

# Calibrating the Helium Pressurization System for the Space Shuttle Liquid-Hydrogen Tank



Hazardous-Leak  
Detection and  
Isolation

Analysis of the results from the STS-114 tanking tests and subsequent launch called into question existing thermal and mass models of helium pressurization of the liquid-hydrogen tank. This hydrogen tank, which makes up the bottom two-thirds of the External Tank, is pressurized prior to launch to avoid cavitation in the Shuttle Main Engine pumps. At about 2 minutes prior to launch, the main vent valve is closed, and pressurized helium flows into the tank ullage space to achieve set point pressure. As the helium gas cools, its pressure drops, calling for additional helium. Subsequent helium flows are provided in short, timed pulses. The number of pulses is taken as a rough leak indicator. An analysis of thermal models by Marshall Space Flight Center showed considerable uncertainty in the pressure-versus-time behavior of the helium ullage space and the ability to predict the number of pulses normally expected.

Kennedy Space Center proposed to calibrate the dime-sized orifice, which together with valves, controls the helium flow quantity (Figure 1). Pressure and temperature sensors were installed to provide upstream and downstream measurements necessary to compute flow rate based on the orifice discharge coefficient. An assessment of flow testing with helium indicated an extremely costly use of this critical resource. In order to reduce costs, we proposed removing the orifices from each Mobile Launcher Platform (MLP) and asking Colorado Engineering Experiment Station Inc. (CEESI) to calibrate the flow. CEESI has a high-pressure air flow system with traceable flow meters capable of handling the large flow rates. However, literature research indicated that square-edged orifices of small diameters often exhibit significant hysteresis and nonrepeatability in the vicinity of choked or sonic flow. Fortunately, the MLP orifices behaved relatively well in testing (Figure 2). Using

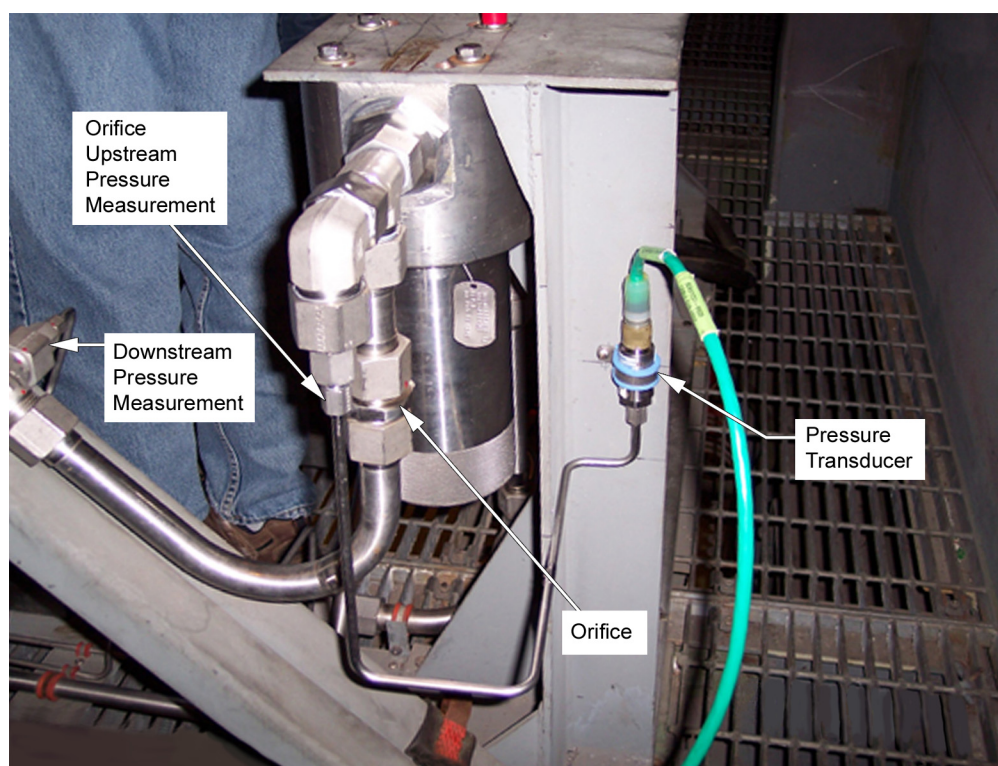


Figure 1. The helium flow control orifice and associated instrumentation.

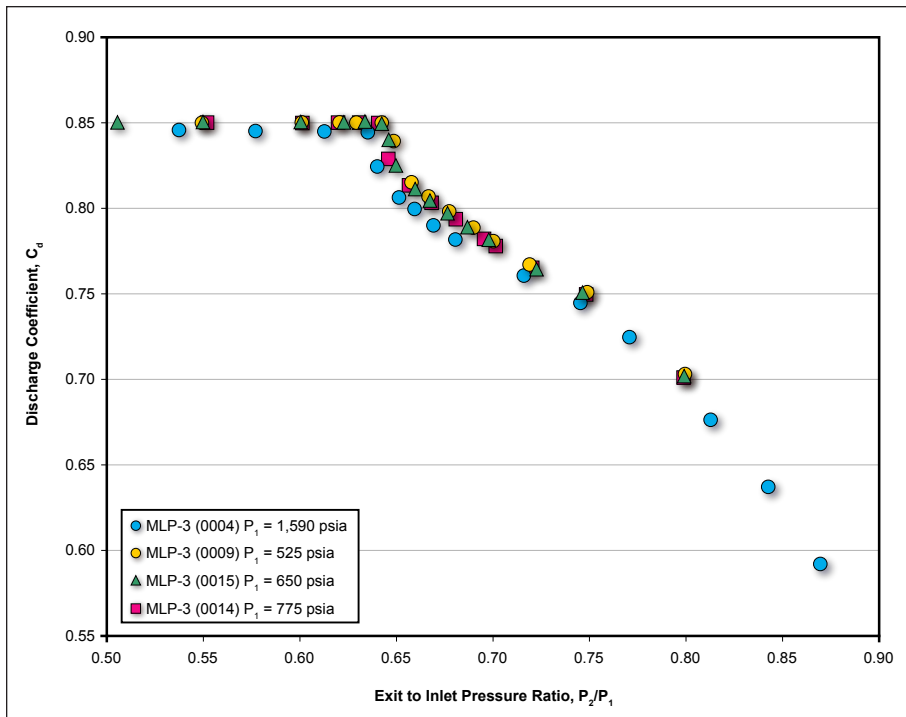


Figure 2. Typical flow-versus-pressure ratio curve, as measured in air by CEESI.

curve fitting of the air-flow data, in conjunction with ASME orifice modeling equations, a method of relating the helium mass flow to measured air flow data was obtained. This analysis showed that the highest uncertainty in flow occurred in the vicinity of the choking pressure ratio, as would be expected. In addition, analysis of typical flow pulses showed that most of the helium flow occurred either well below or well above this uncertain area. The final result is the ability to provide postlaunch estimates of helium mass flows that are within 1.5 percent of the actual value.

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