



DOE Hydrogen Program

Inexpensive Delivery of Cold Hydrogen in High Performance Glass Fiber Composite Pressure Vessels

**Andrew Weisberg, Salvador Aceves,
Blake Myers, Gene Berry,
Francisco Espinosa, Tim Ross,
Elias Ledesma-Orozco**

**Lawrence Livermore National Laboratory
June 11, 2008**

This presentation does not contain any proprietary or confidential information

Project ID #
PDP8



Overview

Timeline

- Start date: **June 2008**
- End date: **June 2011**
- Percent complete: **0%**

Budget

- Total project funding
 - DOE: **\$1500 k**
 - Spencer: **\$375 k**
- Funding received in FY08:
 - **\$500 k**
- Funding for FY07:
 - **New project**

Barriers

- **F. Gaseous hydrogen storage and tube trailer delivery cost**

Targets

- **700 kg tube trailer delivery capacity**
- **\$300 k purchase cost for 700 kg trailer**

Partners

- **Spencer Composites provides manufacturing expertise and cost share**

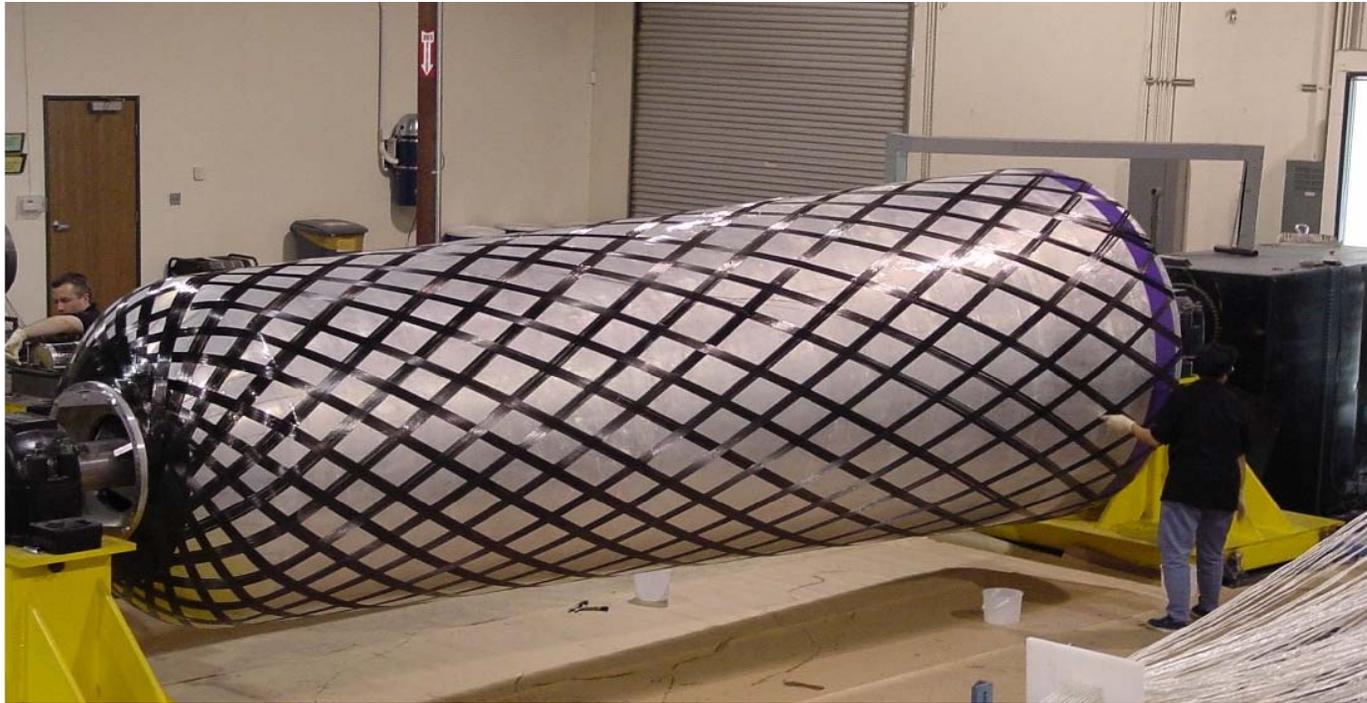


Objective: Demonstrate inexpensive hydrogen delivery through synergy between low temperature (200 K) hydrogen densification and glass fiber strengthening

