Four Bed Carbon Dioxide Scrubber Engineering Development Unit Cabin Air Inlet Testing

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FBCO2 Scrubber 2022-2023 Outline

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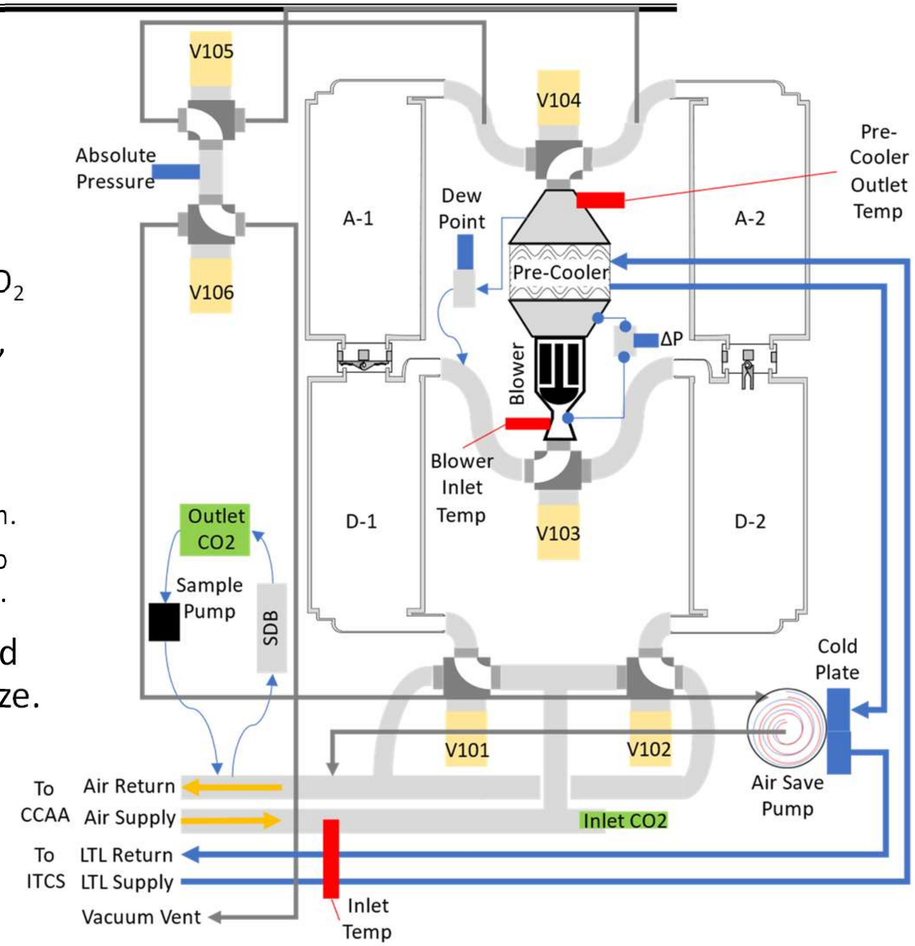
Introduction

- Four Bed Carbon Dioxide Scrubber
  - ISS CO_2 Removal Technology Demonstration
  - Launched August 10, 2021
  - Activated onboard ISS September 2021
  - Total run time of 1.5 years on ~ June 4, 2023

