Development of Improved Composite Pressure Vessels for Hydrogen Storage

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Lincoln Composites

20 May 2009

Project ID# STP_15_Newhouse

Overview

Timeline

- Phase 1 start 1 Feb 2009
- Phase 1 end 31 Jan 2011
- 3% complete

Budget

- Project funding $2,000,000
- Phase 1 funding $761,466
  - DOE share $609,156
  - Contractor share $152,290
- FY08 = $ 0
- FY09 = $300,000 (plan)

Barriers

- Barriers addressed
  - A. System Weight and Volume
  - B. System Cost
  - G. Materials of Construction
- Targets (2010)
  - Gravimetric capacity > 6%
  - Volumetric capacity > 0.045 kg H_2/L
  - Storage system cost < $133/kg H_2

Partners

- HSECoE HSECoE
  SRNL, PNNL, LANL, JPL, NREL, UTRC, GM, Ford, LC, Oregon State Univ, UQTR
- Project lead = Don Anton, SRNL SRNL

Objectives

- Meet DOE 2010 and 2015 Hydrogen Storage Goals for the storage system by identifying appropriate materials and design approaches for the composite container

	2010	2015
Gravimetric capacity	> 6%	> 9%
Volumetric capacity	> 0.045 kg H_2/L	> 0.081 kg H_2/L
Storage system cost	< \$133/kg H_2	< \$67/kg H_2

- Maintain durability, operability, and safety characteristics that already meet DOE guidelines for 2010 and 2015
- Work with HSECoE Partners to identify pressure vessel characteristics and opportunities for performance improvement
- Develop high pressure tanks as are required to:
  - Enable hybrid tank approaches to meet weight and volume goals
  - Allow metal hydrides with slow charging kinetics to meet charging goals

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Phase 1 Approach

- *Establish and document baseline* design, materials, and manufacturing process
- Evaluate potential improvements for design, material, and process to achieve cylinder performance improvements for weight, volume, and cost
- Down select most promising engineering concepts
- Evaluate design concepts and ability to meet Go/No-Go requirements for moving forward
- Document progress in periodic reports and support HSECoE Partner meetings and teleconferences

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Phase 1 Milestones

- Establish baseline design and identify options for improvement
- Document baseline design summary
- Report on Phase 1 evaluation of design, material, and process improvements
- Identify the of most promising engineering concepts
- Report on Phase 1 selection of most promising design, material, and process improvements
- Document revised baseline design summary
- Evaluate likelihood of composite container meeting system and DOE objectives

Progress – Baseline Design/Materials

- Design
  - Fiber reinforced composite structure
  - Plastic liner /permeation barrier
  - Metallic end bosses
  - 350 bar pressure capability

- Materials
  - Carbon fiber
  - Epoxy resin
  - HDPE liner
  - AA 6061-T6 bosses

Progress – Potential Improvements

- Reinforcing fibers with higher delivered strength per unit cost
  - Decreased weight, decreased cost, increased volume
  - *Two higher strength commercial carbon fibers identified*
    - *Indicated 5%-10% higher strength*
    - *One is same cost as baseline, one is higher cost*
- Resin systems with lower cost per unit volume
  - Reduced cost, but must be traded against performance and manufacturability

Progress – Potential Improvements

- Toughened resin systems that provide better damage tolerance, allowing thinner composite walls
  - Decreased weight, increased volume
  - *Toughening agents for resin systems have been identified*
    - *ATBN has shown some promise in high energy impact testing*
    - *Additional materials have been identified for inclusion in study*
- Resin systems with high temperature capability
  - Meet safety goals in case of accidental thermal excursion

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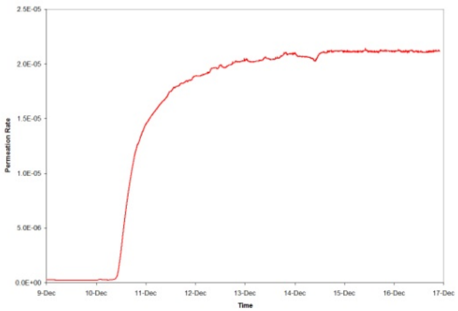
Progress – Potential Improvements