- **Colder temperatures (~200 K) increase density ~35% with small increases in theoretical storage energy requirements**
- **Low temperatures are synergistic with glass fiber composites**
 - **higher glass fiber strength (by 50%?) at 200 Kelvin (vs. 300 K)**
 - **higher gH₂ density increases mass-limited trailer capacity**
- **glass composites (~\$1.50/kg) minimize material cost**
- **Increased pressure (7,000 psi) minimizes delivery costs**
- **Dispensing of cold hydrogen reduces vehicle vessel cost ~25%**



Milestones: We have established a detailed work plan leading to reduced hydrogen delivery cost



- *Produce Generation 1 cryogenic glass fiber vessel: June 2009*
- *Fabricate 3 Generation 2 pressure vessels with improved performance: October 2010*
- *Conduct performance tests on Generation 2 vessels: April 2011*
- *Write final report: June 2011*



Approach: Build and test inexpensive glass fiber pressure vessels that reduce hydrogen delivery cost to below \$1/kg



Wind vessels



Test at cryogenic conditions



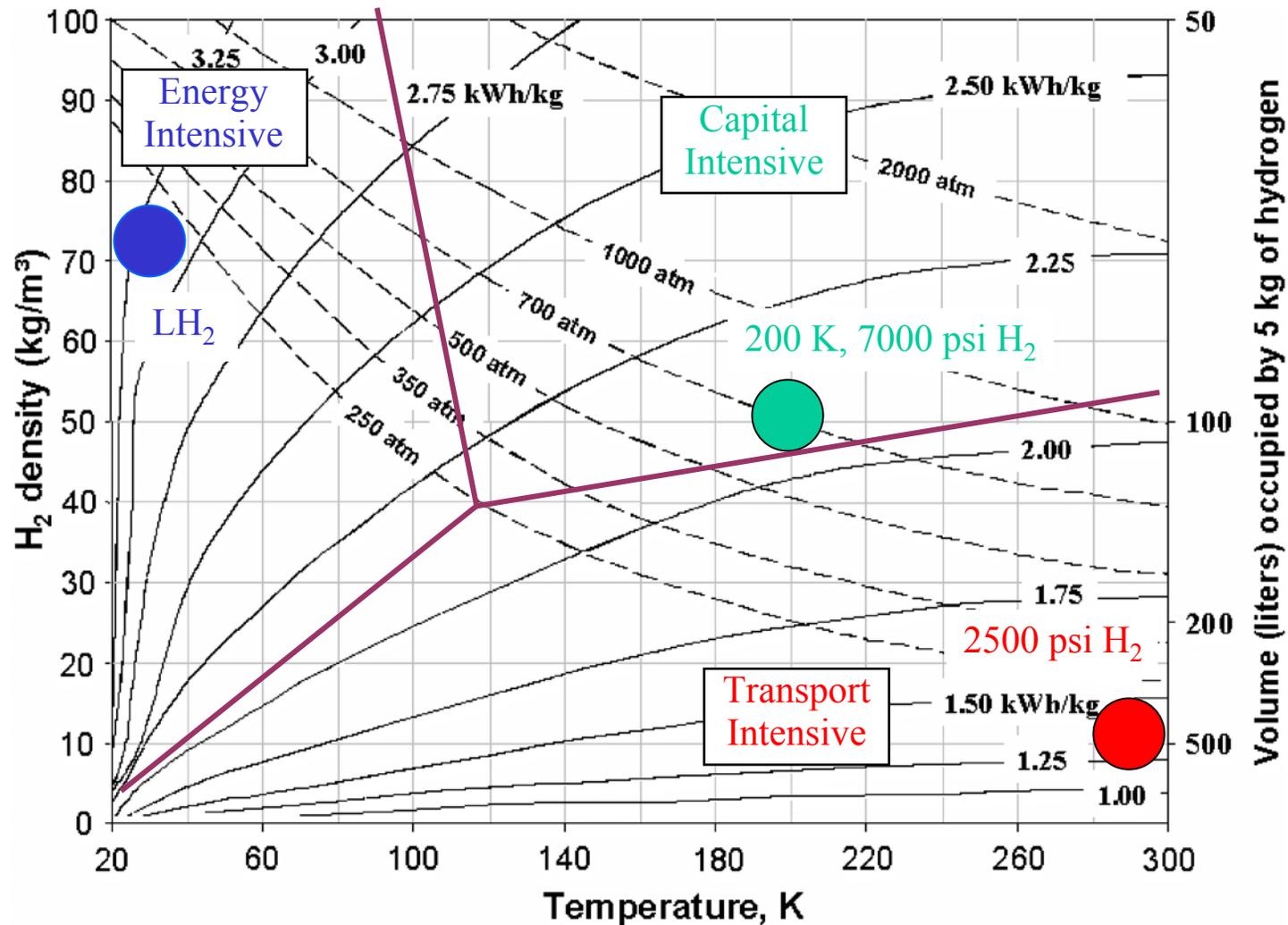
Burst tests



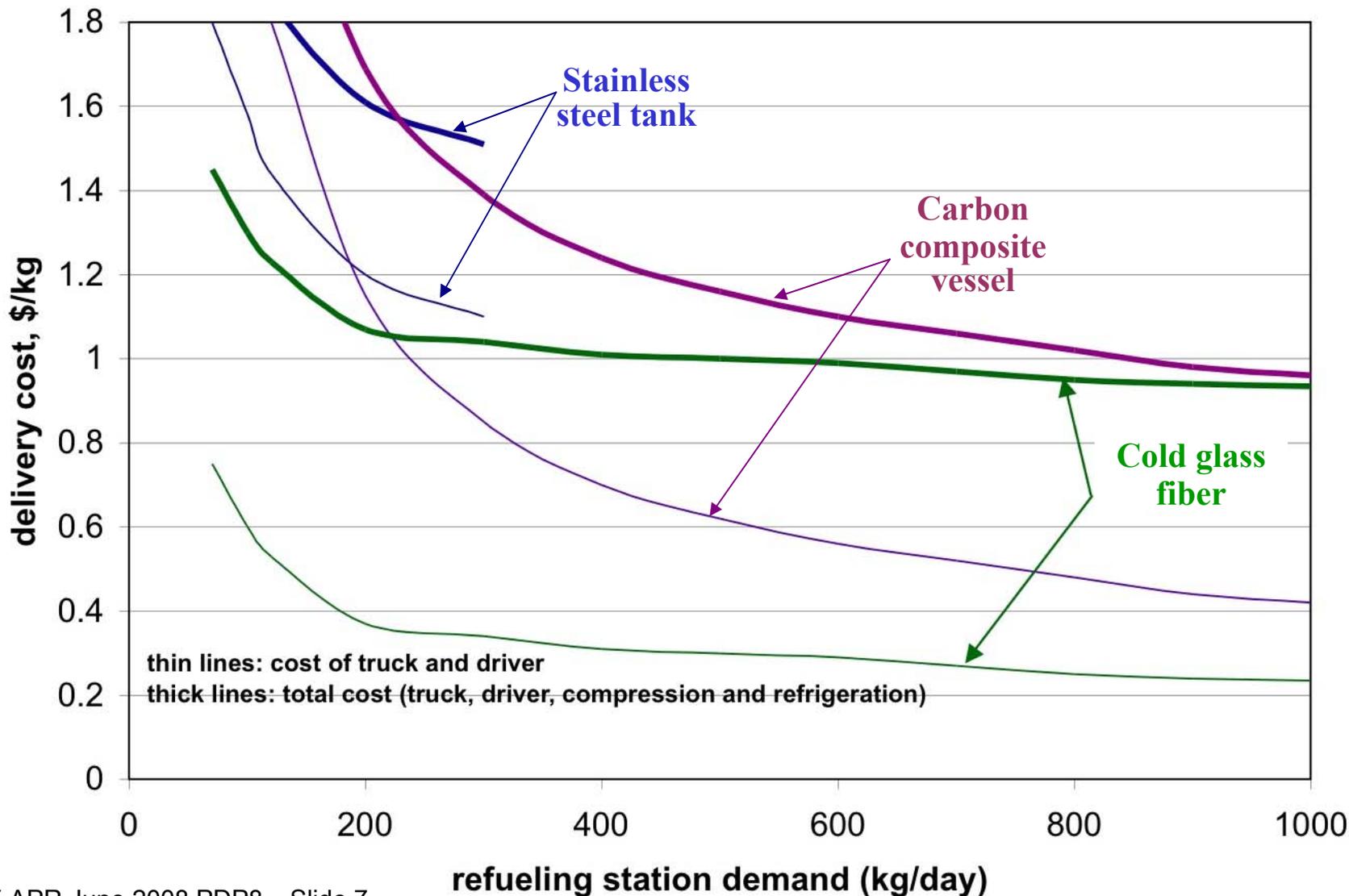
Cycle test



Accomplishments: we have identified an operating regime (200 K, 7 ksi) that shows promise for minimizing delivery cost