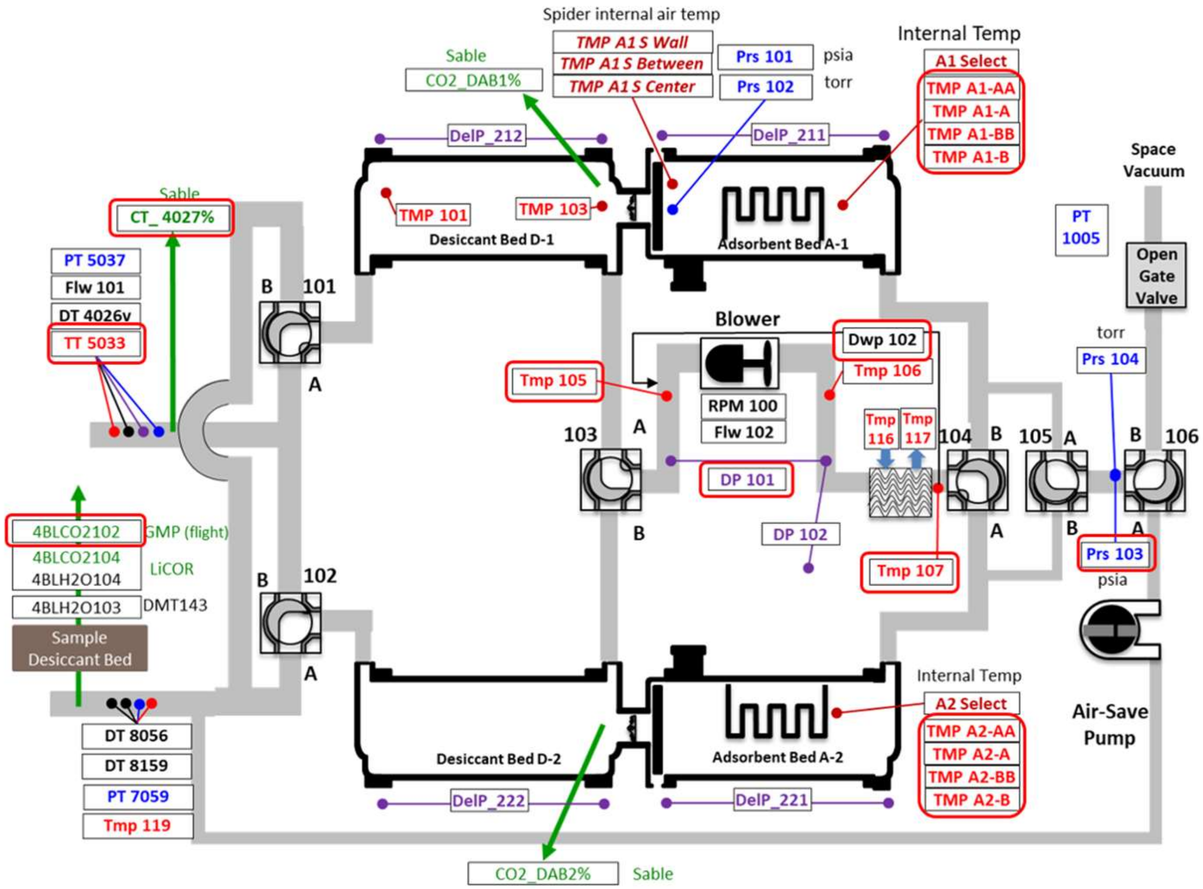
Operation of the FBCO2 scrubber

- Operations are split into half-cycles (HC) A and B
  - These are mirrors of each other. Schematic shows HC A
- Tracing the flow path through system:

1. Air is drawn from cabin air system (CCAA). Air contains O_2/N_2, H_2O, and CO_2
2. Air flow path is supply duct, V101, bed D-1, V103, blower, precooler, V104, bed A-2, bed D-2, V102, return duct
   1. In this path, D-1 is scrubbing H_2O, but CO_2 and O_2/N_2 pass.
   2. Then, A-2 is scrubbing CO_2, but O_2/N_2 pass.
   3. Finally, the air passing through bed D-2 picks up H_2O and returns it to the cabin.
   4. While this is happening, A-1 is heated and connected to vacuum to vent CO_2 to space through V105 and V106. This heat will be used to desorb D-1 next cycle.
3. Half-cycle time is part of design process and can be adjusted based on volume of air flow, humidity at supply, heating rate, and bed size.
4. At end of HC A transitioning to HC B, all 6 valves rotate.
   1. V106 links the Air Save Pump to the now-desorbing bed A-2 to recover O_2/N_2 trapped in voids of ducts and bed.
   2. Once air save is complete, A-2 is linked to space vacuum to vent CO_2



