Status of the Four Bed Carbon Dioxide Scrubber ISS Technology Demonstration 2022-2023

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FBCO2 Scrubber 2022-2023 Outline

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- FBCO2 scrubber performance

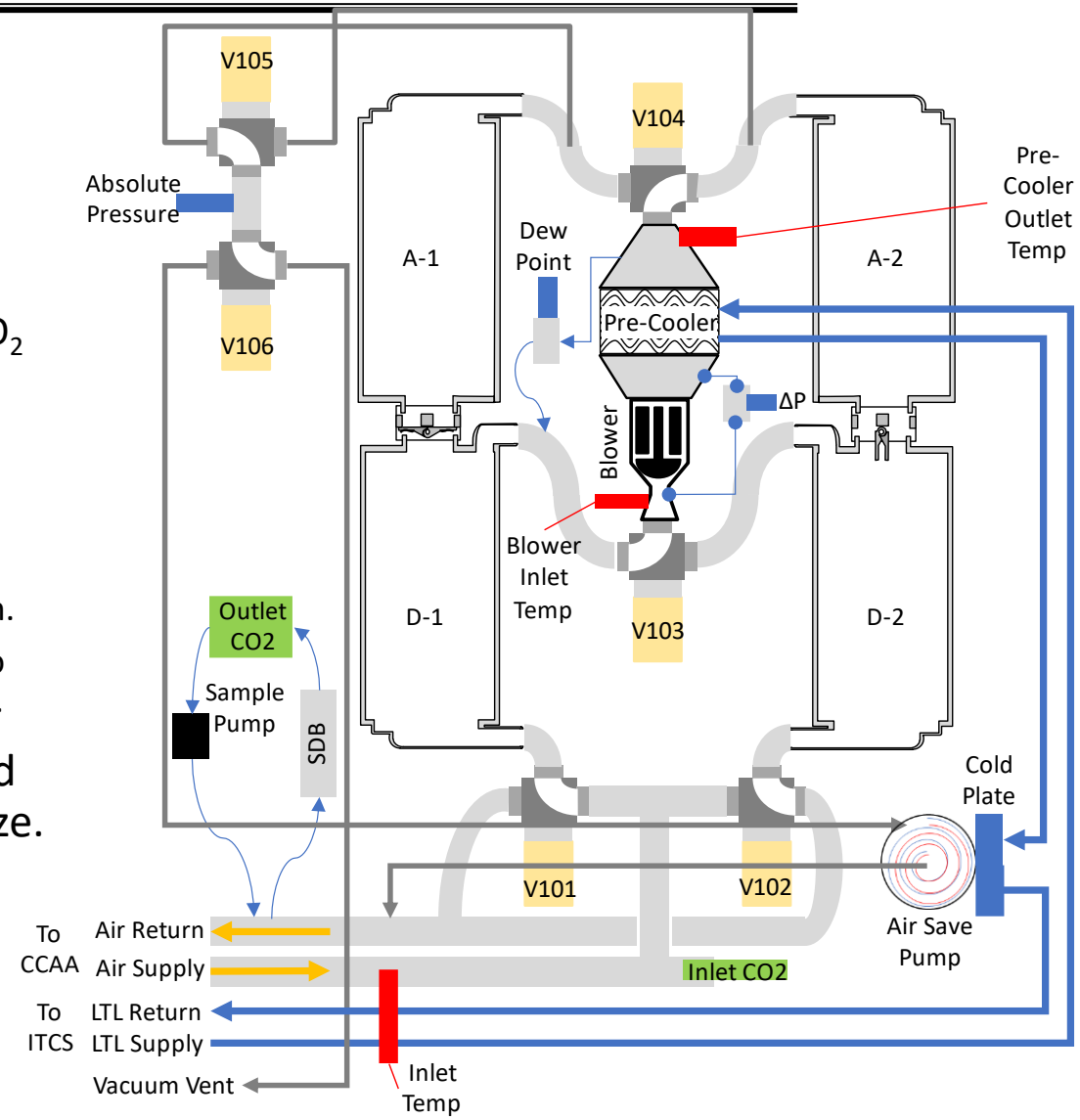