- Decrease safety factor requirements for reinforcing fibers
  - Decreased weight, decreased cost, increased volume
  - *Evaluate stress rupture, fatigue and damage tolerance characteristics further through Leader-of-the-Fleet testing*
    - *Leader-of-the-Fleet program has been drafted, is in review and comment by collaborators*
  - *Evaluate damage vs. impact to characterize safety and ability to remain in service after damage*
  - *Evaluate NDE as a means of monitoring the structural integrity, allowing thinner laminates and removal from service before rupture*
    - *Low cost AE sensors have been identified, are in evaluation for inclusion in LOTF program*

Progress – Potential Improvements

- Liner materials with lower permeation and absorption
  - Thinner liner decreases weight, increases volume if envelope limited, but may increase cost
  - Less absorption reduces potential for contamination
  - *Permeation testing with 5%H_2 / 95%N_2 is being conducted*
    - *Baseline results for HDPE liner material*
    - *Filled HDPE material showed no benefit*
    - *Filled alternate material showed 90% - 95% reduction in permeation, need to confirm other properties of alternate material*
    - *Additional filled materials are in process*
    - *Coatings are being evaluated*



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Progress – Potential Improvements

- Stronger boss materials, allowing thinner sections
  - Reduced cost and weight, increased volume
  - *Alternate boss materials are being evaluated*
    - *AA7075 has significantly higher yield and tensile strength than AA6061*
    - *316SS has higher tensile strength and temperature capability than AA6061*
- Manufacturing processes that increase throughput
  - Decreased overhead costs

Accomplishments

- Kick-off meeting in December 2008, Washington DC
- IP agreement signed January 2009
- Face to Face Meeting February 23-25, 2009, Golden, CO
- Safety plan completed May 1, 2009

Collaborations

Hydrogen Storage Engineering Center of Excellence

D. Anton, SRNL
T. Motyka, SRNL

Materials Operating Requirements

D. Herling, PNNL

- Materials Centers of Excellence Collaboration – SRNL, LANL, NREL
- Reactivity – UTRC
- Adsorption Properties – UQTR
- Metal Hydride Properties – SRNL
- Chemical Hydride Properties - LANL

Transport Phenomena

B. Hardy, SRNL

- Bulk Materials Handling – PNNL
- Mass Transport – SRNL
- Thermal Transport – SRNL
- Media Structure - GM

Enabling Technologies

J. Reiter, JPL

- Thermal Insulation – JPL
- Hydrogen Purity – UTRC
- Sensors – LANL
- Materials Compatibility – PNNL
- Pressure Vessels - PNNL

Performance Analysis

M. Thornton

- Vehicle Requirements– NREL
- Tank-to-Wheels Analysis – NREL
- Forecourt Requirements - UTRC
- Manufacturing & Cost Analysis - PNNL

Integrated Power Plant/ Storage System Modeling

D. Mosher, UTRC

- Off-Board Rechargeable - UTRC
- On-Board Rechargeable – GM
- Power Plant – Ford

Subscale Prototype Construction, Testing & Evaluation

T. Semelsberger, LANL

- Risk Assessment & Mitigation – UTRC
- System Design Concepts and Integration - LANL
- Design Optimization & Subscale Systems – LANL, SRNL, UQTR
- Fabricate Subscale Systems Components – SRNL, LANL
- Assemble & Evaluate subscale Systems – LANL, JPL, UQTR

Technology Area

Technology Area Lead

- Technology Team – TT Lead
- Technology Team – TT Lead
- Technology Team – TT Lead