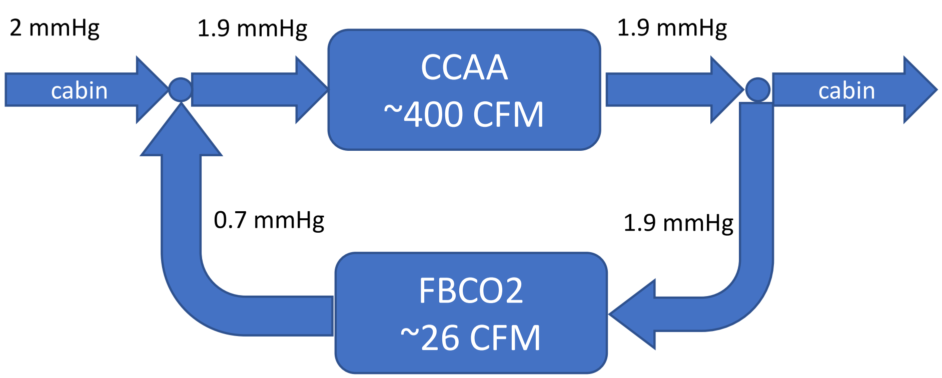
FBCO2 Scrubber Engineering Development Unit



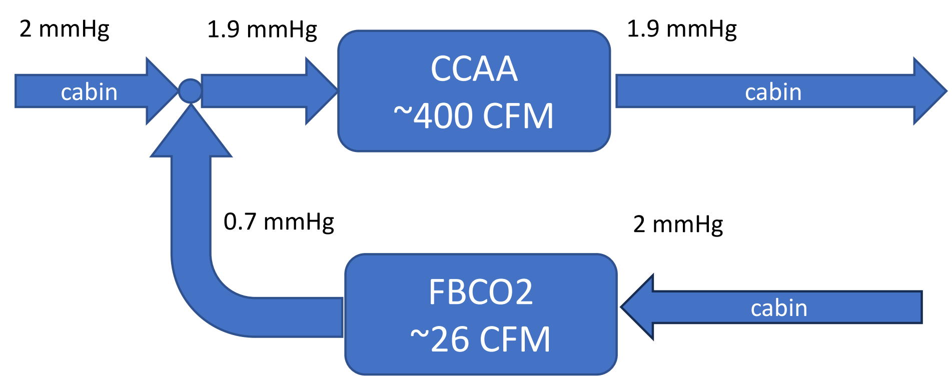
- Red boxes indicate system sensors retained on the flight system
- Abundance of sensors allows for greater visibility into the physics of the adsorption process
- Sampling CO2 sorbent bed effluent provides CO2 sorbent bed breakthrough
- Flight system measures only system CO2 effluent after the desiccant bed has significantly altered the breakthrough curve

Cabin Air Inlet Test Conditions and Configuration

	Air Flow Rate, SCFM	Total Cycle Time, Min	Inlet Temp., degF	Inlet Dewpoint, degF	P/C In H2O Temp., degF	P/C In H2O flow, GPM	Heater Setpoint, degF
Cabin Air Inlet Test	24.4	160	75	54	49	0.4	408
Baseline Conditions	24.4	160	56	50	49	0.4	408