Introduction

- 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

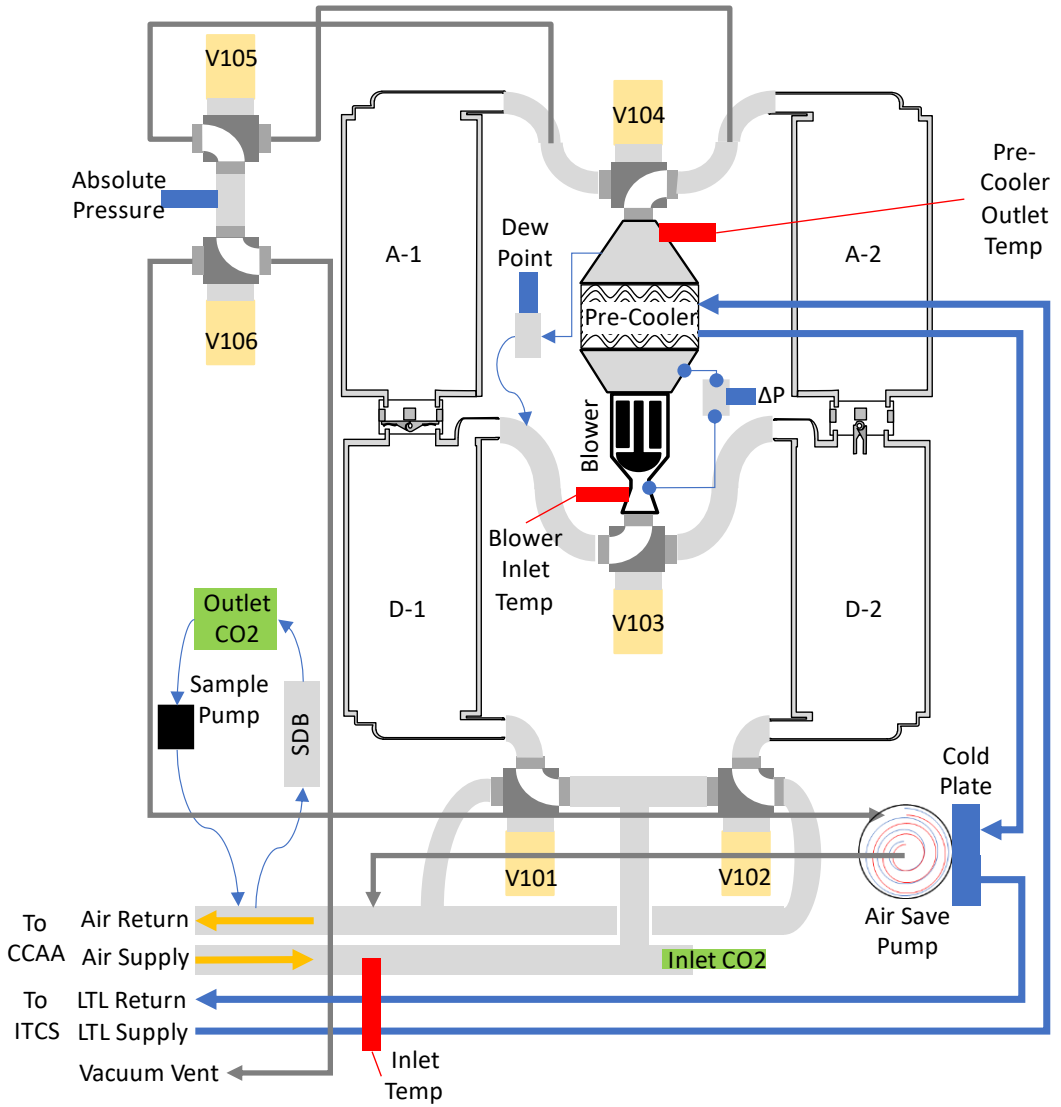
- Operations are split into half-cycles (HC) A and B
  - These are mirrors of each other. Schematic shows HC A
- Tracing the flow path through system:

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

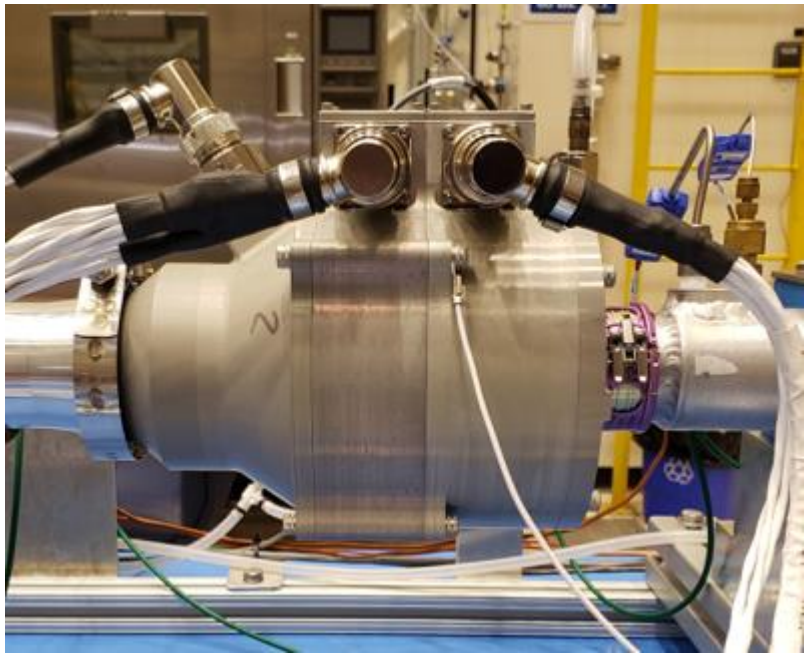


Characteristics relative to ISS CDRA

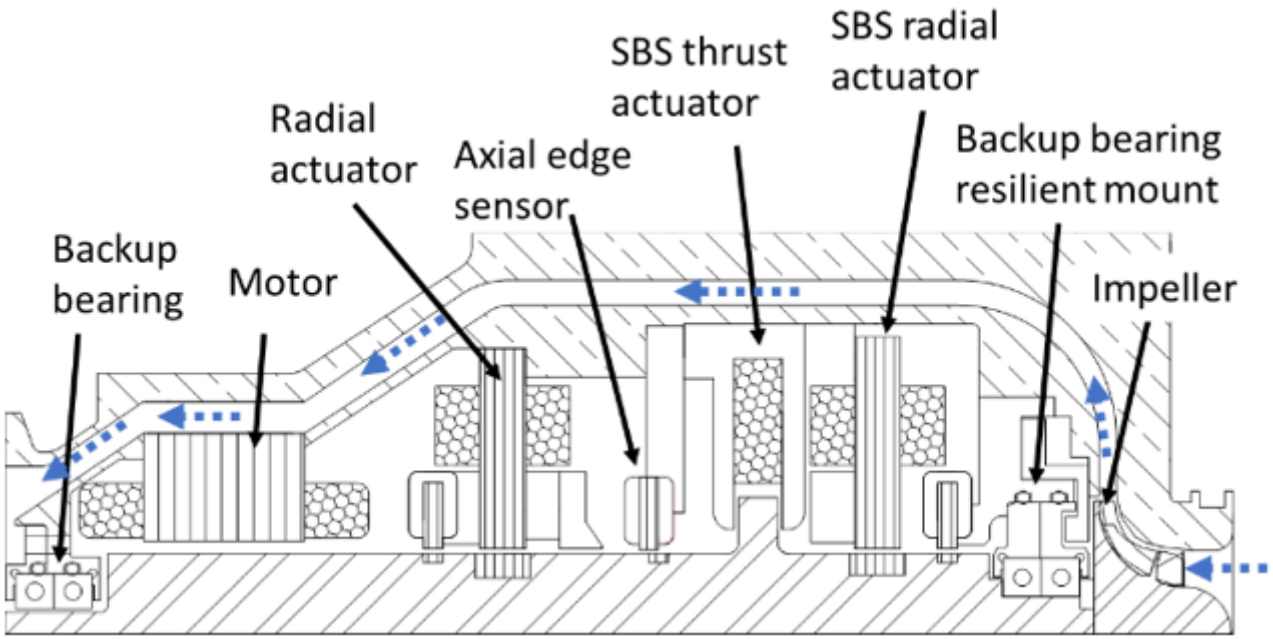
- 6 valves
  - New valves, same flow paths
  - Bleed port allows gentle repress
- 8 sensors
  - Similar T, P measurements
  - Direct measurement of inlet and outlet CO_2 %
  - Direct measurement of dew point after desiccant beds
  - Direct measurement of blower dP
- Similar functional components but new hardware in most places
  - Previously used heritage air blower
  - Currently using magnetically levitated blower (will provide higher flowrates)



