Real-time Contaminant Evolution from a CO_2 Scrubber

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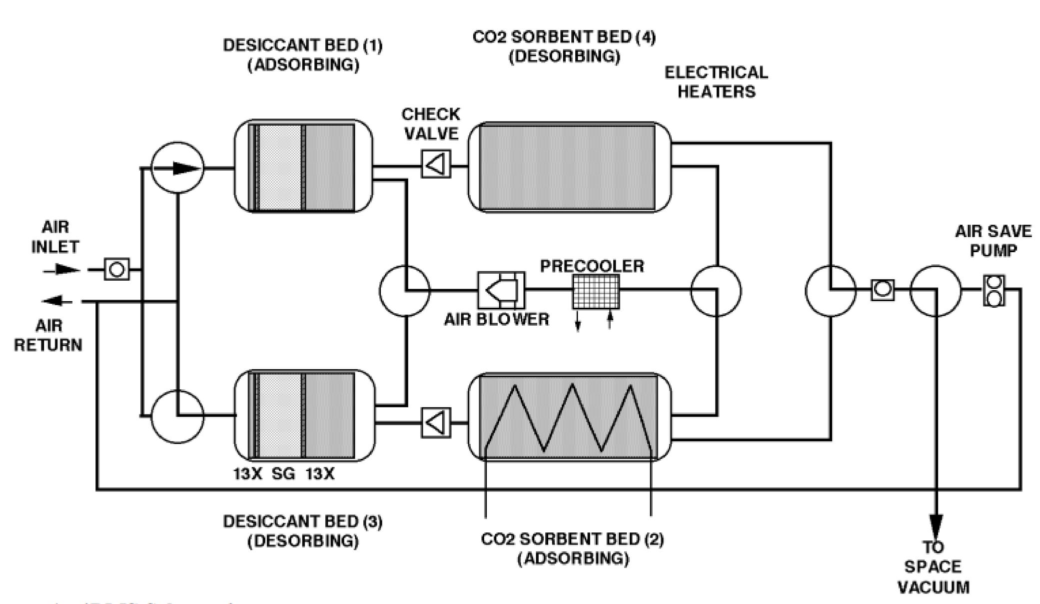
INTRODUCTION

Spaceflight requires recycling and revitalization of cabin air within the spacecraft during missions. Marshall Space Flight Center's (MSFC) Environmental Control and Life Support Systems Engineering Development Branch (ES-62), develops and tests novel regenerative life support systems, supports the International Space Station (ISS) operations, and plans life support for future missions, such as Gateway and Mars transit.

Removing CO_2 from Cabin Air

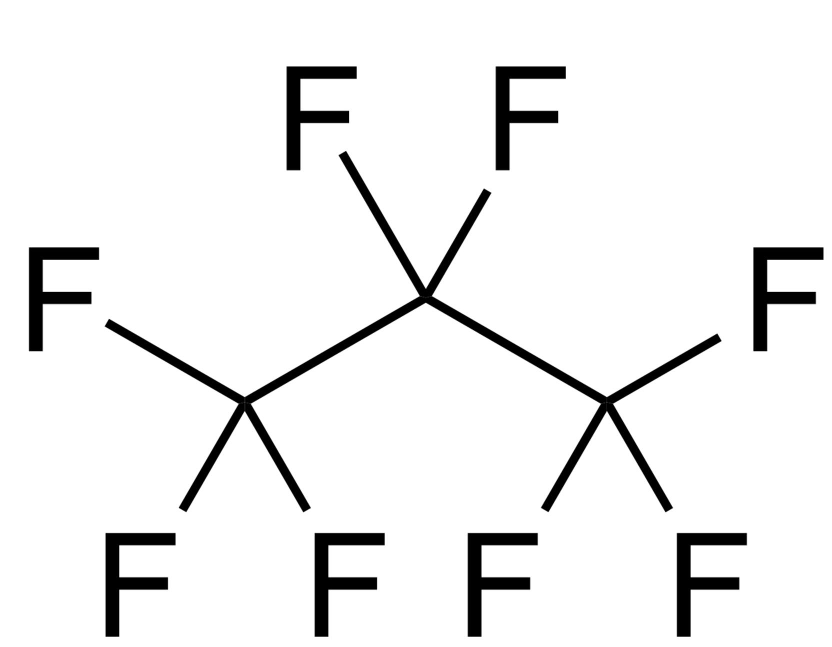
On missions, crew metabolic functions, such as exhaling, can lead to unhealthy levels of carbon dioxide in the cabin. A MSFC ES-62 in-house designed, built, and tested carbon dioxide (CO_2) mitigation system has been deployed on the ISS to remove CO_2 from the incoming cabin air and return humidified air to the cabin. The four-bed molecular sieve (4BMS) carbon dioxide removal system is known as the Four Bed CO2 Scrubber (4BCO2).



