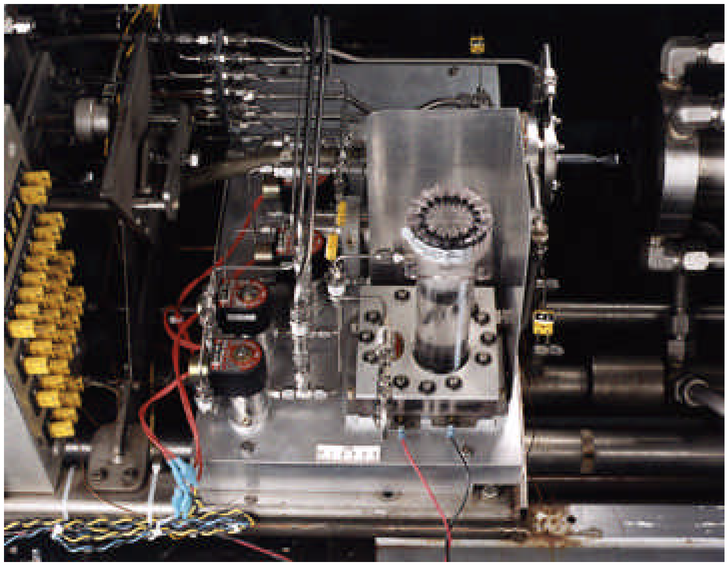
Electrolysis Propulsion Provides High-Performance, Inexpensive, Clean Spacecraft Propulsion

An electrolysis propulsion system consumes electrical energy to decompose water into hydrogen and oxygen. These gases are stored in separate tanks and used when needed in gaseous bipropellant thrusters for spacecraft propulsion. The propellant and combustion products are clean and nontoxic. As a result, costs associated with testing, handling, and launching can be an order of magnitude lower than for conventional propulsion systems, making electrolysis a cost-effective alternative to state-of-the-art systems. The electrical conversion efficiency is high (>85 percent), and maximum thrust-to-power ratios of 0.2 newtons per kilowatt (N/kW), a 370-sec specific impulse, can be obtained. A further advantage of the water rocket is its dual-mode potential. For relatively high thrust applications, the system can be used as a bipropellant engine. For low thrust levels and/or small impulse bit requirements, cold gas oxygen can be used alone. An added innovation is that the same hardware, with modest modifications, can be converted into an energy-storage and power-generation fuel cell, reducing the spacecraft power and propulsion system weight by an order of magnitude.

In a cooperative NASA Lewis Research Center, Hamilton Standard, and Lawrence Livermore National Laboratory effort, an electrolysis propulsion testbed was assembled. It consisted of a gravity-fed percolating water electrolysis system, storage tanks for hydrogen and oxygen with a volume ratio of approximately 2:1, and a 1.1-N rhenium/iridium high-temperature, oxidation-resistant temperature thruster. The feed system was designed to operate in a blowdown mode in order to limit weight and complexity. Calibrated flow venturis determined the propellant mass flow rates. The testbed was installed in a high-altitude simulation chamber for cycle testing, as shown in the following photo.



Electrolysis propulsion breadboard installed inside a high-altitude simulation chamber.

Parameters recorded during testing were the electrolysis unit supply current and voltage, and temperatures and pressures inside the electrolysis unit, near the storage tanks, and in the 1.1-N thruster. Quantities derived from these data were the propellant generation rate as a function of supplied power and electrolysis unit gas pressure, thruster mass flow rates, and propellant mixture ratios. The test bed was cycled with input powers varying from 1 to 18 W. Results showed a high degree of repeatability. Combustion chamber oxygen-to-fuel mass flow rates varied from 7 to 9 during blowdown tests. Combustion chamber outer wall temperatures did not exceed 1600 °F for the duration of the thruster firings, which lasted between 2.5 and 4.5 seconds.

In a flight system, the gravity-fed electrolyzer utilized for these experiments is replaced with a vapor-feed electrolyzer. Neither mechanical pumps nor pressurant gas is required to feed a water electrolysis rocket system because electrolyzers are able to electrochemically "pump" water decomposition products from ambient pressure up to pressures of at least 20 MPa. The absence of a pressurization system simplifies the propellant feed significantly and eliminates components that must have long-term compatibility with propellants. For deep space missions, water is significantly easier to contain than hypergolic Earth storables (those that can ignite without an outside source of ignition), offering stability over a relatively wide temperature range.

Bibliography

Mitlitsky, F., et al.: Integrated Modular Propulsion and Regenerative Electro-Energy Storage System (IMPRESS) for Small Satellites. 10th Annual AIAA/USU Conference on Small Satellites, 1996.

de Groot, W.A., et al.: Electrolysis Propulsion for Spacecraft Applications. AIAA Paper 97-2948, 1997.

Lewis contact: Dr. Wim A. de Groot, (216) 977-7485,

Wilhelmus.A.Degroot@grc.nasa.gov
Author: Dr. Wim A. de Groot
Headquarters program office: OSS
Programs/Projects: ATMS