Calnetix magnetically levitated blower



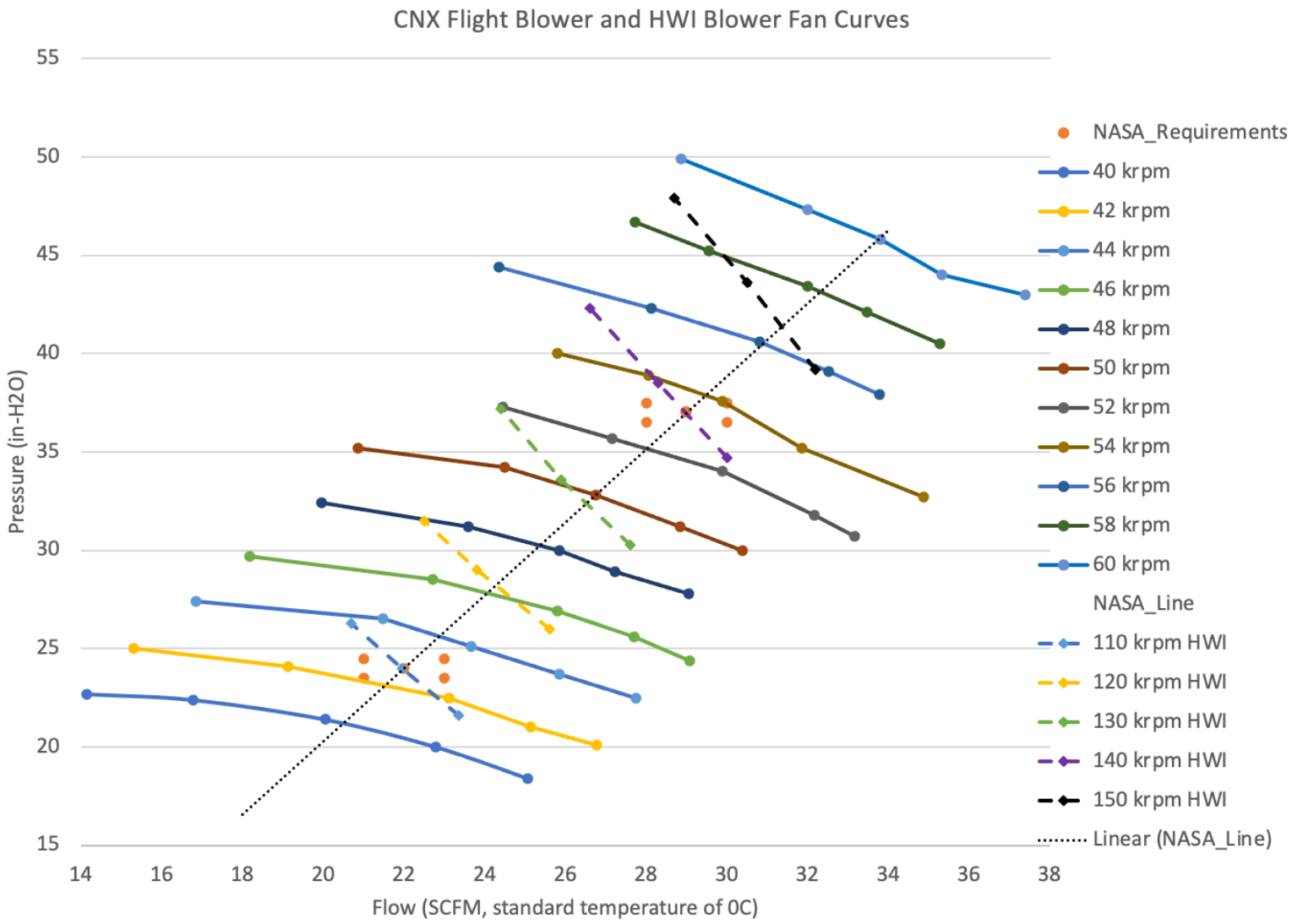
Calnetix magnetically levitated blower for FBCO2. Calnetix Blower overview. (a) Layout of Calnetix blower highlighting major components and its airflow path and (b) an image of the blower installed into the performance test stand.



