22nd IAA SYMPOSIUM ON HUMAN EXPLORATION OF THE SOLAR SYSTEM (A5)
Human Exploration of Mars (2)

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DESIGN AND MODELING OF AN ELECTROCHEMICAL DEVICE PRODUCING METHANE/OXYGEN AND POLYETHYLENE FROM IN-SITU RESOURCES ON MARS

Abstract

This work was conducted on behalf of Opus 12, Inc. as part of a Phase II NASA SBIR titled "In-Situ Ethylene and Methane Production from CO2 as Plastic Precursors." Opus 12 has developed technology to enable one-pot electrochemical synthesis of methane (CH4), ethylene (C2H4) and oxygen (O2) from Martian CO2 and water. Other reduced products such as hydrogen (H2), carbon monoxide (CO), etc. are also synthesized in the device. Emerging Futures, LLC developed preliminary engineering designs for two devices that would work in tandem with the Opus 12 electrochemical device, adding considerable capabilities to both robotic and human missions.

The first device would use the output from the Opus 12 device and separate CH4 and C2H4 from other fuel products and unreacted CO2 and water. O2 is produced in a separate chamber from the fuels and only needs to have water vapor removed. The design includes a water-gas shift system to convert CO into H2, membrane separation stages, gas drying, and an integrated heat management system to reject waste heat to the Martian atmosphere. The resulting CH4/C2H4 mixture can be used in a suitably-modified CH4/O2 rocket engine (the specific impulse of such an engine is virtually identical to that of a pure CH4/O2 engine). Balance of system mass and energy budgets were developed, along with exploration of parameter sensitivities. The system is sized to supply sufficient propellant to refuel a 2009 Design Reference Architecture Mars Ascent Vehicle (MAV) (7 mt CH4 and 23 mt O2) over 480 days, with ample O2 available for other uses (life support, etc.). The baseline system mass is 412 kg including 265 kg for radiators; the device draws 30 kW, rejecting 13 kW.

The second device feeds the CH4/C2H4 mixture into a polymerization reactor to produce high-density polyethylene, a versatile, food-compatible plastic with high strength, and good resistance to fatigue, wear and organic solvents. A small amount of H2, readily available as a separated byproduct from the first device, is also required to quench the reaction, along with a catalyst that must eventually be replenished (140 kg provides a five-year supply). CH4 remains unreacted and emerges at 97 percent purity, potentially suitable for use in an unmodified CH4/O2 engine. Mass and energy budgets were developed for this device also. The device has a mass of 36 kg and consumes 750 W, producing 9 kg/day of polyethylene plus sufficient CH4 and O2 to replenish the MAV.