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# A Xenon Mass Gauging through Heat Transfer Modeling for Electric Propulsion Thrusters

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**Abstract :** The current state-of-the-art methods of mass gauging of Electric Propulsion (EP) propellants in microgravity conditions rely on external measurements that are taken at the surface of the tank. The tanks are operated under a constant thermal duty cycle to store the propellant within a pre-defined temperature and pressure range. We demonstrate using computational fluid dynamics (CFD) simulations that the heat-transfer within the pressurized propellant generates temperature and density anisotropies. This challenges the standard mass gauging methods that rely on the use of time changing skin-temperatures and pressures. We observe that the domes of the tanks are prone to be overheated, and that a long time after the heaters of the thermal cycle are switched off, the system reaches a quasi-equilibrium state with a more uniform density. We propose a new gauging method, which we call the Improved PVT method, based on universal physics and thermodynamics principles, existing TRL-9 technology and telemetry data. This method only uses as inputs the temperature and pressure readings of sensors externally attached to the tank. These sensors can operate during the nominal thermal duty cycle. The improved PVT method shows little sensitivity to the pressure sensor drifts which are critical towards the end-of-life of the missions, as well as little sensitivity to systematic temperature errors. The retrieval method has been validated experimentally with CO<sub>2</sub> in gas and fluid state in a chamber that operates up to 82 bar within a nominal thermal cycle of 38 °C to 42 °C. The mass gauging error is shown to be lower than 1% the mass at the beginning of life, assuming an initial tank load at 100 bar. In particular, for a pressure of about 70 bar, just below the critical pressure of CO<sub>2</sub>, the error of the mass gauging in gas phase goes down to 0.1% and for 77 bar, just above the critical point, the error of the mass gauging of the liquid phase is 0.6% of initial tank load. This gauging method improves by a factor of 8 the accuracy of the standard PVT retrievals using look-up tables with tabulated data from the National Institute of Standards and Technology.

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