Calnetix blower installation and other activities

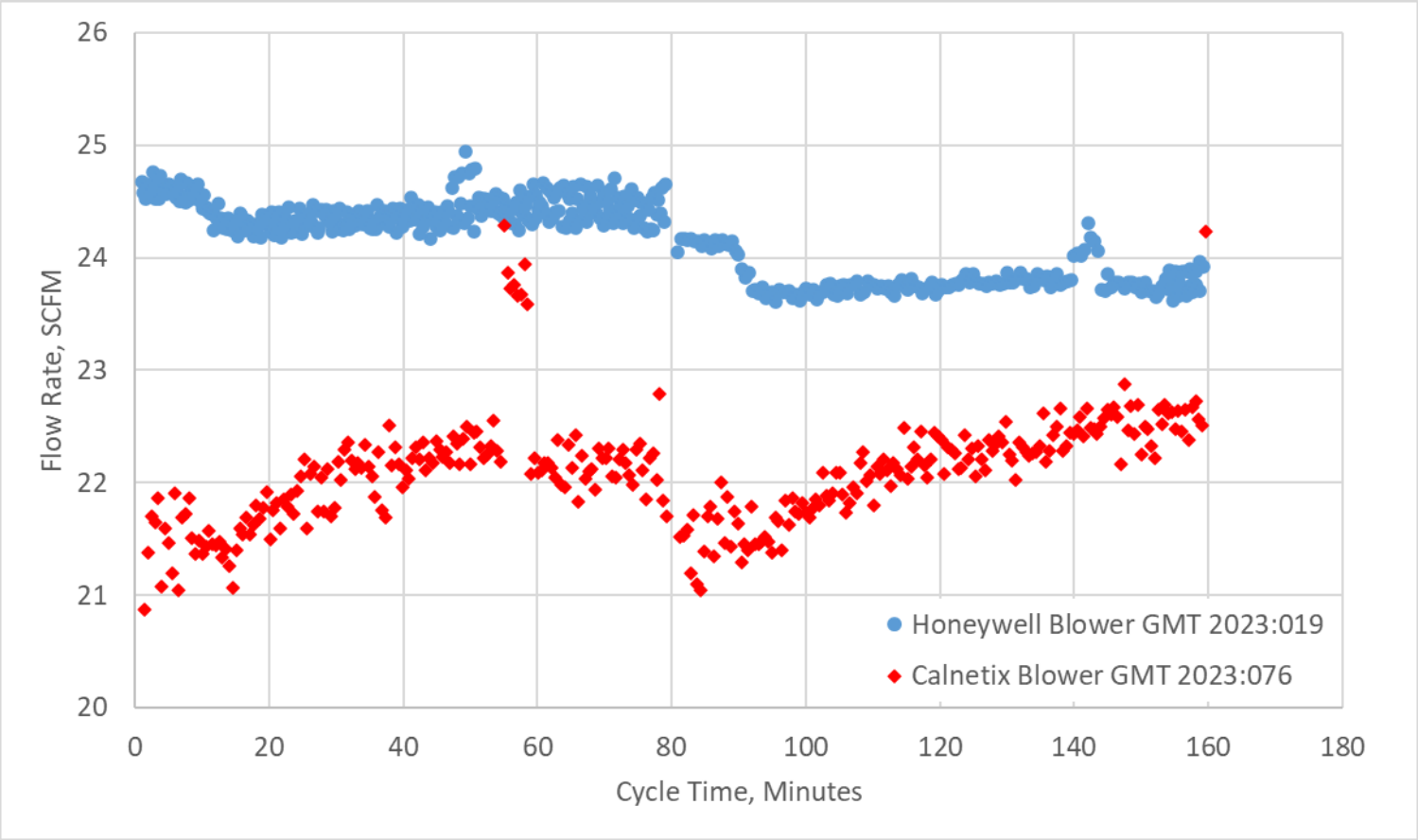
- Calnetix blower installation 2/13 and 2/15/2023
  - Some software errors and faults encountered, corrections/workarounds initiated
  - Initially rpm limited to 54k
  - Increased to 56k on 5/18/2023
- Acoustics blanket installation and acoustics measurements 2/15/2023
  - Continuous operation authorized for 56k and 58.5k
  - Additional measurements recommended for 60k operation
- Rack slider mount installation 2/15/2023

Performance of the Calnetix blower



- Overall Calnetix blower and Honeywell blower performance.
- Beige dots are NASA requirements;
- Solid lines connect CNX blower test points
- Dashed lines connect HWI blower test points.
- Black dotted diagonal line passing through all blower curves approximates the FBCO2 system differential pressure drop

