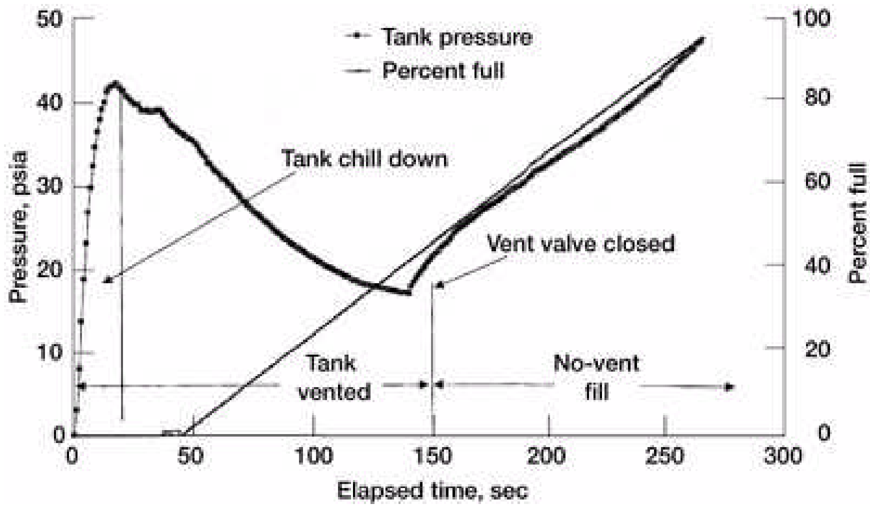
Rapid Chill and Fill of a Liquid Hydrogen Tank Demonstrated

The NASA Lewis Research Center, in conjunction with Boeing North American, has been supporting the High Energy Upper Stage (HEUS) program by performing feasibility studies at Lewis' Supplemental Multilayer Insulation Research Facility (SMIRF). These tests were performed to demonstrate the feasibility of chilling and filling a tank with liquid hydrogen in under 5 minutes.

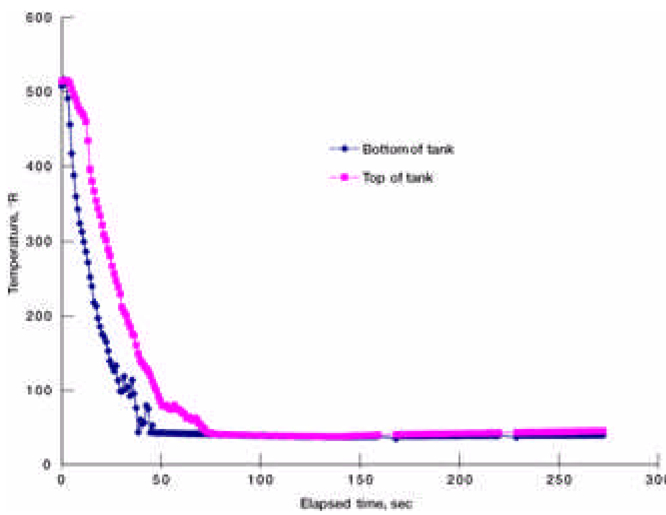
The goal of the HEUS program is to release a satellite from the shuttle cargo bay and then use a cryogenic (high-energy) upper stage to allow the satellite to achieve final orbit. Because of safety considerations, the propellant tanks for the upper stage will be launched warm and dry. They will be filled from the shuttle's external tank during the mission phase after the solid rocket boosters have jettisoned and prior to jettison of the external tank. Data from previous shuttle missions have been analyzed to ensure that sufficient propellant would be available in the external tank to fill the propellant tank of the proposed vehicle upper stage. Because of mission time-line considerations, the propellant tanks for the upper stage will have to be chilled down and filled in approximately 5 minutes.

An existing uninsulated flight weight test tank was installed inside the vacuum chamber at SMIRF, and the chamber was evacuated to the 10^{-5} torr range to simulate space vacuum conditions in the cargo bay with the doors open. During prerun operations, the facility liquid hydrogen (LH_2) supply piping was prechilled with the vent gas bypassing the test article. The liquid hydrogen supply dewar was saturated at local ambient pressure and then pressurized with ambient temperature gaseous helium to the test pressure. A control system was used to ensure that the liquid hydrogen supply pressure was maintained at the test pressure.

During the initial phase of the test, the test tank vent valve was open. Despite the open valve, pressure in the test article rose rapidly until it approached the supply dewar pressure. During this initial pressure rise, the warm test tank walls were sprayed with liquid. As the walls reached near liquid temperatures, the quantity of gas evolved began to decrease and test tank pressure began to drop. When the test tank pressure had fallen close to atmospheric pressure, the tank vent valve was closed and the fill process was allowed to continue. The purpose of closing the vent valve was to demonstrate the no-vent fill process, which conserves propellant and yields a pressurized propellant tank when the fill is complete. See the graphs for the pressure, temperature, and fill level, and temperature traces for a typical test.



Typical tank pressure and liquid level versus elapsed time.



Typical tank temperatures versus elapsed time.

Four demonstrations of the rapid chill and fill process were completed at the SMIRF facility. All tests resulted in greater than 85-percent fills obtained in under 5 minutes. Some parametric studies were performed to provide a relationship between the liquid hydrogen supply dewar pressure and the fill efficiency. The timing of the test tank vent-valve closure was also studied. Testing at the SMIRF facility demonstrated the feasibility of the rapid chill and fill technique and reduced the technology risks for the High Energy Upper Stage program.

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