EXPERIMENTAL STUDY OF A WATER VAPOR ADSORPTION REACTOR FOR MARS IN SITU RESOURCE UTILIZATION. Steven C. Coons, John D. Williams, Adam P. Bruckner, Department of Aeronautics and Astronautics, University of Washington, Box 352250, Seattle WA 98195-2250, USA.

The future of cost-effective exploration of Mars, and indeed the solar system, depends strongly on the development of a strategy known as *in situ* resource utilization, or ISRU. *In situ* resource utilization is defined as the use of indigenous resources at the site of an interplanetary mission for the production of propellant and/or life support consumables. For the past five years, University of Washington design teams have conducted Mars mission analyses for both piloted and robotic exploration. All of these missions have used ISRU propellant production plants and all have shown the significant merit of the ISRU approach over more conventional designs in which the return propellants are brought from Earth.

The UW designs have primarily incorporated some form of the Sabatier/electrolysis (S/E) cycle for production of methane/oxygen propellant. These designs (as well as other Mars ISRU mission designs using S/E propellant plants) have required hydrogen feedstock which must be transported from Earth. The problems associated with long-term cryogenic hydrogen storage prompted the search for alternative methods for getting hydrogen to Mars, including the transport of water. While the mass penalty for taking water from Earth to Mars turned out to be too great, it was thought that if a reliable source of water on Mars were accessible, a completely ISRU mission using an S/E propellant plant could be undertaken.

Water is present on Mars as ice in the polar caps, adsorbed in the regolith, and possibly in subsurface deposits, but the atmosphere of Mars is the most highly characterized and globally distributed water source on the planet. The desire to utilize this atmospheric water led to the development of the Water Vapor Adsorption Reactor (WAVAR) concept by the authors.[1] Past designs for extracting atmospheric water have used a compression-cooling process, which requires a high power input.[2] Water vapor separation by adsorption has fewer moving parts, and is both less massive and less energy intensive. Adsorption is a separation process utilizing molecular sieves, which selectively attract molecules of a fluid as the fluid passes through a stationary bed. Adsorption itself is an exothermic process requiring no energy input other than that required to move the fluid. Removal of the adsorbed molecules from the bed, however, does require energy.

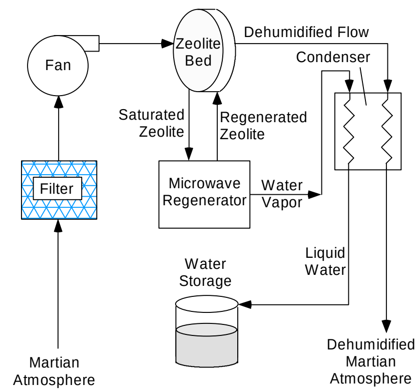

Fig. 1. Process schematic of WAVAR, the Water Vapor Adsorption Reactor.

WAVAR is conceptually very simple, as can be seen from Fig. 1. Martian atmosphere is brought into the system through a filter by an axial-flow fan. The filtered atmosphere is passed over the adsorbent bed where the water vapor is removed from the flow by the zeolite 3A molecular sieve. The disk-shaped bed is divided into sectors by insulative separators. Once a sector has reached saturation, it is rotated into a chamber and sealed off from the outside. A microwave emitter is engaged, heating the adsorbent bed sector and driving off the water vapor. The desorbed water vapor is condensed and piped to storage, where it is available for utilization by a S/E propellant production plant or for use by a manned Mars base. The WAVAR design has only six components: a filter, a pump, an adsorption bed, a regeneration unit, a condenser and a-control system. These subsystems are shown in Fig. 2.