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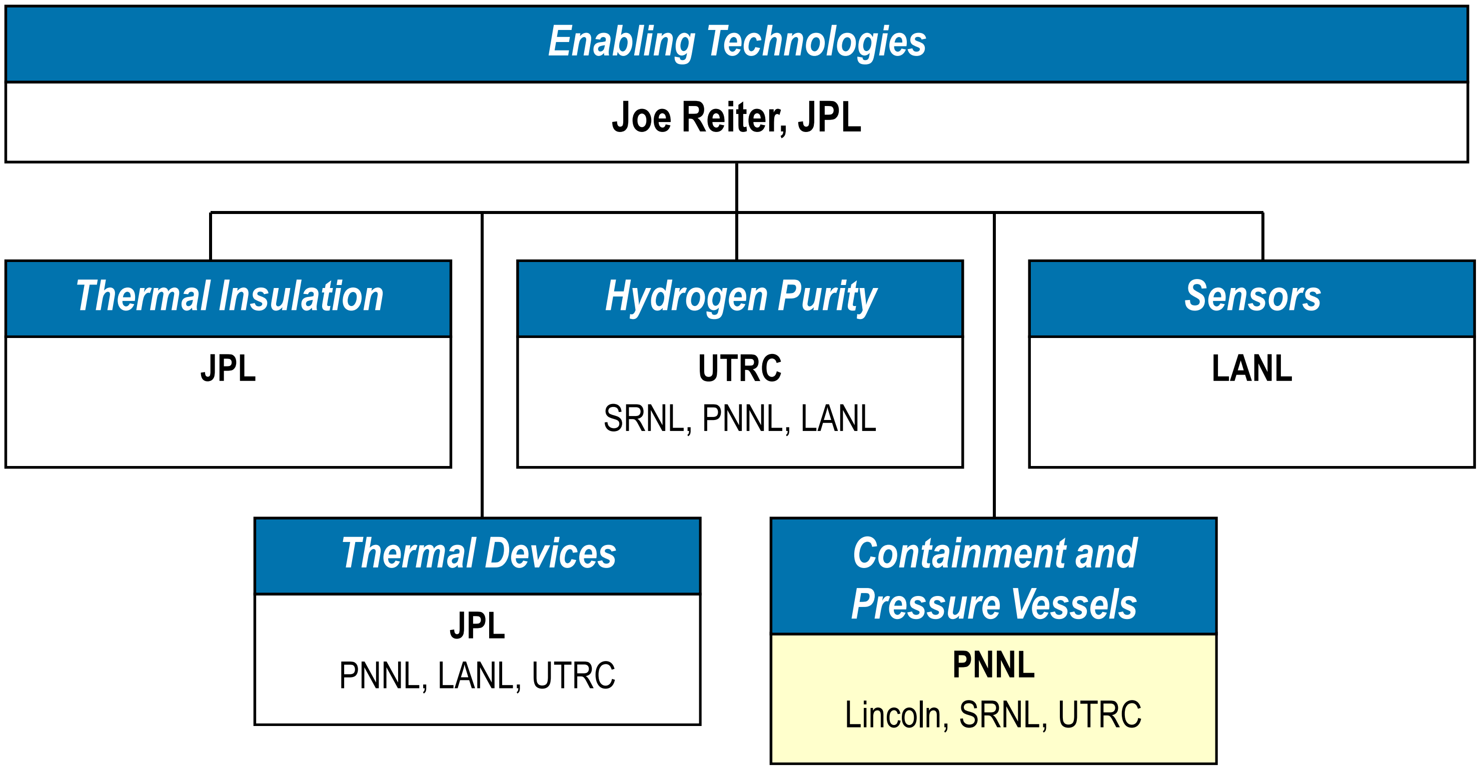
Collaborations



Collaborations

Subscale Prototype Construction, Testing, & Evaluation

T. Semelsberger, LANL

Risk Assessment & Mitigation

UTRC
All Other Partners

Design & Optimize Subscale Systems

LANL, SRNL, UQTR
JPL, UTRC, PNNL, OSU

Fabricate Subscale System Components

SRNL, LANL
Lincoln, OSU, PNNL, UTRC

Assemble & Evaluate Subscale System

LANL, JPL, UQTR

Future Work

- Continue progress on evaluating potential improvements
- Down select most promising engineering concepts.
- Evaluate design against DOE 2010 and 2015 Hydrogen Storage Go / No Go Criteria
- Phase 2 – continuation of container development in support of system requirements
- Phase 3 – fabrication of subscale containers to support assembly of prototype systems for evaluation

Summary

- Lincoln Composites has initiated work under the DOE contract funding the HSECoE
- Design, material and process improvements have been identified that show potential to meet DOE 2010 and 2015 goals for the storage system
- Work is progressing on schedule with expectation of meeting go/no-go criteria to proceed to Phase 2
  - 4 of the DOE 2010 numerical system storage targets must be fully met
  - The status of the remaining numerical targets must be at least 40% of the target or higher