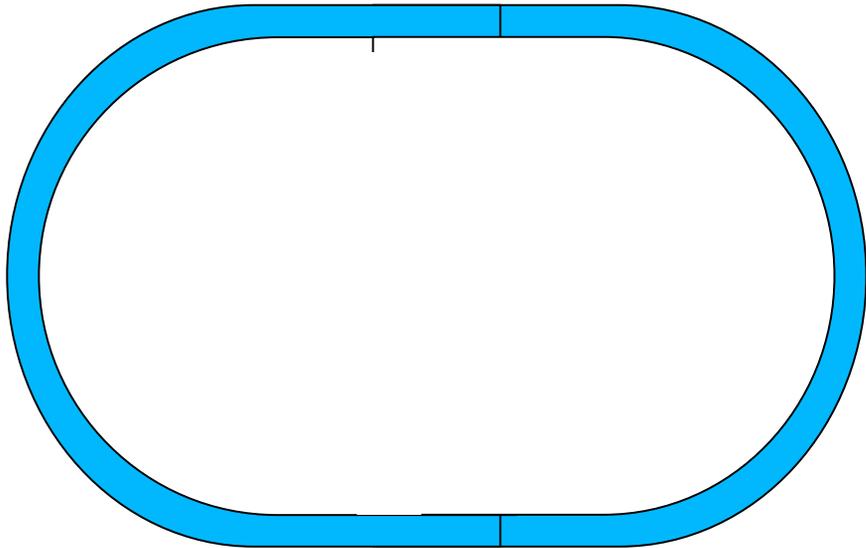


Cold glass fiber pressure vessels minimize tanker truck cost, enabling inexpensive hydrogen delivery



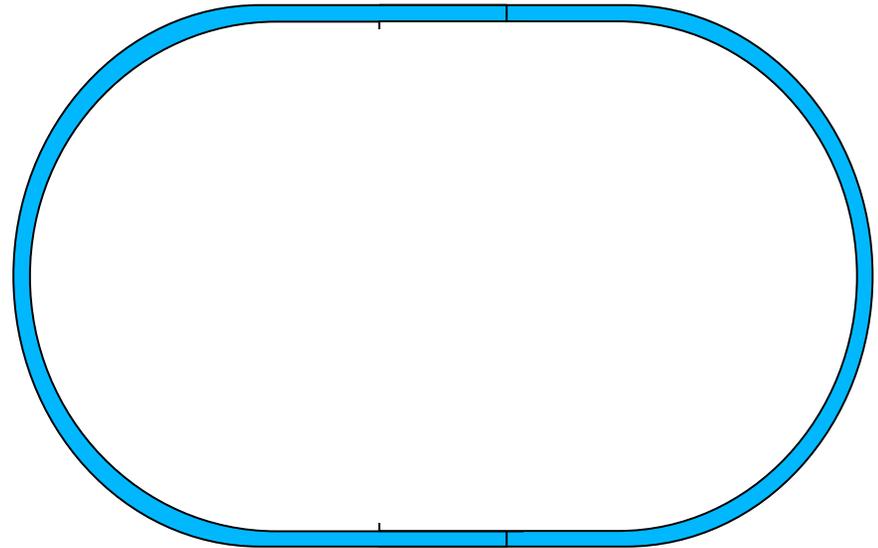
**Dispensing cold hydrogen avoids overpressure during fill,
reducing vessel cost by 25%**

**Reduced vessel cost saves a driver \$0.20/kg H₂
(assuming a vessel that meets the 2010 DOE goal of \$4/kWh)**



Today's automotive vessel

- **Filled with warm hydrogen**
- **Service pressure: 5000 psi**
- **Fill pressure: 6250 psi**
- **Burst pressure: 11,250 psi**
- **Cost: \$ 1333 (2010 goal)**



Future automotive vessel

- **filled only with cold H₂**
- **Service pressure: 5000 psi**
- **Fill pressure: 5000 psi**
- **Burst pressure: 9000 psi**
- **Cost: \$ 1066**



We have demonstrated the feasibility and practical advantage of cryogenic pressure vessels in an experimental vehicle



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

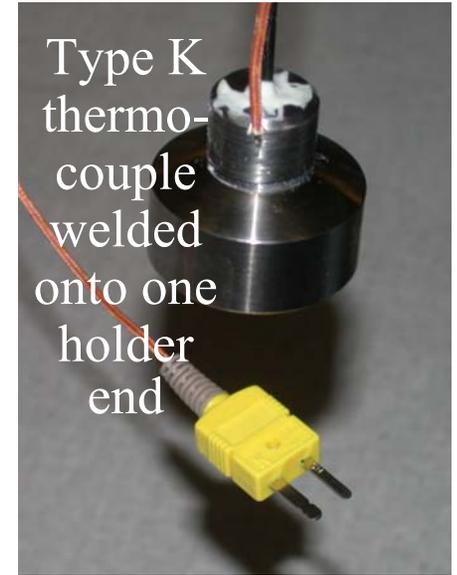
- *Less expensive than compressed hydrogen vessels:* LH₂ capable vessels use 2-3x less carbon fiber than conventional compressed H₂ vessels.



