EXPERIMENTAL DESIGN AND PRELIMINARY ANALYSIS OF MARS CO2 RAPID CYCLE ADSORPTION PUMP. J. J. Berg[1] and A. C. Iannetti[2], [1]NASA Glenn Research Center (Mail Stop: 86-12, Cleveland, OH 44135, jared.j.berg@nasa.gov), [2]NASA Glenn Research Center (Mail Stop: 86-12, Cleveland, OH 44135, anthony.c.iannetti@nasa.gov).

Introduction: Temperature-swing adsorption pumps have been proposed since at least the 1980s [1,2] as a method of compressing Martian atmospheric CO_2 for propellant production. Most previous work targeted at space in-situ resource utilization (ISRU) utilized long temperature swing durations, limited by the the thermal conductivity of typical sorbent beds. A rapid cycle adsorption pump (RCAP) reduces these periods in the hope of increasing overall throughput. This paper details the design and preliminary experimental results from testing an RCAP in a simulated Martian environment. The test configuration features a liquid-solid heat exchanger plate surrounded by rectangular sorbent beds. Various bed thicknesses and commercially available Zeolite 13X sorbent particle sizes are evaluated to both determine performance and provide data for a parallel modeling effort.

Rapid cycling emphasizes the limits on heat and mass transfer inherent in the adsorption pump concept and introduces many complex trades between various design features. Sorbents tend to have low thermal conductivity due to their high porosity and are traditionally manufactured as pellets for use in packed beds, where limited inter-pellet contact and wall-packing effects further impede conduction. Various attempts to boost bed conductivity have been made [3,4] but no solution seems obviously superior, mainly because any high-conductivity material added displaces bed volume that could have been occupied by sorbent.

Despite the disadvantages of packed beds for heat transfer, they are generally good for mass transfer of the target gas species. This is important due to the difficulty of moving the low density ambient atmosphere throughout a proposed pump apparatus. Different methods of packaging the pump, choosing heat transfer fluids, and whether the RCAP should have multiple stages are all critical questions with interrelated answers, often dependent on higher-level ISRU architecture choices.

Testing was performed in the Mars Atmospheric Chemistry Simulator (MACS) chamber at NASA Glenn Research Center. The MACS is a 200 L volume stainless steel bell jar, with two side viewing ports and nine feedthrough ports in the base. It also features connections for gas and fluid exchange. The chamber is evacuated by a Varian TriScroll 600 roughing pump, connected in parallel with an Alicat PCR pressure controller. Supply gas can be bled into the chamber at a constant rate through three parallel Alicat mass flow controllers while the pressure controller modulates the applied vacuum yielding a simulated Martian atmosphere of 95% CO_2, 2.7% N_2, and 1.6% Ar at 6-9 Torr.

The RCAP utilizes a liquid-solid heat exchanger, as discussed below, which is supplied by separate heated and chilled baths. The chosen heat exchange liquid was 3M Fluorinert FC-770. Fluorinert is widely used as a high-performance heat transfer fluid in the electronics industry because it is non-conductive, has

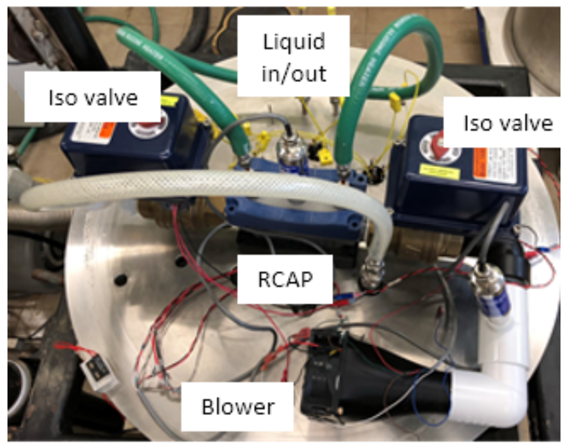

Figure 1. RCAP test configuration.

wide material compatibility, a broad operating temperature range, and leaves no residue. A similar fluorinated liquid (3M HFE-7200) is used in the Orion capsule. The main disadvantage of FC-770 is its relatively high cost.