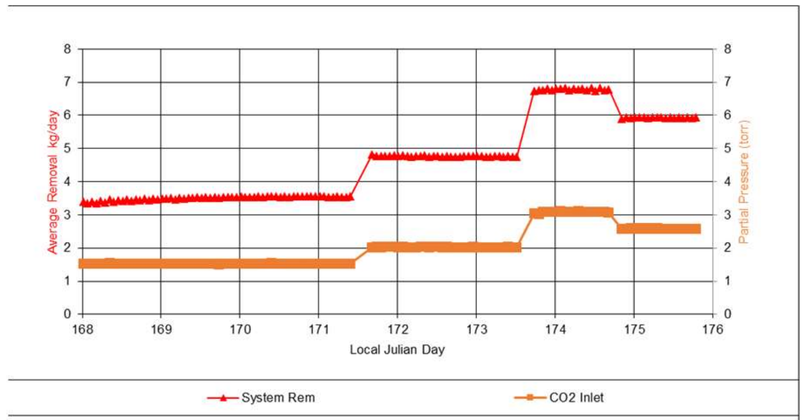
Baseline Configuration

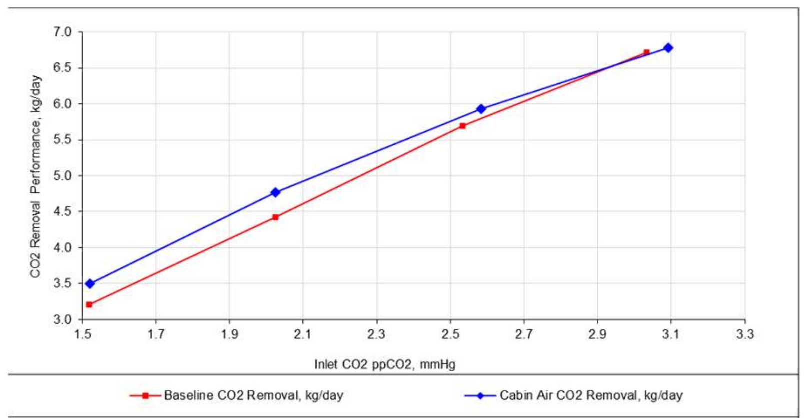


Cabin Air Inlet Configuration

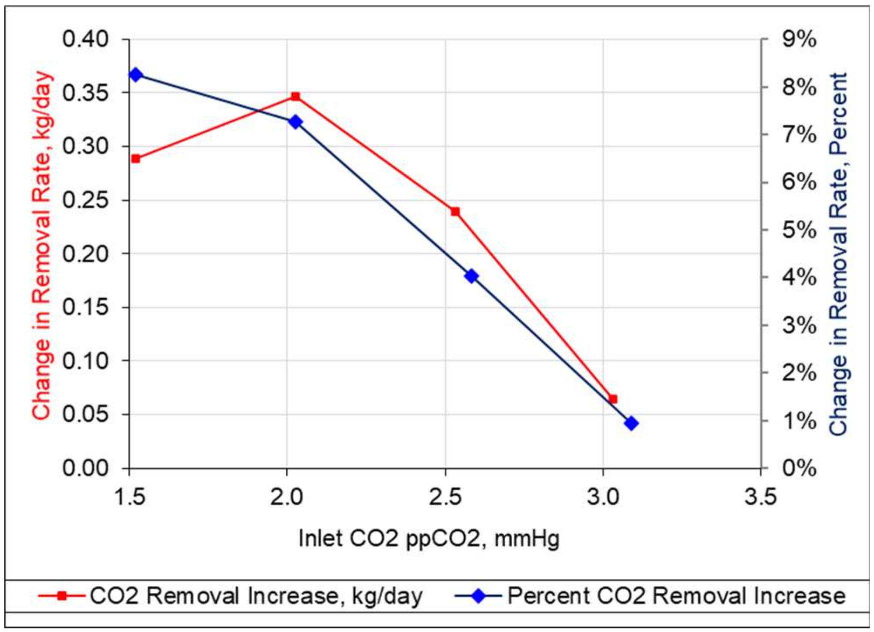
Impacts of Increased Temperature and Humidity

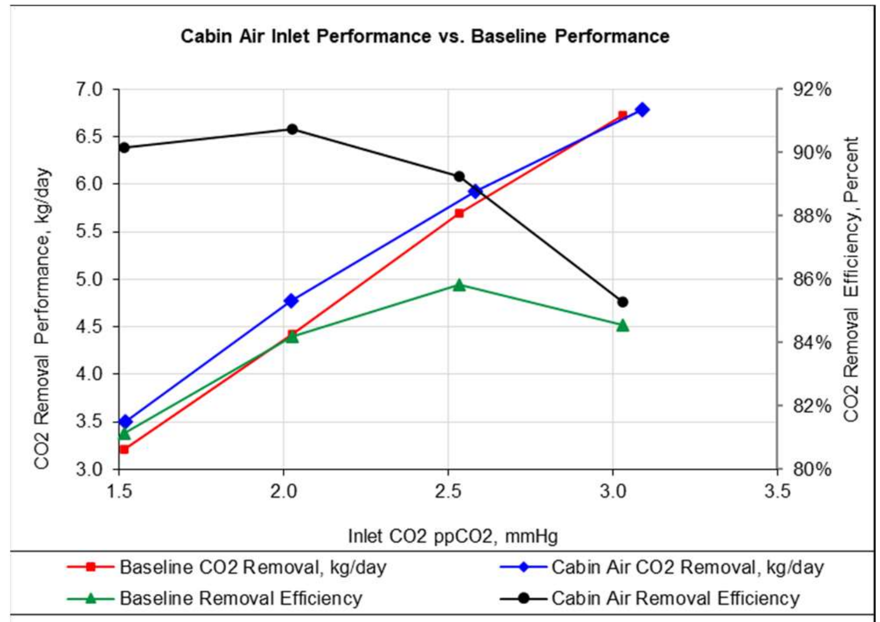
- Top plot shows timeline of CO_2 inlet partial pressure and CO_2 removal rates over the test series
- Bottom plot shows change in CO_2 removal rate and efficiency for various inlet CO_2 partial pressures
- Increased CO_2 removal rate due to reduction in desiccant bed CO_2 holdup via:
    1. Increased inlet temperature (immediate impact)
    2. Increased humidity (gradual impact)





