

dynamic characteristics demonstrated a reduced deceleration peak and improved landing accuracy. The analytic expressions of the longitudinal aerodynamic coefficients were derived, and guidance laws that track reference heat flux, drag, and aerodynamic acceleration loads are also proposed. These guidance laws, based on dynamic inversion, have been tested in an integrated simulation environment, and

the results indicate that use of variable geometry is feasible to track specific profiles of dynamic and heat load conditions during reentry.

The proposed concept of a decelerator system that is first deployed and then is able to adaptively change its geometry during operation is novel and is expected to lead to reductions of drag up to 20 percent and peak temperature by

20 percent, thus obviating the need for both expensive thermal protection systems and heavy expelled mass ballast to change the aerodynamic configuration of the vehicle.

This work was done by Marco B. Quadrelli, Sergio Pellegrino, and Kawai Kwok of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).NPO-47102

Pressure Regulator With Internal Ejector Circulation Pump, Flow and Pressure Measurement Porting, and Fuel Cell System Integration Options

Potential uses include regenerative and primary fuel cell power systems.

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An advanced reactant pressure regulator with an internal ejector reactant circulation pump has been developed to support NASA's future fuel cell power systems needs. These needs include reliable and safe operation in variable-gravity environments, and for exploration activities with both manned and unmanned vehicles. This product was developed for use in Proton Exchange Membrane Fuel Cell (PEMFC) power plant reactant circulation systems, but the design could also be applied to other fuel cell system types, (e.g., solid-oxide or alkaline) or for other gas pressure regulation and circulation needs. The regulator design includes porting for measurement of flow and pressure at key points in the system, and also includes several fuel cell system integration options.

NASA has recognized ejectors as a viable alternative to mechanical pumps for use in spacecraft fuel cell power systems. The ejector motive force is provided by a variable, high-pressure supply gas that travels through the ejector's jet nozzle, whereby the pressure energy of the fluid stream is converted to kinetic energy in the gas jet. The ejector can produce circulation-to-consumption-flow ratios that are relatively high (2-3 times), and this phe-

nomenon can potentially (with proper consideration of the remainder of the fuel cell system's design) be used to provide completely for reactant pre-humidification and product water removal in a fuel cell system.

Specifically, a custom pressure regulator has been developed that includes: (1) an ejector reactant circulation pump (with interchangeable jet nozzles and mixer sections, gas-tight sliding and static seals in required locations, and internal fluid porting for pressure-sensing at the regulator's control elements) and (2) internal fluid porting to allow for flow rate and system pressure measurements. The fluid porting also allows for inclusion of purge, relief, and vacuum-breaker check valves on the regulator assembly. In addition, this regulator could also be used with NASA's advanced non-flow-through fuel cell power systems by simply incorporating a jet nozzle with an appropriate nozzle diameter.

For this advanced regulator and ejector concept, ejector flow and outlet pressure are controlled in a manner similar to an "external-sense" regulator. This control method senses the pressure downstream of the ejector mixer outlet, and uses that signal as the feedback to its internal control valve. As changes in

ejector mixer outlet pressure occur as a result of consumption of gases in the fuel cell stack (or system), the regulator's control elements quickly respond with the variable supply of high-pressure gas to the inlet of the ejector jet nozzle to match the real-time flow needs of the fuel cell stack (or system).

In earlier tests of the regulator and ejector assembly at NASA's test facilities, purposefully selected geometry (ejector jet nozzle and mixer internal diameters), pressure, and flow ranges were tested to gather useful performance data to support the development of design guidelines for fuel cell systems utilizing ejectors for reactant circulation. The results of these tests (and with the particular ranges tested) showed that approximate 10:1 ejector-mixer-to-jet diameter ratios could produce performance (scalable over the range of fuel cell power output of 0.7 to 20 kW) that matched the presumed closed fuel cell circulation requirements of total-to-motive flow ratios of 2.5 to 4.5 at the higher motive flow ranges, and with pressure differences developed as high as about 2.5 psid (≈ 17.2 kPa) with reactant gas circulation.

This work was done by Arturo Vasquez of Johnson Space Center. Further information is contained in a TSP (see page 1).MSC-24731-1