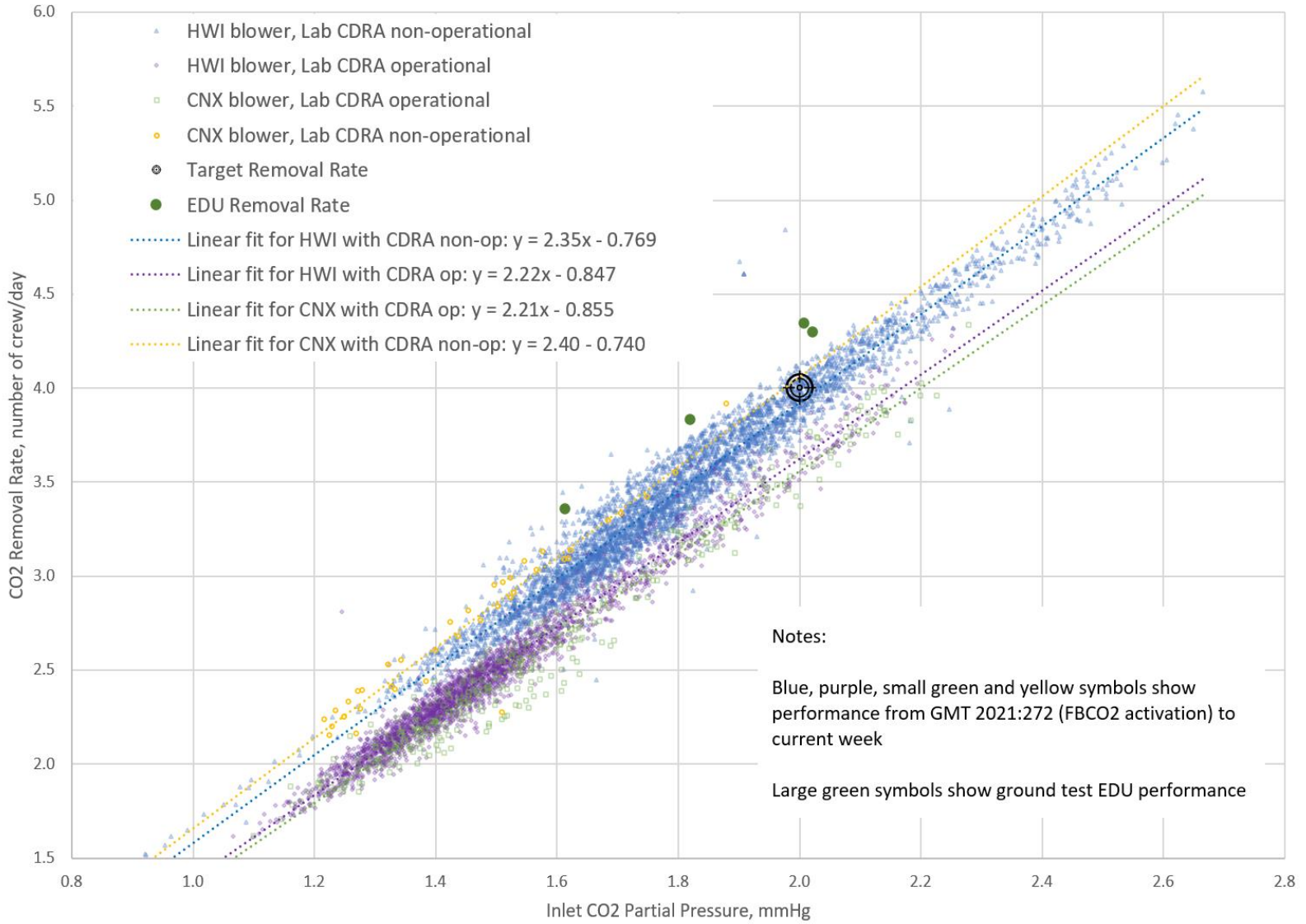
Performance of the Calnetix blower



- Flow rate variations over a half-cycle for the HWI and CNX blower under similar ISS configurations.
- The HWI blower (blue circles) is at 130,000 rpm.
- The CNX blower (red diamonds) is at 54,000 rpm.
- After software adjustments below, the CNX blower rpm was increased to 56,000 rpm.

