Suborbital Testing of a Large-Scale Liquid Acquisition Device for Cryogenic Fluid Management

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Abstract

Improvement of cryogenic fluid storage and transfer technology for in-space propulsion and storage systems is required for long-term space missions. Screened-channel liquid acquisition devices (LADs) have long been used with storable propellants to deliver vapor-free liquid during engine restart and liquid transfer processes. The use of LADs with cryogenic fluids is problematic due to the low temperatures associated with cryogenic fluids. External heat leaks will cause vapor bubbles to form within the LAD that are difficult to remove in the existing designs. A new design has been proposed that reliably removes vapor bubbles without costly thrusting maneuvers or active separation systems. This presentation will review suborbital flight tests for several large-scale versions of the tapered LAD design.

Tapered LAD Design

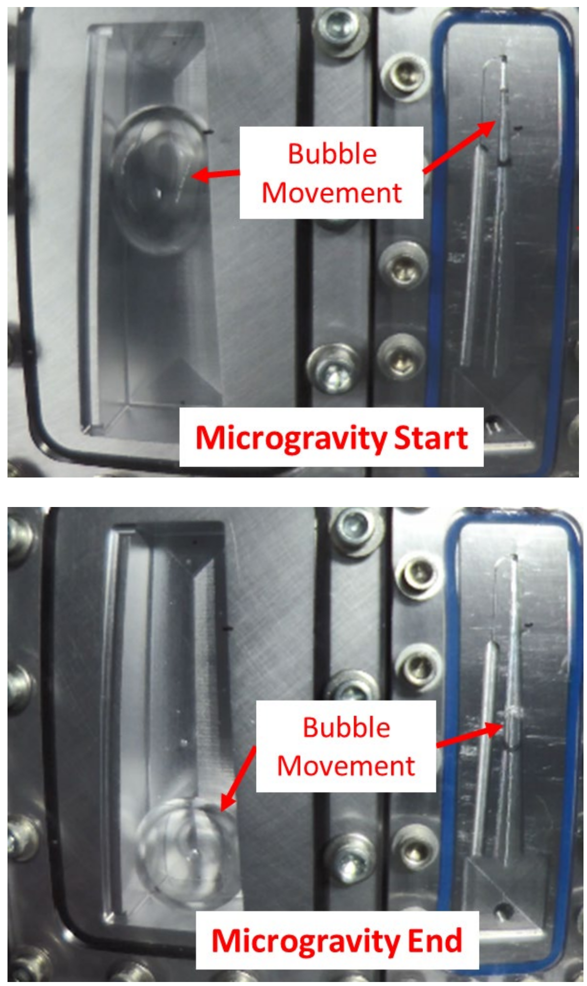
Southwest Research Institute (SwRI®) has evaluated a small modification to a commonly used LAD: a tapered channel. This design passively removes or "pumps out" cryogenic vapor bubbles that are internally generated using surface tension forces, substantially improving the vapor-free transfer or delivery of cryogenic fluids. A model has been developed by SwRI to predict the bubble movement in tapered LADs and three suborbital tests have been conducted to validate the model and design approach.

Suborbital Testing

Utilizing funding from NASA's Flight Opportunities Program, several tapered channels were tested in microgravity aboard Blue Origin's New Shepard vehicle in 2019, 2020, and 2021. This vehicle provided more than three minutes of high-quality microgravity. This duration of microgravity is required for the evaluation of this technology since it takes several minutes for the bubble to migrate to the wider end of the channel. Several variations of a tapered LAD design were explored including: taper angle, fluid type, channel cross-sectional geometry, and bubble size.

Conclusions

The data generated during the three flights show that the tapered LAD concept is viable for passively migrating bubbles to the wider end of the channel. This presentation will discuss the flight test results and the lessons learned. Future flight testing is needed to verify methods for either collapsing or expelling the bubble from the end of the channel.



Tapered LAD Bubble Movement in the 2019 Suborbital Test

In microgravity, the bubble moved towards the wider end of the channel due to capillary action.