Metabolic Heat Regenerated Temperature Swing Adsorption for Carbon Dioxide and Heat Removal/ Rejection in a Martian Portable Life Support System

Heather L. Paul, *Johnson Space Center*
Christine Iacomini,
Paragon Space Development Corporation
Aaron Powers,
Paragon Space Development Corporation
Chad Bower, *Paragon Space Development Corporation*
Kathrine Straub-Lopez,
Paragon Space Development Corporation
Grant Anderson,
Paragon Space Development Corporation
Taber MacCallum,
Paragon Space Development Corporation

Two of the fundamental problems facing the development of a Portable Life Support System (PLSS) for use on Mars are: 1) heat rejection (traditional technologies use sublimation of water, which wastes a scarce resource and contaminates the premises); and 2) rejection of carbon dioxide (CO_2) in an environment with a CO_2 partial pressure of 0.4-0.9 kPa. Patent-pending Metabolic heat-regenerated Temperature Swing Adsorption (MTSA) technology is currently being investigated to address these issues.

The metabolically produced CO_2 present in the ventilation loop gas is collected using a CO_2 selective adsorbent that has been cooled via a heat exchanger to near CO_2 sublimation temperatures (~195°K) with liquid CO_2 obtained from martian resources. Once the adsorbent is fully loaded, a fresh, warm, moist ventilation loop (~300°K) is used to heat the adsorbent via another heat exchanger (figure 1). The adsorbent will then reject the collected CO_2 to the martian ambient.

Two beds were used to achieve continuous CO_2 removal by cycling between the cold and warm conditions for adsorbent loading and regeneration, respectively (figure 2). Small experiments have been completed to show that an adsorbent can be cycled between these PLSS operating conditions to provide adequate conditions for CO_2 removal from a simulated ventilation loop.

One of the remaining technical challenges is extracting enough heat from the ventilation loop to warm the adsorbent in an appreciable time frame to meet the required adsorb/desorb

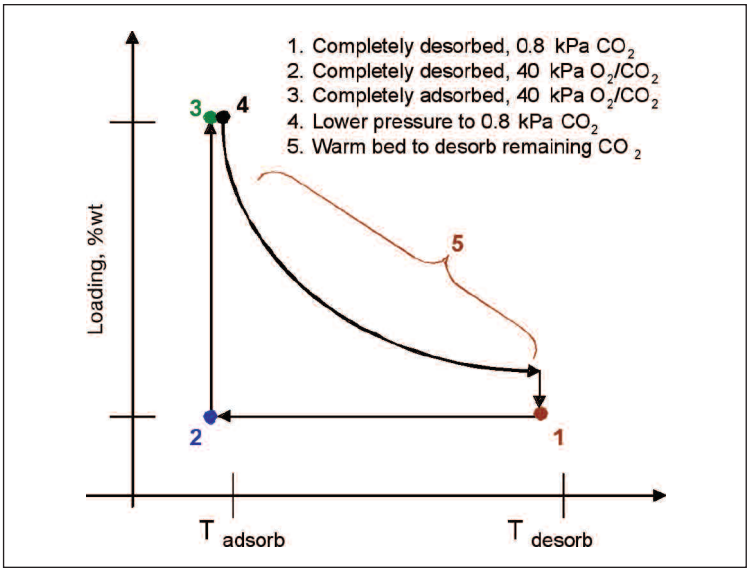

Fig. 1. Loading changes vs temperature.

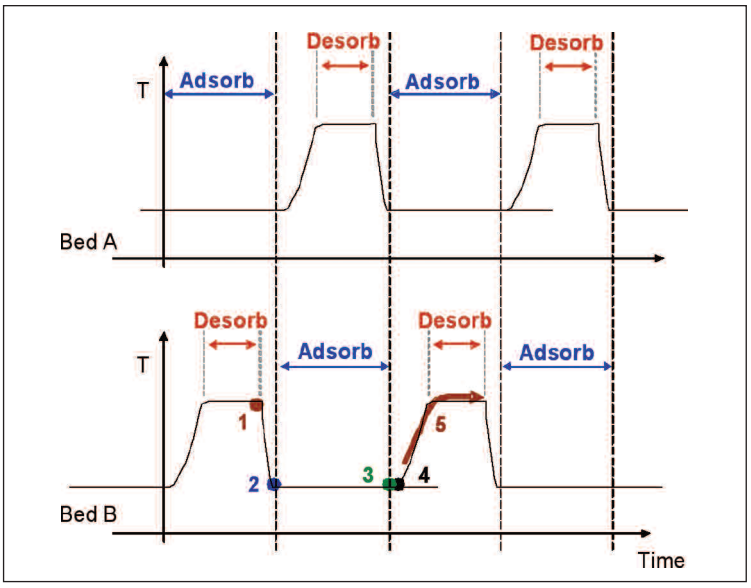

Fig. 2. Loading cycles.