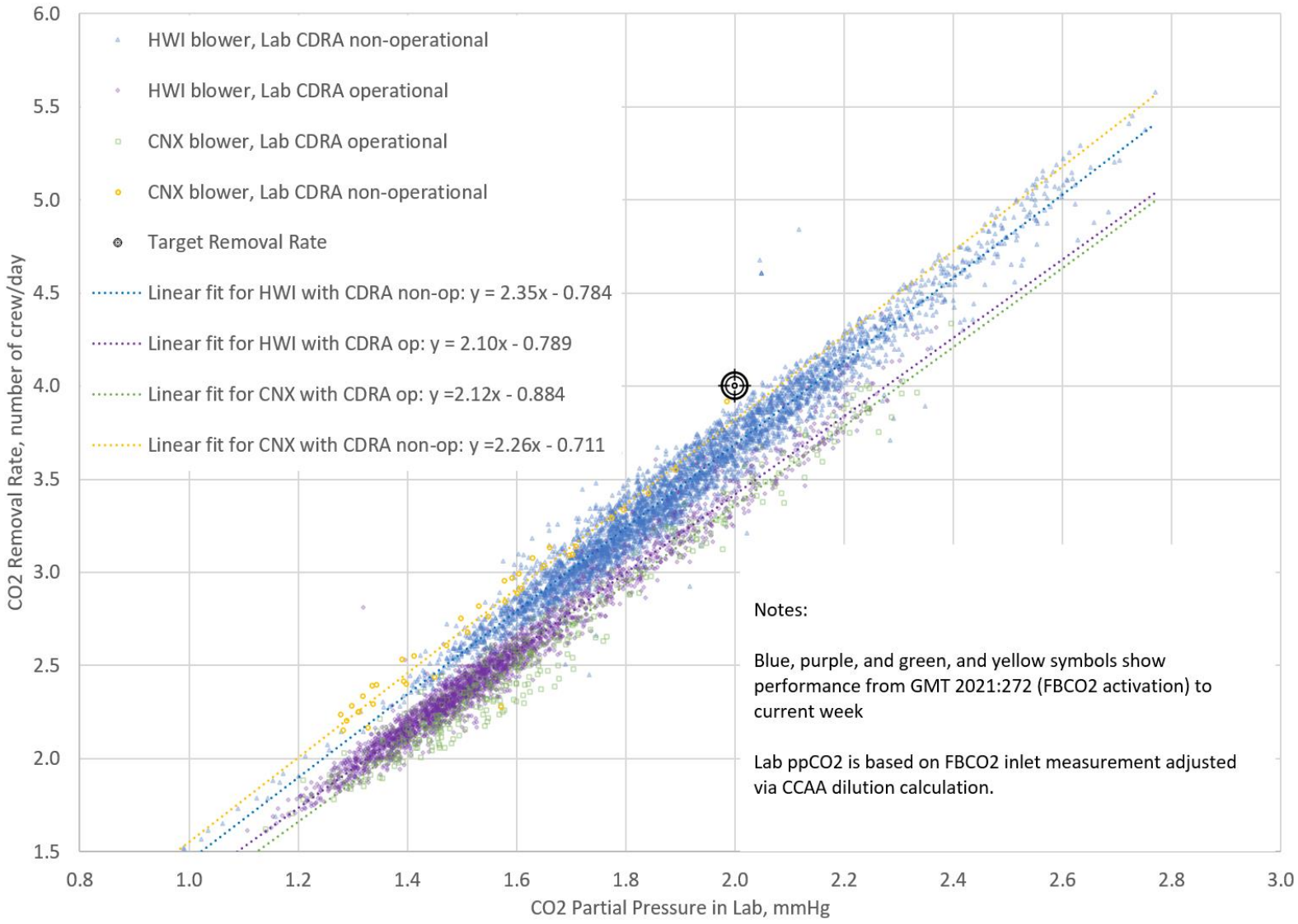
FBCO2 Performance vs. inlet ppCO2

- Average removal rate achieved target performance based on inlet ppCO2 for Lab CDRA non-operational
- Ground test hardware performance higher at similar conditions, cause for difference under review



FBCO2 Performance vs. Lab ppCO2

- Performance slightly lower than target using Lab ppCO2 basis
- Self-dilution of inlet ppCO2 results from integration with CCAA
- Results shown with blower at 54 krpm (max speed is 60 krpm)



Observations

- The FBCO2 Scrubber has operated for approximately 1.2 years without mechanical issues requiring maintenance
- The blower differential pressure has not shown any increase that would indicate zeolite dust is building up on the retainment screens.
- Although performance is lower than the requirement presently, the magnetically levitated blower installed this year has the potential for greater flow rates.
- As a result, CO_2 removal rates are expected to meet or exceed requirements.