Overall Results Summary

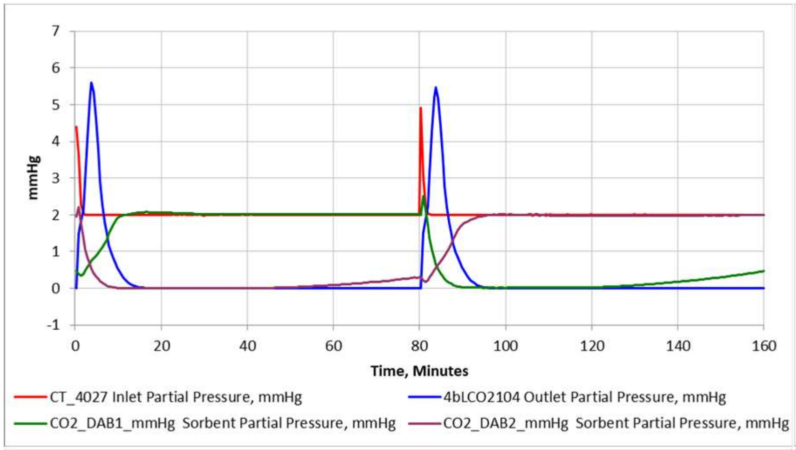


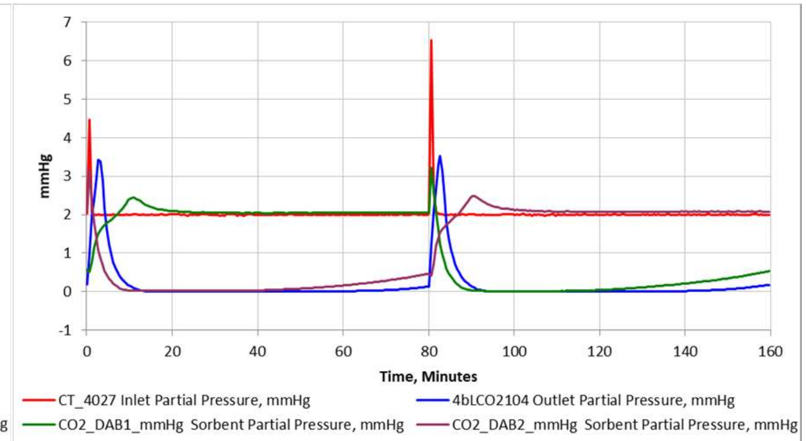


Graphical performance results from baseline and cabin air inlet test points

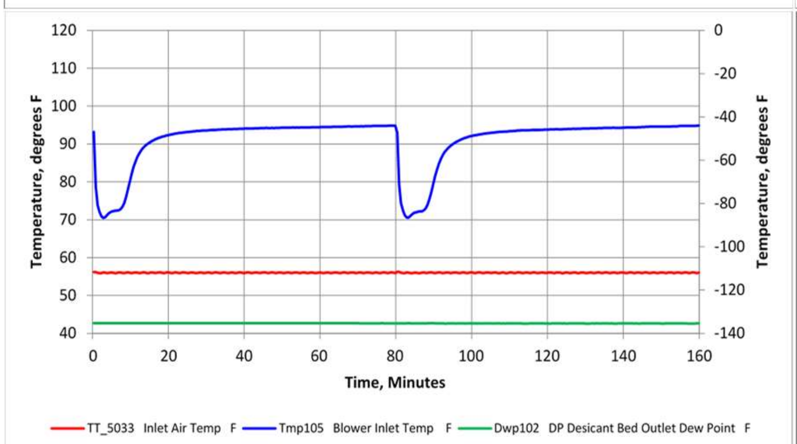
Transient data for 2 torr inlet ppCO2

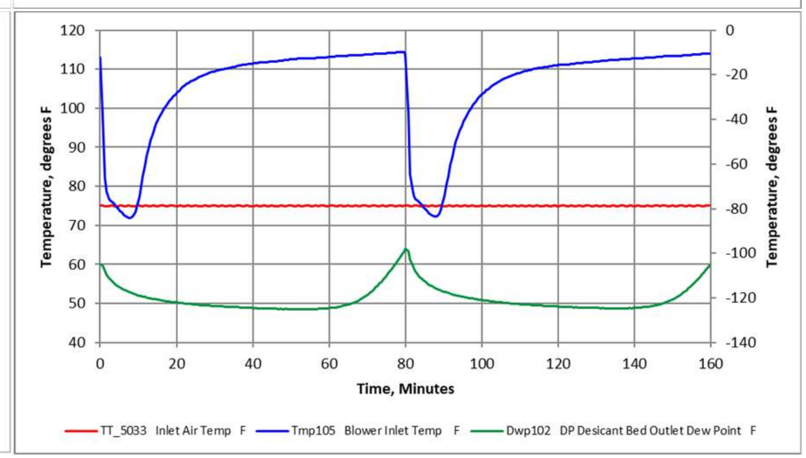
Inlet (red), system outlet (blue), and sorbent outlet CO_2 partial pressures (green and brown) at 2 torr inlet





