Flow Control of Liquid Metal Propellants for In-Space Electric Propulsion Systems

Kevin W. Bonds, Kurt A. Polzin
NASA-Marshall Space Flight Center Huntsville, AL

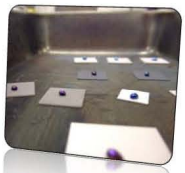
Hall Thrusters

Operation of Hall thrusters with bismuth propellant has been shown to be a promising path for development of high-power (140 kW per thruster), high performance (8000s I_{sp} at >70% efficiency) electric propulsion systems [1].

DEVELOPMENT

Hotspot Flow Sensor [2, 3]

- Sensor to yield precise flow rate measurements for thruster control and performance
- Low propellant volume flow rate (0.1-1.0 µL/sec)
- The temperature at which bismuth is free flowing (around 300°C) and extremely low flow rate preclude the use of off-the-shelf sensing equipment.
- Sensor body made from non-conductive material
- The precise placement of very small components in a solid body without internal access to verify positioning is of major concern
- Active heating of flow chamber required to maintain propellant in liquid phase



How Does It Work?

A very short high-current pulse, generates a thermal feature (or "Hotspot") in the bismuth through Ohmic heating. The time it takes the "Hotspot" to convect downstream can be used to determine flow rate.

- Flow speed of ~0.5 cm/sec at a mass flow rate of ~10 mg/sec [3]
- Flow chamber cross section: 0.031" x 0.020"
- Timescale for thermal diffusion >> convective timescale
- Time resolution for detection of the thermal feature is essential for accuracy– absolute temperature measurement is not required

CONSTRUCTION

TESTING

Calibration Testing and Evaluation

Electromagnetic pump

- A small electromagnetic pump is used to supply pressure to the system
- Flow can be easily varied to obtain calibration over a range of flow rates

Pulse Circuitry

- A capacitor pulse circuit supplies the high-current pulse that generates the "Hotspot" (or thermal peak)

Two methods of peak detection under investigation

- Fiber-optic based IR detector and thermocouple

http://vhital.wikidot.com

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[2] K.A. Polzin, Y. Korman, T.E. Markusic and B.J. Stanojev. "System and Method for Determining Velocity of Electrically Conductive Fluid." U.S. Patent 7,409,875, Aug. 2008.
[3] K.A. Polzin, T.E. Markusic, B.J. Stanojev, C. Marrese-Reading, "Integrated Liquid Bismuth Propellant Feed System," 42nd AIAA Joint Propulsion Conference, Sacramento, CA, AIAA 2006-4636..