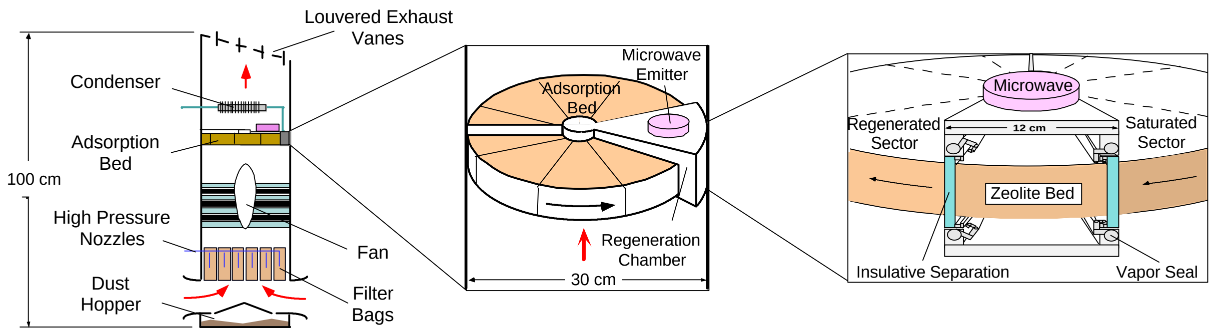

Fig. 2. Water Vapor Adsorption Reactor.

The Water Vapor Adsorption Reactor is an energy efficient method of extracting water from the Martian atmosphere. For the assumed conditions, (253K, 800 Pa, 0.06% humidity)[2] WAVAR uses 4.9 kW-hr for every kilogram of water it extracts. In comparison, an optimized compression-refrigeration cycle operating under the same conditions requires 70 kW-hr per kilogram water.[2]

The possible uses of a WAVAR unit on Mars are as numerous as the number of ways water is used here on Earth, but one of the most important uses will be for propellant production. With a reliable water source, an S/E propellant plant would be able to produce methane/oxygen propellant entirely from indigenous resources. WAVAR would extract water vapor from the Martian atmosphere and the water would be electrolyzed, with the O_2 stored for oxidizer and the H_2 processed with ambient CO_2 in a Sabatier reactor to produce CH_4, more O_2, and additional water which is recycled.

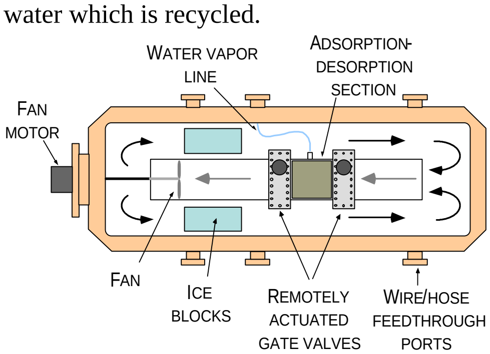

Fig. 3. WAVAR experimental test chamber.

The current status of WAVAR is that of the initial design and theoretical calculations described above.[1] A recently updated description is also available electronically on the World Wide Web.[3] However, initial proof-of-concept experiments are needed and are currently in the planning stage at the University of Washington. To obtain experimental data, a low pressure, low temperature, CO_2-rich environment must be produced in which some level of humidity control can be attained. Simulation of the Martian atmosphere will be conducted by using a vacuum chamber that will be placed in a Scientemp Low-temperature Cabinet (model #85-6.8) which will provide the required refrigeration down to 188 K. The vacuum chamber (Fig. 3) will be filled with CO_2 and pumped down to the required pressure (~6 Torr) using a vacuum pump. Within the vacuum chamber will be a duct with an adsorption/desorption test section between two gate valves. Low pressure CO_2 will be drawn into the duct and across the test bed by a fan. Constant humidity will be maintained via the sublimation of water vapor from blocks of ice placed in the bottom of the chamber. This will ensure a saturated level of humidity commensurate with the temperature, very nearly approximating conditions on the surface of Mars. Once the test section has been saturated, the gate valves will isolate the test section and resistive heating tape around the test section will desorb the sample and the water vapor will be piped off for measurement. These proof-of-concept experiments validating water vapor adsorption under simulated Martian conditions are expected to be under way by Spring 1997.

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[1]Williams, J.D., Coons, S.C., Bruckner, A.P., "Design of a Water Vapor Adsorption Reactor for Martian *In Situ* Resource Utilization," *J. Brit. Interplanet. Soc.*, **48**, No. 8, August, 1995, pp. 347–354. [2]Clapp, W.M., "Water Supply for a Manned Mars Base," *The Case for Mars II*, McKay, C.P., ed., AAS Publications, 1985, pp. 557–566. [3] *WAVAR on the Web*, http://weber.u.washington.edu/~stevencc/ WAVAR/