Desiccant bed inlet (red) and outlet temperatures (blue) and outlet dewpoint (green) at 2 torr inlet



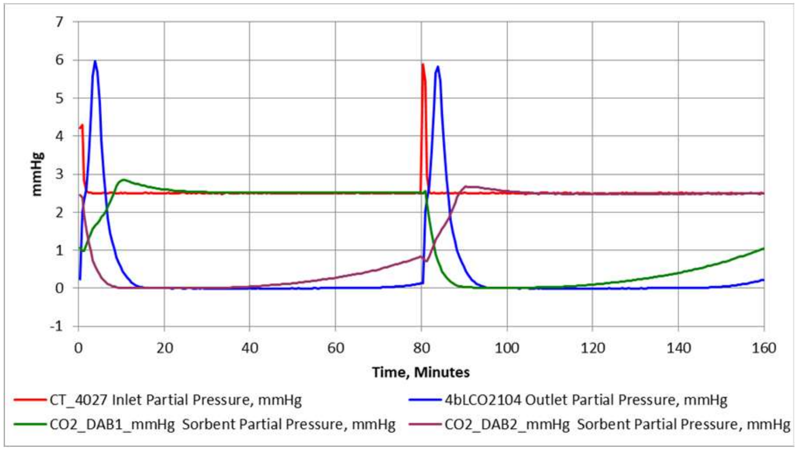


Baseline air inlet

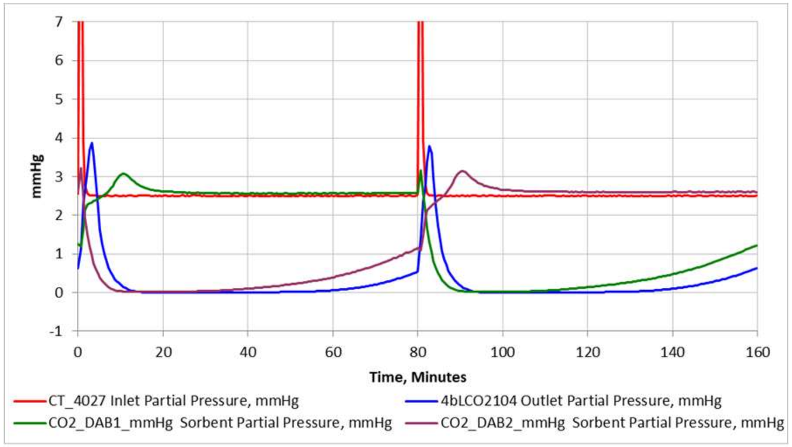
Cabin air inlet

Transient data for 2.5 torr inlet ppCO2

Inlet (red), system outlet (blue), and sorbent outlet CO_2 partial pressures (green and brown) at 2 torr inlet