Schematic of the Engineering Design Unit for Four Bed CO_2 Scrubber (4BCO2) located in the 4755 High Bay at MSFC.

Presence of Contaminants

4BCO2 utilizes zeolite, a microporous, crystalline aluminosilicate substance, in the adsorbent beds to capture CO_2 from the cabin air. However, zeolite also captures R-218, a freon contaminant on ISS among other small volatile organic chemicals (VOCs). If the 4BCO2 effluent contains contaminants, it could negatively impact down stream life support processes. Therefore, it is imperative to understand when contaminants evolve off 4BCO2 in order to remove them prior to downstream life support processes.



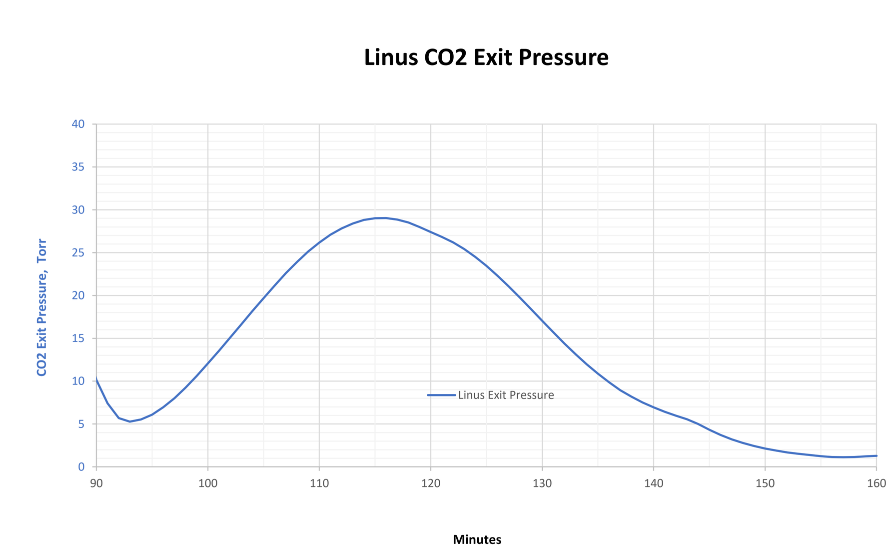
Molecular structure of R-218.

CONCENTRATION

The ISS air regeneration system relies on CO_2 removal from the cabin air to maintain a safe and healthy environment for the crew. Recently, there is a concern that certain contaminants, such as a freon called R218, can impact downstream life support processes. R218 and other contaminants are captured by the CO_2 removal system and concentrated in the CO_2 that is used in downstream life support processes. Removing the contaminants from the CO_2 effluent is imperative to maintaining the functionality of life support systems. Here we evaluate contaminate evolution from the CO_2 removal system in real-time utilizing Fourier transform infrared (FTIR) spectroscopy.

HYPOTHESIS & REASONING

To release the collected CO_2 from the 4BCO2 ground test unit called Linus, a vacuum pump is in place to pull the CO_2 evolution off the Linus adsorbent bed while the adsorbent bed temperature is ramped from ambient to 390°F over 70 minutes. The bed pressure during the evolution is between 5 to 30 torr. Contaminants may evolve off at different temperatures and pressures depending on their chemical characteristics. One way to remove the contaminants is to see at what temperature they evolve off the Linus adsorbent bed and prevent the effluent from that time from proceeding downstream. For example, if R-218 evolves off first before the majority of CO_2, then the that portion of the effluent containing R218 could be discarded and the remaining effluent containing the CO_2 would proceed to the subsequent downstream life support process.



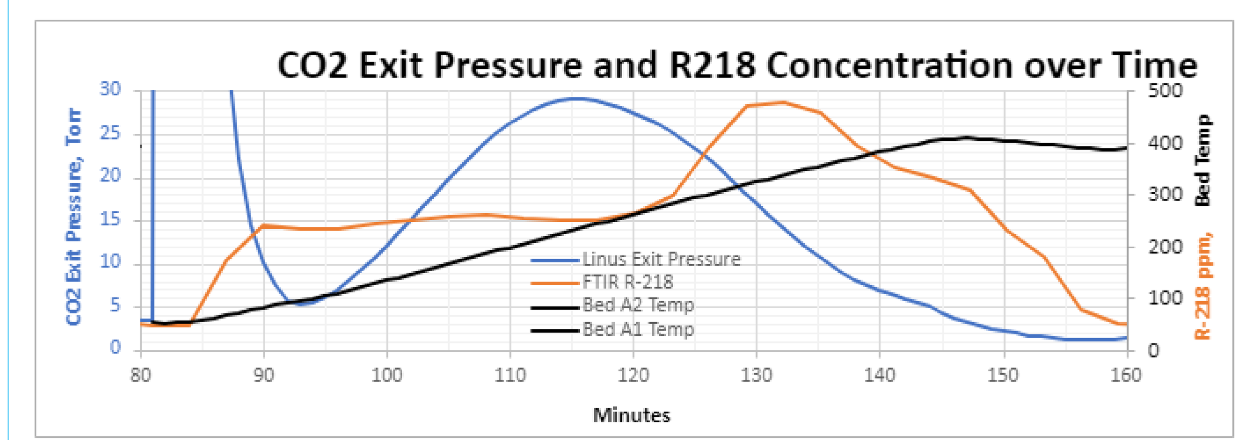
Linus CO_2 Exit Pressure

R218 evolution was monitored from Linus over the half cycles using a Gasmet DX4040 FTIR with 8 cm^{-1} resolution and a 9.8 m optical path length.

