Simulation and Optimization of Vacuum Swing Adsorption Units for Spacesuit Carbon Dioxide and Humidity Control

Michael J. Swickrath* and Molly Anderson
†NASA Johnson Space Center, Houston, TX, 77058

Summer McMillin
‡Engineering and Science Contract Group - Jacobs Technology, Houston, TX, 77058

Craig Broerman
§Engineering and Science Contract Group - Hamilton Sundstrand, Houston, TX, 77058

Controlling carbon dioxide (CO_2) and humidity levels in a spacesuit is critical to ensuring both the safety and comfort of an astronaut during extra-vehicular activity (EVA). Traditionally, this has been accomplished utilizing non-regenerative lithium hydroxide (LiOH) or regenerative metal oxide (MetOx) canisters which pose a significant weight burden. Although such technology enables air revitalization, the volume requirements to store the waste canisters as well as the mass to transport multiple units become prohibitive as mission durations increase. Consequently, motivation exists toward developing a fully regenerative technology for environmental control.

The application of solid amine materials with vacuum swing adsorption technology has shown the capacity to control CO_2 and concomitantly manage humidity levels through a fully regenerative cycle eliminating mission constraints imposed with non-regenerative technologies. Experimental results for full-size and sub-scale test articles have been collected and are described herein. In order to accelerate the developmental efforts, an axially-dispersed plug flow model with an accompanying energy balance has been established and correlated with the experimental data. The experimental and simulation results display good agreement for a variety of flow rates (110-170 SLM), replicated metabolic challenges (100-590 Watts), and atmosphere pressures under consideration for the spacesuit (248 and 760 mm Hg). The relationship between swing adsorption cycles for an outlet criterion of 6.0 mm Hg of CO_2 partial pressure has been established for each metabolic challenge. In addition, variable metabolic profiles were imposed on the test articles in order to assess the ability of the technology to transition to new operational constraints. The advent of the model provides the capacity to apply computer-aided engineering practices to support the ongoing efforts to optimize and mature this technology for future application to space exploration.

*Analyst, Crew and Thermal Systems Division, 2101 NASA Parkway, EC211, Houston, TX, 77058, AIAA Member.
†Analysis Lead, Crew and Thermal Systems Division, 2101 NASA Parkway, EC211, Houston, TX, 77058, AIAA Member.
‡Project Engineer,EVA and Health Systems Group, 2224 Bay Area Blvd., Houston, TX, Member AIAA.
§Project Engineer, CxP and Advanced Systems Group, 2224 Bay Area Blvd., Houston, TX, Member AIAA.