Automotive Cryogenic Capable Pressure Vessels for Compact, High Dormancy (L)H₂ Storage

Salvador Aceves, Gene Berry, Francisco Espinosa, Tim Ross, Vernon Switzer, Andrew Weisberg, Elias Ledesma-Orozco

Lawrence Livermore National Laboratory
June 10, 2008

This presentation does not contain any proprietary or confidential information

Project ID # TV9
Overview

Timeline
• Start date: October 2004
• End date: September 2011
• Percent complete: 60%

Budget
• Total project funding
  – DOE: $2500 k
• Funding received in FY08:
  – $800 k
• Funding for FY07:
  – $750 k

Barriers
• A. Volume and weight
• O. Hydrogen boil-off

Targets
• 2010 DOE volume target
• 2010 DOE weight target

Partners
• Finalizing CRADA with major automobile manufacturer
• Negotiating CRADA with major pressure vessel manufacturer
Objective: Demonstrate the practical advantages of cryogenic capable pressure vessels

- High energy density
- No evaporative losses
- Flexible refueling
- Safe
Milestones: We have made considerable progress toward demonstrating the practicality of cryogenic pressure vessels

- **Install pressure vessel in experimental Prius vehicle** (November 2006)

- **Demonstrate long vehicle range:** Drove 650 miles on a single H\(_2\) tank (January 2007)

- **Resolved technical risk of dormancy & high pressure:** Demonstrated potential for 3 weeks dormancy. Test cut short at 6 days due to valve (January 2008)

- **Demonstrating vacuum stability:** Stable vacuum measured at 10\(^{-5}\) torr or below as vessel warms from 30 K to ambient over ~ 1 month. Currently at 200 K (April 2008)
Approach: Study crucial aspects of cryogenic pressure vessels as onboard storage systems

- dormancy
- vacuum stability
- outgassing
- cycle test
Accomplishments: We integrated our cryogenic pressure vessel onboard an experimental hydrogen vehicle & demonstrated record unrefueled driving range (650 miles)

**LLNL Cryotank**
- Within 10% of DOE 2007 volume using LH₂ and including all system components
- Meets DOE 2007 weight goal
- stores 10.7 kg LH₂ (151 L capacity)
- stores 3.5 kg H₂ at 300 K, 5000 psi

**The vehicle**
- Toyota Prius converted to H₂ fuel by Quantum Technologies.
- Originally equipped with 5000 psi 68 L pressure vessels (1.6 kg H₂)
- Increased capacity to a single 151 liter vessel (3.5-10.7 kg)
We demonstrated longest LH₂ dormancy onboard a vehicle (6 days) and potential for 3 weeks at ~3.5 Watts heat transfer rate.
We demonstrated longest LH$_2$ dormancy onboard a vehicle (6 days) and potential for 3 weeks at ~3.5 Watts heat transfer rate.
Vacuum stability is a key issue for cryogenic vessels. We are measuring outgassing from the surface of vessels with multiple surface treatments.
We are conducting outgassing experiments inside an oven installed within a high pressure cell.
System was fully built, tested and baked. Three sets of experiments have been run.
At the request of our industrial partner, we have monitored vacuum quality over a month as our vessel warmed up from cryogenic to ambient temperature.
Our experimental results to date indicate good vacuum stability as the vessel warms up from 30 K to 200 K
Our cryogenic capable pressure vessels are projected to be less expensive than compressed hydrogen vessels.

Source: TIAH
Future plans: In collaboration with our industrial partners, design and manufacture a new cryogenic pressure vessel for full cycle testing.
Future plans: we will build and demonstrate a cryogenic capable onboard storage system meeting 2010 weight & volume targets.
Summary: We will demonstrate the most compact and we believe ultimately practical hydrogen storage technology

- **The high capacity of liquid hydrogen vessels without the evaporative losses:**
  ~10X longer thermal endurance than low pressure LH₂ tanks essentially eliminates boil-off.

- **Less expensive than compressed hydrogen vessels:** LH₂ capable vessels use 2-3x less carbon fiber than conventional compressed H₂ vessels.

- **Refueling flexibility yields infrastructure and driver advantages:**
  Meets real time driver priorities (range, cost, ease, energy) and increases fuel availability