Mars Atmosphere Acquisition and Compression

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In-situ resource utilization (ISRU) is a fundamental, key technology for human exploration of the solar system. In-situ propellant production (ISPP) is the nearest term aspect of ISRU and represents the bridge between robotic exploration and human exploration of Mars. ISPP involves producing propellants at the site of exploration using indigenous planetary resources and possibly Earth supplied consumables (if necessary). ISPP concepts for Mars primarily consider atmospheric carbon dioxide (CO_2) as the most readily available in-situ resource for the production of oxygen (O_2) and possibly a hydrocarbon fuel. Acquisition and compression of CO_2 from the Mars atmosphere as a feedstock for ISRU is a fundamental and basic part of almost any conceivable ISRU process. Since it is currently doubtful that nuclear power sources will be permitted on Mars, acquisition and compression will have to use power during the day when photovoltaic power is available, with minimal power usage at night. It will have to function through 500-600 diurnal cycles in the Mars environment to accumulate enough propellants for a return flight to Earth.

The atmosphere of Mars is known from Viking measurements to have the approximate composition of 95.4% CO_2, 2.7% N_2, 1.6% Ar, 0.15% O_2, 0.06% CO and 0.03% H_2O. The prevailing atmospheric pressure on Mars varies with location and season but a typical average value is roughly 6 torr (8 mb). For ISRU processes that require high pressure CO_2, (typically in the range of 100 to 2000 torr), the first step in the conversion process is compression from 6 torr to the higher pressure. Therefore, these processes require a flight-qualified Mars compressor capable of generating these pressures. Additionally, the compressor should be relatively small, lightweight, highly efficient, tolerant to dust contamination, capable of separating out non-CO_2 gases, and rugged and reliable enough to operate for at least two years on the surface of Mars under severe daily and seasonal temperature variations.

One type of compressor which satisfies these requirements is an adsorption compressor. Adsorption compressors have the ability to selectively adsorb certain gases from a mixture of gases. With an adsorption compressor, CO_2 may be selectively extracted from the Martian atmosphere and supplied to a conversion reactor at near 100% purity. Unlike a mechanical compressor, an adsorption compressor contains virtually no moving parts (except for solenoid valves) and achieves its compression by alternately heating and cooling a solid-state pelletized sorbent material which adsorbs low pressure gas at low temperatures and drives off high pressure gas at higher temperatures. Due to the lack of rotating/moving parts, it inherently has significant potential for exhibiting increased lifetime, reliability, and robustness.

Because the gas extraction and compression is achieved thermally rather than mechanically, there is also the potential of utilizing system waste heat for sorbent bed heating, thereby achieving improved overall system efficiency. Also, by utilizing the large daily temperature swing on Mars to contribute to the heating and cooling of the adsorption compressor, additional increased energy efficiency can be realized. Specifically, very little power is required at night when the sorbent acquires CO_2 from the Mars atmosphere, and some reactor waste heat can help reduce the power requirements during the day when the

sorbent bed is heated to drive off high pressure CO_2.

An experiment has been devised which will serve to demonstrate a scaled down model of just such a CO_2 adsorption compressor. This experiment has been named the Mars Atmosphere Acquisition and Compression (MAAC) and is one of six planned experiments of the Mars ISPP Precursor (MIP) package which will be attached to the Mars 2001 Lander. The JPL authors are working in collaboration with Johnson Space Center, Lewis Research Center and Lockheed Martin Services on the development of the MIP experiment package. This paper will describe the design philosophy of the MAAC experiment and will present the design configuration as it is currently planned. A prototype of the MAAC is now being fabricated and will be tested in November, 1997. It includes a sorbent bed with heaters, a radiator, and a gas pressure actuated heat switch connecting the two. It features use of a small container of high pressure carbon dioxide to flush out the buildup of permanent gases at periodic intervals during the night.

Keywords: ISRU, ISPP, MAAC, adsorption, compressor