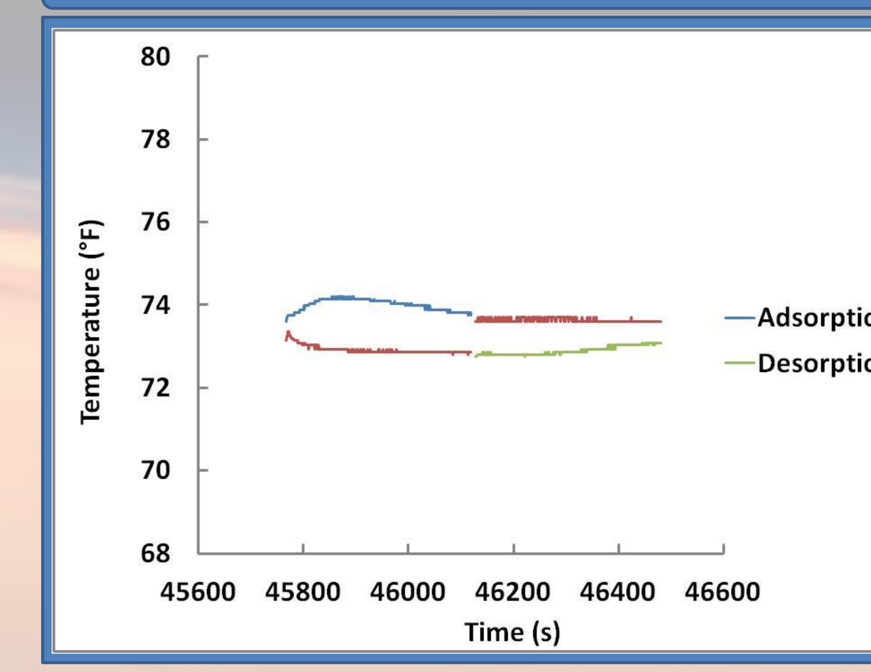
Isolated Adsorption Bed



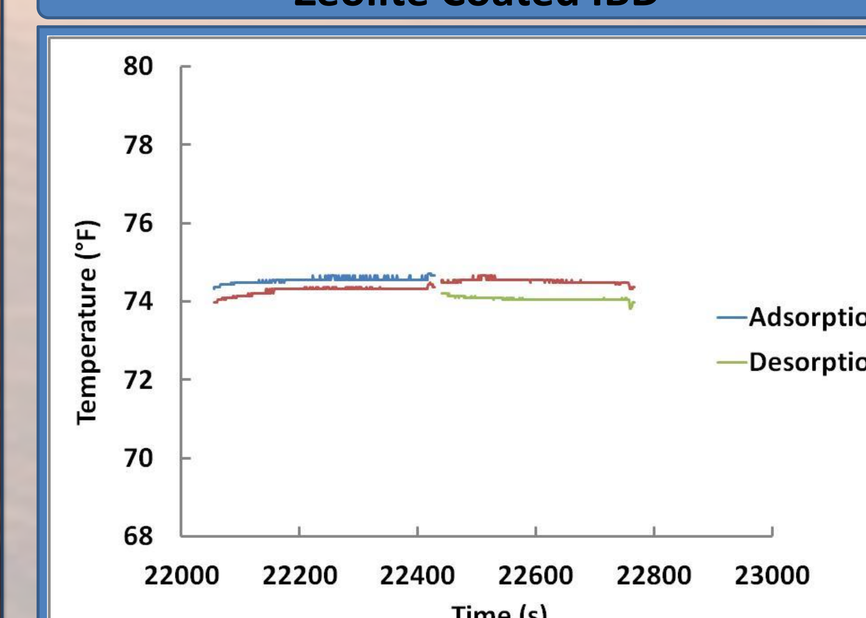
- The Isolated adsorption bed was tested for 12 hours.
- Data is consistent with theoretical model
- During adsorption temperature increases by 5°F
- During desorption temperature decreases by 3°F

Black Anodized IBD

- The IBD test article was tested for 12 hours.
- Temperature data is consistent for each cycle once the system reaches equilibrium.
- The temperature increases by less than 1°F during adsorption
- The temperature decreases by less than 1°F during desorption.



Zeolite Coated IBD



- The zeolite coated IBD was tested for 12 hours.
- Temperature data is consistent for each cycle once the system reaches equilibrium.
- The temperature increases by less than 1°F during adsorption
- The temperature decreases by less than 1°F during desorption.

Conclusions

The heat generated by temperature swings during adsorption was effectively transferred between beds within IBD. Desorption does not occur at the same rate as adsorption, but increasing the flowrate of air to the desorbing beds will allow for longer adsorption cycles.

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