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Liquid Bismuth Propellant Flow Sensor

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ABSTRACT
Quantifying the propellant mass flow rate in liquid bismuth-fed electric propulsion systems has two challenging facets. First, the flow sensors must be capable of providing a resolvable measurement at propellant mass flow rates on the order of 10 mg/sec with and uncertainty of less that 5%. The second challenge has to do with the fact that the materials from which the flow sensors are fabricated must be capable of resisting any of the corrosive effects associated with the high-temperature propellant. The measurement itself is necessary in order to properly assess the performance (thrust efficiency, Isp) of thruster systems in the laboratory environment.

The hotspot sensor[1] has been designed to provide the bismuth propellant mass flow rate measurement. In the hotspot sensor, a pulse of thermal energy (derived from a current pulse and associated joule heating) is applied near the inlet of the sensor. The flow is 'tagged' with a thermal feature that is convected downstream by the flowing liquid metal. Downstream, a temperature measurement is performed to detect a "ripple" in the local temperature associated with the passing 'hotspot' in the propellant. By measuring the time between the upstream generation and downstream detection of the thermal feature, the flow speed can be calculated using a 'time of flight' analysis. In addition, the system can be calibrated by measuring the accumulated mass exiting the system as a function of time and correlating this with the time it takes the hotspot to convect through the sensor. The primary advantage of this technique is that it doesn't depend on an absolute measurement of temperature but, instead, relies on the observation of thermal features. This makes the technique insensitive to other externally generated thermal fluctuations.

In this paper, we describe experiments performed using the hotspot flow sensor aimed at quantifying the resolution of the sensor technology. Propellant is expelled onto an electronic scale to provide an independent measure of the propellant mass flow rate as a function of time. In addition, two separate detection schemes are employed. The first uses a thermocouple to directly measure temperature in the fluid. The second involves the use of a fiber optic coupled to a photodiode allowing for detection of an increase in light emission from the fluid as the hotspot passes the detection location.

REFERENCES
[1] T.E. Markusic, K.A. Polzin, B.J. Stanojev, C. Dodson, and A. Dehoyos, "Liquid metal flow sensors for electric propulsion", in 53rd JANNAF Propulsion Meeting/2nd Liquid Propulsion/1st Spacecraft Propulsion Subcommittee Joint Meeting, Monterey, CA, Dec. 2005.