cycle. The other key technical aspect of the technology is employing liquid CO_2 (LCO_2) to achieve the appropriate cooling. A technology demonstrator was designed, built, and tested (figures 3 and 4) to investigate the feasibility of: 1) warming the adsorbent using the moist ventilation loop; 2) cooling the adsorbent using LCO_2; and 3) using these two methods in conjunction to successfully remove CO_2 from a simulated ventilation loop and reject it to simulated Mars ambient.

The demonstrator successfully operated at MTSA operating conditions. LCO_2 was used to reach a cold adsorbent loading temperature of 210°K. A warm, dry, simulated ventilation loop was used to achieve an adsorbent regeneration temperature of 280°K. The demonstrator withstood the various pressure and vacuum environments, maintaining leak rates of less than $1x10^{-3}$ sccs. Even CO_2 loading on the adsorbent was achieved at an amount similar to that observed in previous simpler loading experiments.

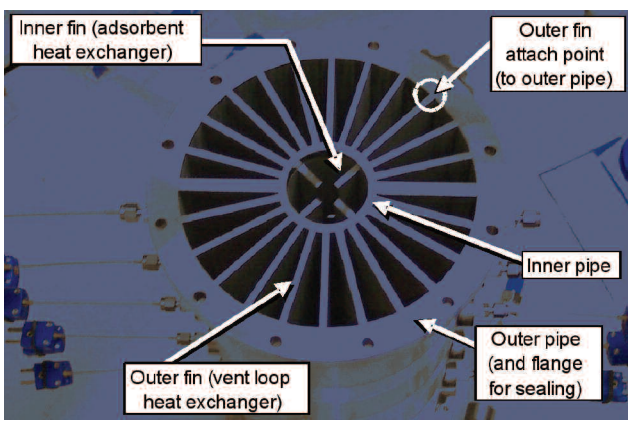

Fig. 3. Cross section of MTSA demonstrator showing internal heat exchanger core geometry.

The demonstrator has proven that MTSA technology is feasible for a PLSS application. It will continue to serve as a means for exploring the limits and benefits of the technology. The results thus far, as well as those to be gained from future testing, can be used to design the next engineering design unit. The goal of that effort should be to focus on reducing mass and volume on a scale more realistic for a PLSS.

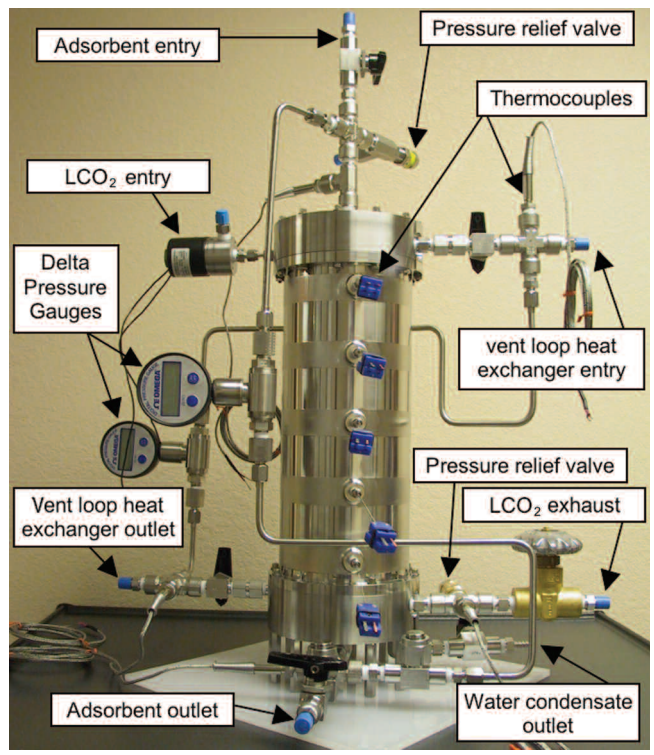

Fig. 4. Demonstrator assembly without insulation.