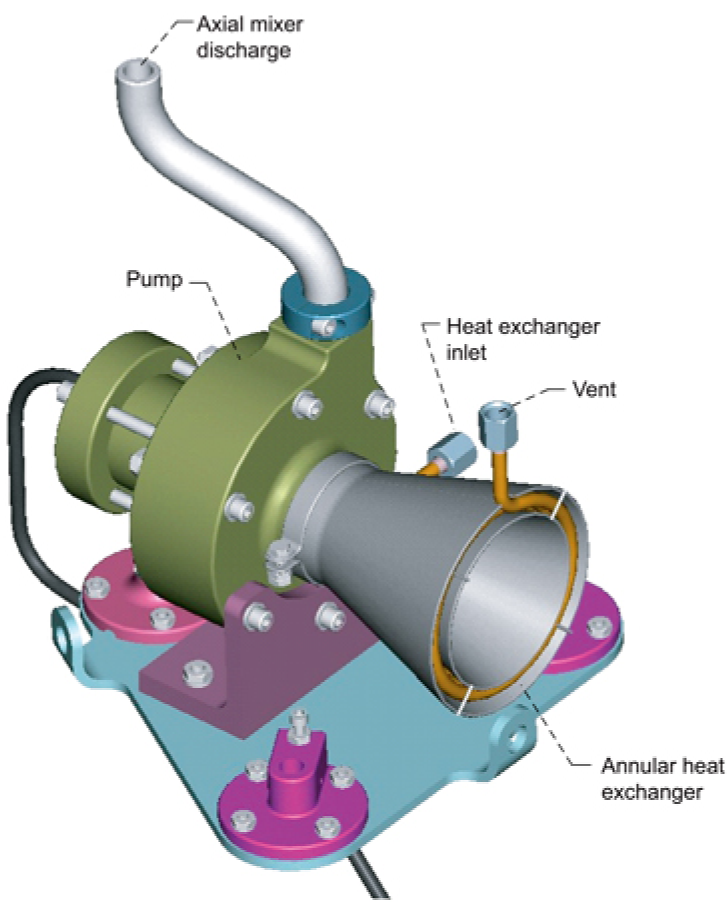
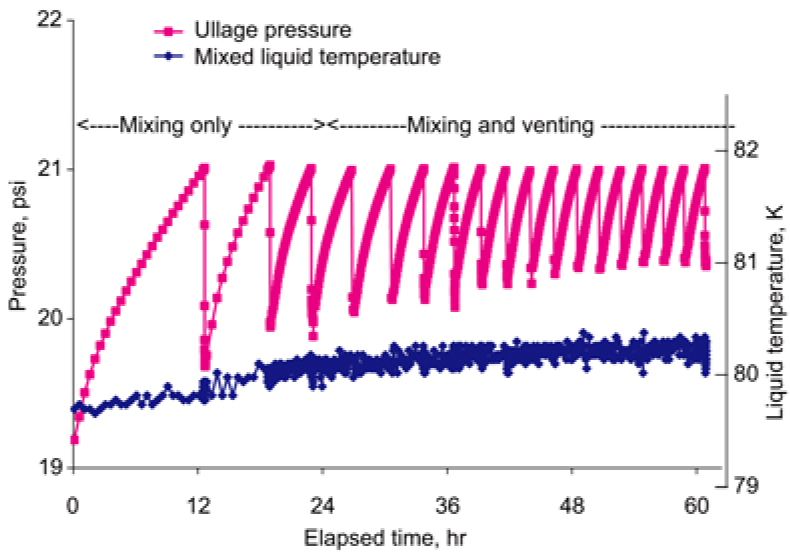
Pressure Control for Low Earth Orbit Investigated

There is renewed interest in cryogenic oxygen storage for an advanced second-generation orbital maneuvering system and reaction control systems in a low Earth orbit because cryogenic propellants are more energetic and environmentally friendly than current storable propellants. Unfortunately, heat transfer or heat leak into these storage systems increases tank pressure. On Earth, pressure is easily controlled by venting from the gaseous, or ullage,[1] space above the liquid. In low gravity, the location of vapor is unknown and direct venting would expel liquid. Historically, upper stages have used auxiliary thrusters to resettle the tank contents and fix the location of the ullage space in orbit.



Centrifugal mixer pump with TVS heat exchanger.

Thrusters, however, have weight penalties, and resettling may be required at inopportune times in the mission. An active thermodynamic vent system (TVS), which consists of a Joule-Thomson valve and a heat exchanger coupled with a mixer pump, has been proposed for low gravity. The combination is used to extract thermal energy from the tank fluid, reducing temperature, thus inducing condensation and reducing pressure. At the NASA Glenn Research Center, a pressure-control test was conducted to characterize the TVS concept for orbital cryogenic oxygen storage (ref. 1). A previous TVS test was much simpler and at ambient pressure (ref. 2). A 50-ft^3 flight-weight tank was used. It was almost completely surrounded by a cryoshroud in a large vacuum tank. The cryoshroud was used to simulate low-Earth-orbit temperatures. Because mixer operation also caused tank heating, the TVS was sized so that the mixer only operated a small fraction of the time. Initially, the mixer used subcooled liquid to control pressure. After the mixed liquid temperature had risen, venting had to be used to limit further tank temperature increase. Pressure cycles were performed until steady-state operation was demonstrated. The following graph shows the ullage pressure and liquid temperature in the middle of the tank for the first test run. Three successful pressure control runs were conducted. Two lower fills had time-averaged vent rates very close to steady-state boiloff rates. Thus, the TVS venting was almost as efficient as the traditional Earth-gravity (1g) vent system for lower tank fills, and the vent fluid was completely vaporized within the test tank.



Ullage pressure and mixed-fluid temperature for the first test run.

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[1]The ullage space is the vapor space--the portion of the tank that is not filled with liquid.

References

1. VanOverbeke, Thomas: Thermodynamic Vent System Test in a Low Earth Orbit Simulation. AIAA-2004-3838 (NASA/TM--2004-213193), 2004. http://gltrs.grc.nasa.gov/cgi-bin/GLTRS/browse.pl?2004/TM-2004-213193.html

2. Seigneur, Alban D.: Design, Analysis, Fabrication, and Testing of an Active Heat Exchanger for Use in Cryogenic Fluids. MS. Thesis, Cleveland State University, Mar. 1994.

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