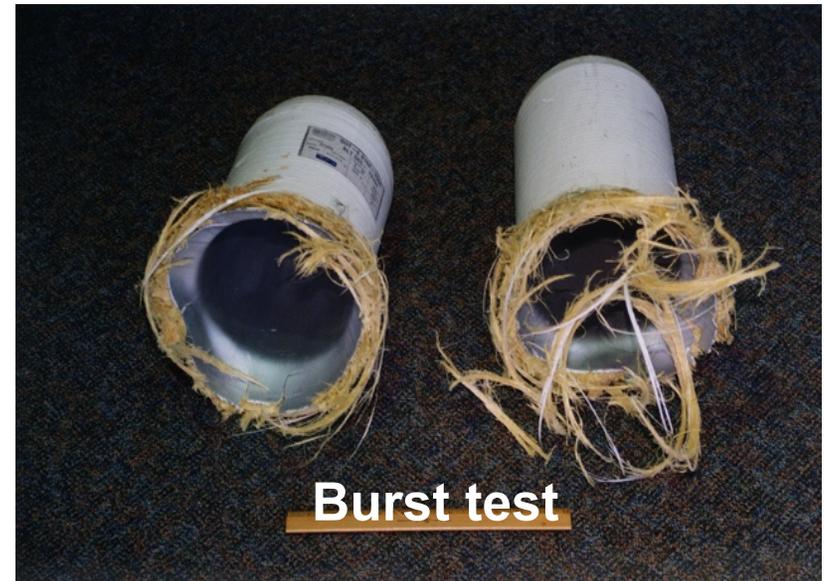
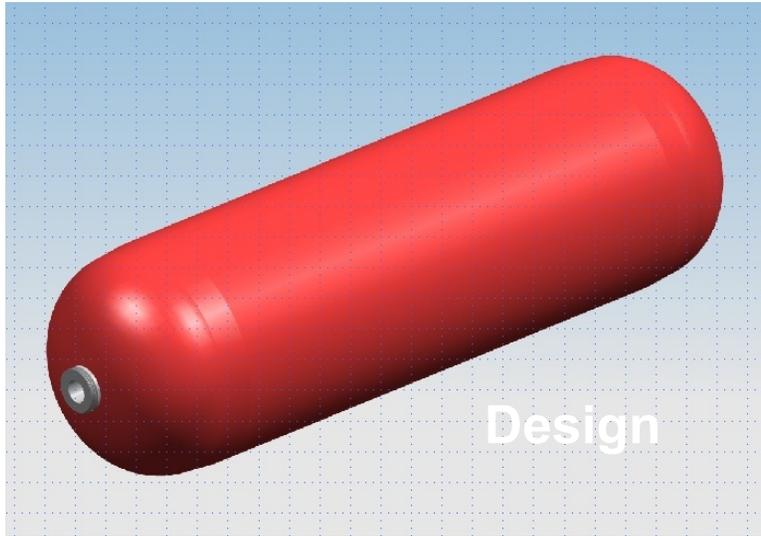
- *Infrastructure and driver advantages from refueling flexibility:* Meets real time driver priorities (range, cost, ease, energy), saves energy of cooling and liquefaction and increases fuel availability.



In a parallel effort, we are measuring the strengthening of glass fiber at reduced temperature



Future work: Build and test inexpensive glass fiber pressure vessels that considerably reduce the cost of hydrogen delivery



Summary: Our synergistic approach to hydrogen delivery considerably reduces distribution cost



Support Frames
(not shown)



36 Wound Tanks

- *Hydrogen cooled to 200 K densifies by 35% at low energetic cost*
- *Inexpensive glass fiber strengthens by ~50% when cooled to 200 K*
- *Cryo-compressed vessels have considerably larger thermal endurance (~10x) than liquid hydrogen tanks*
- *Dispensing of cold (200 K) hydrogen reduces vehicle vessel cost by 25%*