Conclusions

- The FBCO2 Scrubber technology demonstration has been successful during the first year of operation with respect to its primary objective, that is, to require minimal maintenance.
- Current data shows no indication of excessive dust generation, though continued operation period will be required to establish long term maintenance-free operation.
- Operation of the Calnetix blower at the intended flow rate is expected to provide required CO2 removal rates.
- Thus, continued operation of the FBCO2 Scrubber is anticipated to establish its suitability for long-term missions such as part of a Mars Transit mission

Backup

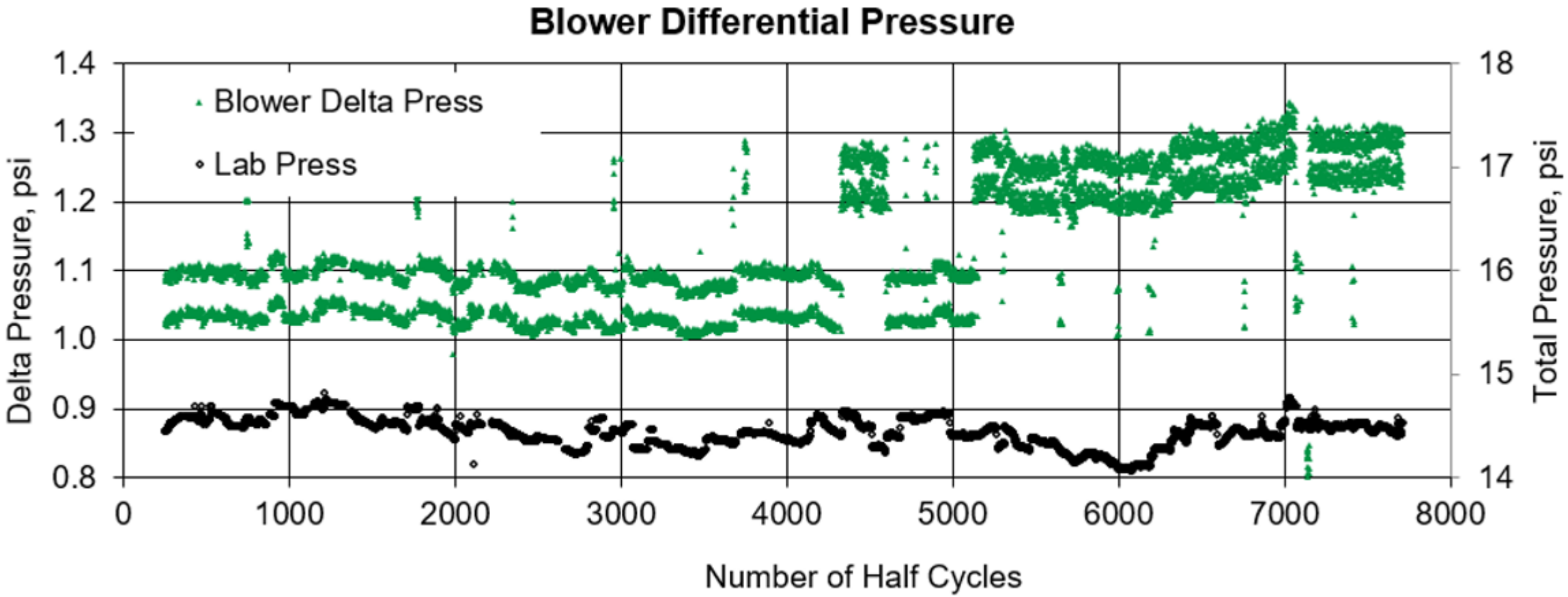


Figure 7. Blower Differential Pressure

Table 2. CO_2 Purity Results

Sample IDs	O2 (%)	N2 (%)	H2O (ppm)
1102 and 1105	0.74	2.47	n/a
1045 and 1050	0.29	0.84	n/a
1052 and 1056	0.24	0.72	n/a
1076 and 1072	2.99	9.62	n/a
1077 and 1074	<0.3	<1.0	n/a