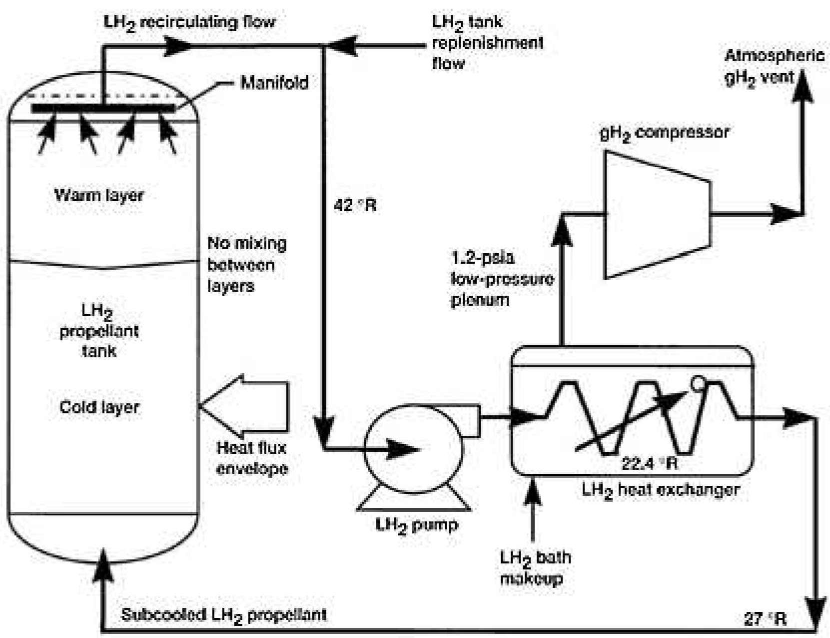
Recent Advancements in Propellant Densification

Next-generation launch vehicles demand several technological improvements to achieve lower cost and more reliable access to space. One technology area whose performance gains may far exceed others is densified propellants. The ideal rocket engine propellant is characterized by high specific impulse, high density, and low vapor pressure. A propellant combination of liquid hydrogen and liquid oxygen (LH_2/LOX) is one of the highest performance propellants, but LH_2 stored at standard conditions has a relatively low density and high vapor pressure. Propellant densification can significantly improve this propellant's properties relative to vehicle design and engine performance. Vehicle performance calculations based on an average of existing launch vehicles indicate that densified propellants may allow an increase in payload mass of up to 5 percent.

Since the NASA Lewis Research Center became involved with the National Aerospace Plane program in the 1980's, it has been leading the way in making densified propellants a viable fuel for next-generation launch vehicles. Lewis researchers have been working to provide a method and critical data for continuous production of densified hydrogen and oxygen.



Integrated reusable launch vehicle propellant tank and liquid hydrogen propellant densification unit based on thermodynamic vent principle.

The LH_2 production process is shown in the simplified schematic. This 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 hydrogen, and a nitrogen boiling bath is used for oxygen. In December 1996, Lewis engineers demonstrated successful operation of an LH_2 propellant densification unit that can subcool LH_2 to near triple-point conditions with this continuous process.

In October 1996, Lewis engineers demonstrated the successful ignition of an existing RL10B-2 rocket engine with densified hydrogen. The fuel pump inlet temperature for the densified hydrogen ignition demonstration test was 27 °R in comparison to 39 °R for the nominal test. The only difference in the ignition sequence between the tests was the time of ignitor activation. For the densified ignition demonstration, the ignitor was activated earlier (T+0.082 sec in comparison to T+0.27 sec for the nominal test). This was done to account for the slight increase in oxygen-to-hydrogen ratio resulting from hydrogen densification. Ignition for the nominal test occurred at 281 msec, whereas ignition for the densified test occurred at 244 msec.

This work has provided the critical steps to bring densified propellants to a technology readiness level of six. As a result, densified propellants will be flown as a flight experiment on the last two flights of the X-33 and are baselined as the fuel for next-generation reusable launch vehicles.

References

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