While a vacuum pump pulls the CO_2 off the Linus adsorbent bed, the bed pressure range is between 5 to 30 torr during the CO2 release. The sample for the FTIR was collected from the effluent downstream of the vacuum pump. A 2 um Teflon filter was place in the effluent line between the vacuum pump exit port and FTIR to remove particulates. An additional pump was utilized to move effluent from the Linus vacuum pump to the FTIR. The Linus effluent was diluted 10-fold with nitrogen so the R218 concentration would be within the linear range of the FTIR calibration.

Sample entered the FTIR at 2 L/min and FTIR data were collected every three minutes.

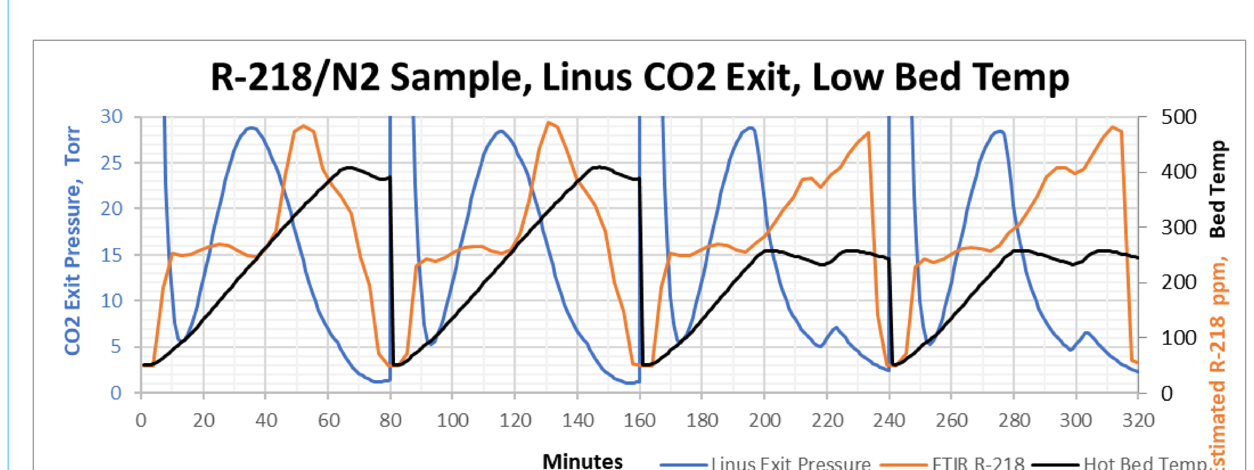
RELATED DATA



Caption: R218 Concentration compared to CO_2 Exit Pressure

The FTIR data demonstrated that R218 evolves off Linus adsorbent bed throughout the half cycle. Therefore, there was no opportunity to vent a portion of the effluent and remove a majority of the R218 under the normal 4BCO2 operating parameters. Capturing the CO_2 between 20 to 40 minutes in the Linus half cycle would still yield approximately 200 ppm of R218 contamination concentration.

To understand if the R218 peak shape was a function of temperature, Linus adsorbent beds were lowered to 250°F for two half cycles. The CO_2 exit pressure increases in a step change at 219 and 300 minutes. The adsorbent bed heaters use a dead-band controller, and changes in the slope of the pressure readings are directly related to the heater turning on or off. This behavior is intrinsic to all 4bed removal systems. Note that both the slope of the CO_2 pressure profile and the R-218 concentration increase when the heaters are turned on.



Variation of 4BCO2 Bed Temperature

CONCLUSION

It was determined that while R218 does have a distinct concentration spike around 55 minutes in the 4BCO2 half cycle, the R218 concentration throughout the half cycle is high enough to warrant additional mitigation via engineering design rather than removing a portion of the effluent prior to down stream processes. The ability to monitor in real-time by FTIR allowed this conclusion to be determined significantly faster than by grab sample analysis.

REFERENCES

1.) Knox, J., Cmarik, G., and Peters, W. "Optimization of the 4-Bed CO2 Scrubber Performance Based on Ground Tests," ICES 2021-71, 50th International Conference on Environmental Systems.

2.) Knox, J., Cmarik, G., and Peters, W. "4-Bed CO2 Scrubber- From design to Build," ICES 2020-176, 49th International Conference on Environmental Systems.