# Propellant Densification Ground Testing Conducted for Launch Vehicles

The NASA Glenn Research Center at Lewis Field has taken the lead in the development of practical densified cryogenic propellants for launch vehicle applications. The technology of subcooling cryogenic propellants below their normal boiling point to produce a denser fluid is one of the key process technologies necessary to meet the challenge of single-stage-to-orbit and reusable launch vehicles. Densified propellants are critical to lowering launch costs because they enable more propellant to be packed into a given unit volume, thus improving the performance by reducing the overall size and weight of the launch vehicle. This two-pronged research and test program has evolved into (1) conducting tank loading tests using densified liquid hydrogen and (2) developing two large-scale propellant densification systems that will be performance tested next year at Glenn.

The propellant-loading test program was undertaken at Glenn in coordination with Lockheed Martin Michoud Space Systems. In this testing, the liquid hydrogen recirculation and densification process was simulated, and the thermal stratification of the densified propellant was recorded throughout the tank. The test article was a flight-weight tank constructed from composite materials similar to those to be used on the X–33 launch vehicle. The tank geometry as designed by Lockheed Martin had two cylindrical lobes with a center septum. Liquid hydrogen flow rate, pressure data, and temperature data plotted over time were collected while the subscale tank was filled with 27 °R (15 K) densified liquid hydrogen propellant. This testing has validated mathematical models and demonstrated the readiness of densified propellant technology for near-term use. It marks the first time that such a process has been carried out with a multiple-lobe, flight-similar tank.

*A composite dual-lobe X–33 prototype test tank is configured for propellant loading and* *recirculation testing with high-density 27 °R liquid hydrogen.*

Glenn researchers have also been working on providing a process and critical test data for the continuous production of densified liquid hydrogen ($LH_2$) and densified liquid oxygen ($LO_2$). Each densification production process uses a high-efficiency, subatmospheric boiling bath heat exchanger to cool the working fluid. A near triple-point hydrogen boiling bath is used to condition and subcool hydrogen to 27 °R (15 K), and a nitrogen boiling bath is used to cool the liquid oxygen to 120 °R (66.7 K). Multistage centrifugal compressors operating at cryogenic inlet conditions maintain the heat exchanger bath vapor pressure below 1 atm. The $LO_2$ propellant densification unit shown in the photograph has a 30 lb/sec capacity, whereas the $LH_2$ unit was designed to process 8 lb/sec of propellant. Each densification unit will be transported to Glenn's South Forty area after all fabrication work is completed sometime late next year. There the $LO_2$ and $LH_2$ densifier performance tests will be conducted with another larger Lockheed Martin tank designated the Structural Test Article (STA). This liquid oxygen tank is a full-scale, flight-weight, prototype aluminum tank designed for the X–33. It has a capacity of 20,000 gallons of $LO_2$. The tank loading and recirculation testing planned for next year with STA will provide the data necessary for full-scale development of propellant densification technology.

*Inside the NASA Glenn hangar, a team of engineers and technicians put the final touches on a 1000-ft$^2$ liquid oxygen propellant densification unit that promises to reduce the cost of access to space.*

# Bibliography


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