The geometry of the RCAP was determined by balancing functional scale, ease of modeling correlation, and operational simplicity. Functional scale is both the amount of sorbent present in the pump, which in the case of the RCAP is 250-300 g, and the size of the sorbent bed relative to the constituent media (pellets). A flight scale unit will feature kilograms of sorbent in order to achieve desired production rates, and the design and packaging of this unit will be crucial for specific productivity (rate of CO_2 production / mass of required hardware) and energy efficiency. Also, sorbent media usually comes as pellets of various types, the size of which may have important impacts on overall performance [5,6] As with any development project, the closer to final scale the more relevant the conclusions.

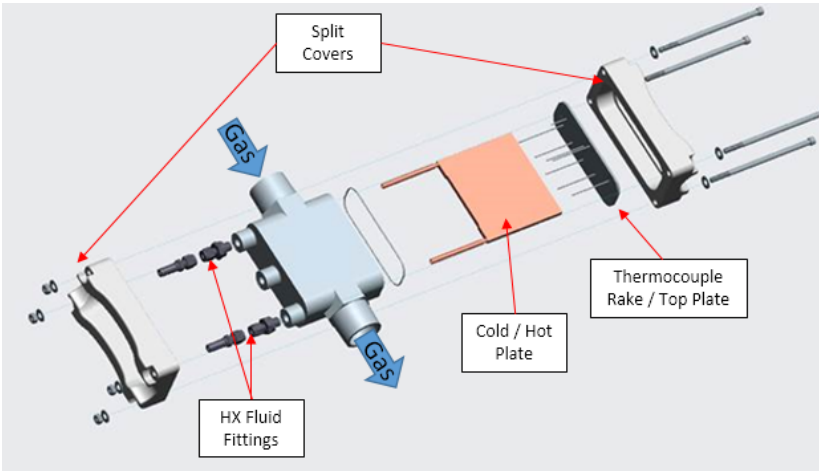

Figure 2. RCAP exploded view.

Model correlation is a key motivation of this experiment, so a choice of geometry that limits the unknown modeling parameters and approximates theoretical boundary conditions is preferable. We decided on a flat heat exchanger plate with sorbent symmetrically distributed on either side and gas flowing perpendicular to the dominant direction of heat transfer. This configuration shares many features with analytical solutions of heat transfer in porous media [7], and the simple geometry is easy to model numerically. We investigated commercially available Zeolite 13X from Strem Chemical in three different formats: 1/8" (3.18 mm) diameter cylindrical pellets, 1/16" (1.59 mm) diameter cylindrical pellets, and 600 mesh powder. In general, larger particle size implies less dense packing (and hence less efficient use of bed volume) and greater macro-porosity, increasing mass transport. Packing behavior will also affect inter-pellet contact and heat conduction.

Three different bed thicknesses were also chosen, 3.0 mm, 5.2 mm, and 9.3 mm. The temperatures of the heated and chilled baths were 90° C and -20° C respectively. The range fits comfortably within the ambient conditions on Mars and temperatures that may be expected as waste heat streams from other ISRU systems. All three Zeolite geometries were tested with each bed thickness, and each test was replicated three times. Both pure CO_2 and simulated Mars atmosphere was used to isolate effects of undesired N_2 adsorption and any diffusion inhibition causes by the trace gases.

Testing is in progress and results will be presented at the meeting. With data from a larger-scale experiment, better systems engineering decisions can be made regarding comparisons to other compression technologies. To maximize mass and energy efficiency, the RCAP concept requires input from the larger ISRU and mission design community, as packaging and techniques like waste heat utilization and recuperation are dependent on choices made by the surrounding hardware. With smart integration into a commodity production plant, the RCAP could help unlock the Martian surface.

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