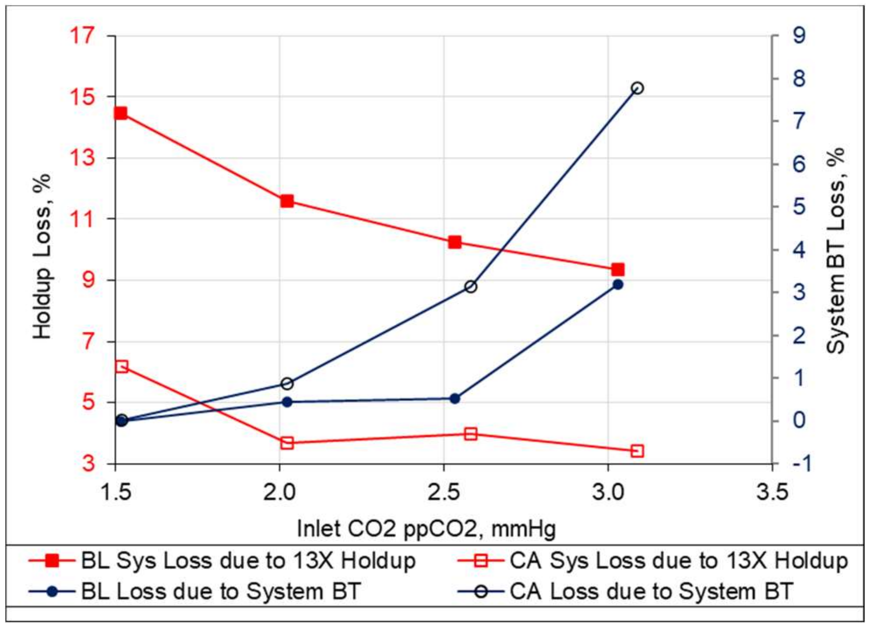


Baseline air inlet



Cabin air inlet

Baseline and cabin air percent holdup and breakthrough losses



Baseline (BL) and cabin air (CA) percent holdup and system breakthrough losses as a function of inlet pp CO_2

Impacts of de-integration from the CCAA on removal rate

Baseline Inlet ppCO2, mmHg	Baseline CO2 Removal, kg/day	Baseline Removal Efficiency	Cabin Air Inlet ppCO2, mmHg	Cabin Air CO2 Removal, kg/day	Cabin Air Removal Efficiency	CO2 Removal Increase, kg/day	Percent CO2 Removal Increase
1.52	3.21	81%	1.52	3.50	90%	0.29	8.3%
2.03	4.42	84%	2.02	4.77	91%	0.35	7.3%
2.53	5.69	86%	2.58	5.93	89%	0.24	4.0%
3.03	6.72	85%	3.09	6.78	85%	0.06	0.9%

Baseline Inlet ppCO2, mmHg	Baseline CO_2 Removal, kg/day	Cabin Air Inlet ppCO2, mmHg	Predicted Cabin Air CO_2 Removal, kg/day	Percent CO_2 Removal Increase
1.52	3.21	1.58	3.65	13.7%
2.03	4.42	2.12	4.97	12.5%
2.53	5.69	2.64	6.18	8.6%
3.03	6.72	3.16	7.08	5.4%

De-integration of the FBCO2 Scrubber inlet air with the CCAA would also eliminate flow rate limitations due to:

- pressure drop associated with the ducting from the CCAA to the FBCO2 inlet
- competition of the Carbon Dioxide Removal Assembly (CDRA) for the same CCAA air supply

Conclusions and Recommendations

- Further investigation of using cabin air as the inlet to the FBCO2 Scrubber is warranted based on the results shown
- The current test series should be repeated with Cabin Air inlet ppCO2 values based on dilution calculations
- The test duration should be extended to determine if increased desiccant bed water vapor breakthrough will occur under these inlet conditions
- If the extended test series proves successful, this operational configuration should be considered as part of the ISS FBCO2 Scrubber Technology demonstration