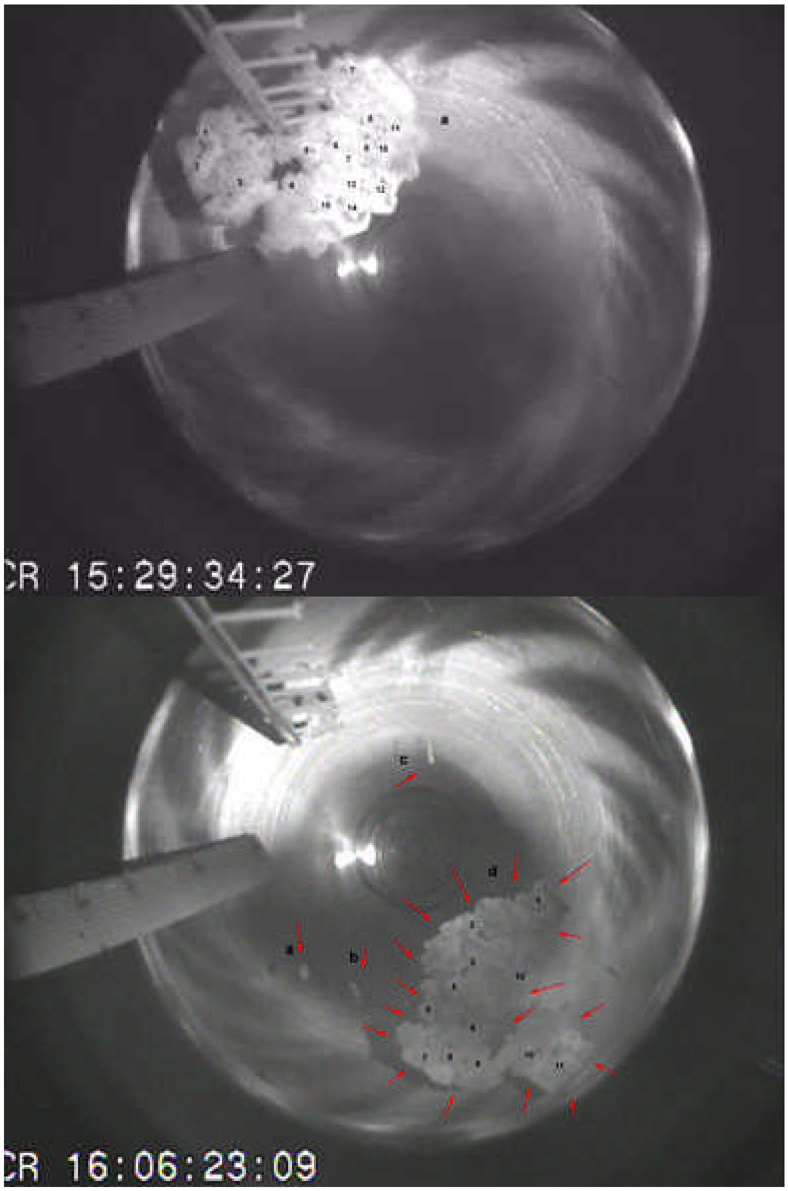
# Solid Hydrogen Particles and Flow Rates Analyzed for Atomic Fuels




*Left: Photograph of solid hydrogen particles floating on the surface of a liquid helium bath. A large number of the frozen particles have clumped together. Right: Photograph of the solid hydrogen particles with unique shapes for the clumped crystals. Some are shaped like long bars.*

Researchers at the NASA Glenn Research Center improved their understanding of tiny particles of frozen hydrogen, an ice that exists at -452 °F (about 4 K, or 4 degrees above absolute zero). This research is directed toward improved very high specific impulse aerospace vehicles (refs. 1 to 4).

The experiments were conducted at Glenn’s Small Multipurpose Research Facility (SMIRF, ref. 5). The experimental setup was placed in the facility’s vacuum tank to prevent heat leaks and subsequent boiloff of the liquid helium. Supporting systems maintained the temperature and pressure of the liquid helium bath where the solid particles were created.

Solid hydrogen particle formation was tested from February 23 to April 2, 2001. Millimeter-sized solid-hydrogen particles were formed in a Dewar of liquid helium as a prelude to creating atomic fuels and propellants for aerospace vehicles. Atomic fuels or propellants are created when atomic boron, carbon, or hydrogen is stored in solid hydrogen particles. The current testing characterized the solid hydrogen particles without the atomic species, as a first step to creating a feed system for the atomic fuels and propellants. This testing did not create atomic species, but only sought to understand the solid hydrogen particle formation and behavior in the liquid helium.

In these tests, video images of the solid particle formation were recorded, and the total mass flow rate of the hydrogen was measured. The mass of hydrogen that went into the gaseous phase was also recorded using a commercially available residual gas analyzer. The temperatures, pressures, and flow rates of the liquids and gases in the test apparatus were recorded as well.

Testing conducted in 1999 recorded particles as small as 2 to 5 mm in diameter. The current testing extended the testing conditions to a very cold Dewar ullage gas of about 20 to 90 K above the 4 K liquid helium. With the very cold Dewar gas, the hydrogen freezing process took on new dimensions, in some cases creating particles so small that they seemed to be microscopic, appearing as infinitesimally small scintillations on the videotaped images.

With a warm ullage gas (170 to 250 K), the current testing also found that the efficiency of creating the solid hydrogen was about 66 to 69 percent. This means that up to 34 percent of the hydrogen entering the Dewar was lost, implying that although a large fraction of the hydrogen froze, about one-third was lost up the stack. This is based on analyses of 2 of the 11 days of data. The remaining experiments, conducted with a lower ullage gas temperature, may lead to higher efficiency solid-hydrogen production. Data from these remaining experiments are under continuing analysis.

**Find out more about Small Business Innovation Research on fuels and space propellants http://sbir.grc.nasa.gov/launch/foctopsb.htm.**

# References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