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RESULTS OF THE MICROGRAVITY ZERO-BOIL-OFF TANK(ZBOT)EXPERIMENT

Abstract

Integral to all phases of NASA's projected planetary expeditions is affordable and reliable cryogenic fluid storage for use in propellant or life support systems. Cryogen vaporization due to heat leaks into the tank from its surroundings and support structure can cause self-pressurization that is currently relieved through venting. This has led to a desire to develop innovative vent-less pressure control designs based on mixing of the bulk tank fluid with active cooling to allow storage of the cryogenic fluid with zero or reduced boil-off.

The Zero-Boil-Off Tank (ZBOT) Experiments are a series of small scale tank pressurization and pressure control experiments aboard the International Space Station (ISS) that use a transparent volatile simulant fluid in a transparent sealed tank to delineate various fundamental fluid flow, heat and mass transport, and phase change phenomena that control storage tank pressurization and pressure control in microgravity. The hardware for ZBOT-1 flew to ISS on the OA-7 flight in April 2017. Operations began in September 2017 and were completed by December 2017, encompassing more than 100 tests. Hand-in-Hand with the experiment a state-of-the-art two-phase CFD model of the storage tank pressurization pressure control is also developed and validated against the experimental results.

In this paper, we present some of the key experimental findings of the microgravity experiment such as:

1. Moderate heat flux strip heating cases produced classic self-pressurization trend at first, but eventually led to boiling at the heaters caused by microgravity thermal stratification resulting in rapid pressure spike.

2. Mixing tests at small jet velocities exhibited a non-intuitive behavior with continuous movement of the ullage towards the nozzle which was more pronounced at lower fill levels(larger ullage sizes).

3. At larger flow velocities, the ullage was significantly penetrated and deformed by the jet and its downward motion was arrested.

4. During pressure control tests with subcooled jet, surprising and sudden evolution and growth of many small bubbles were observed. Here unexpected boiling at both sides of the screened liquid acquisition device (LAD) during the pressure collapseis suspected.

5. Unique self-pressurization tests during three different ISS reboost/coasting maneuvers showed the effect of the resultant accelerations on the movement and re-positioning of the ullage and on subsequent changes in fluid flow tank pressurization rate.

The important underlying transport/phase change phenomena associated with these results are discussed using insight provided by two-phase CFD model simulations.