III.6 Development of High Pressure Hydrogen Storage Tank for Storage and Gaseous Truck Delivery

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Fiscal Year (FY) 2012 Objectives

The objective of this project is to design and develop the most effective bulk hauling and storage solution for hydrogen in terms of:

- Cost
- Safety
- Weight
- Volumetric Efficiency

Technical Barriers

This project addresses the following technical barriers from the Hydrogen Delivery section of the Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan:

(E) Low Cost, High Capacity Solid and Liquid Hydrogen Carrier Systems

(G) Storage Tank Materials and Costs

Technical Targets

This project has focused primarily on the design and qualification of a 3,600 psi pressure vessel and International Organization for Standardization (ISO) frame system to yield a storage capacity solution of approximately 8,500-L of water (Figure 1). Original scope of project was to increase working pressure in current design. Together with DOE, scope has been changed to work towards increasing available volume at the 3,600 psi working pressure.

FY 2012 Accomplishments

Lincoln Composites designed and received a custom-built trailer, see Figure 2, capable of holding four 40-foot pressure vessels and an additional 30 foot pressure vessel. This new design has the potential to increase overall capacity by roughly 18%. Prototype trailer, minus vessels, plumbing, fire protection was received in the first quarter of 2012.

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FIGURE 1. Assembled ISO Container without Outer Panels

TABLE 1. Progress towards Meeting Technical Targets for Hydrogen Storage

Characteristic	Units	2010 Target	2015 Target	2015 Target (Draft)	2020 Target (Draft)	Status	Comments
Storage Costs	$/kg	$500/kg	$300/kg	$300/kg		$500/kg	
Volumetric Capacity	kg/liter	0.030 kg/liter	>0.035 kg/liter	>0.035 kg/liter		0.018 kg/liter	
Delivery Capacity, Trailer	kg	700 kg	1,100 kg	700 kg	940 kg	616 kg	Potential to see 726/775 kg with new Titan5/Titan 5+

Introduction

Hydrogen holds the long-term potential to solve two critical problems related to energy use: energy security and climate control. The U.S. transportation sector is almost completely reliant on petroleum, over half of which is currently imported, and tailpipe emissions remain one of the country's key air quality concerns. Fuel cell vehicles operating on hydrogen produced from domestically available resources would dramatically decrease greenhouse gases and other emissions, while also reducing our dependence on oil from politically volatile regions of the world.

Successful commercialization of hydrogen fuel cell vehicles will depend upon the creation of a hydrogen delivery infrastructure that provides the same level of safety, ease, and functionality as the existing gasoline delivery infrastructure. Today, compressed hydrogen is shipped in tube trailers at pressures up to 3,000 psi (about 200 bar). However, the low hydrogen-carrying capacity of these tube trailers results in high delivery costs.

Hydrogen rail delivery is currently economically feasible only for cryogenic liquid hydrogen; however, almost no hydrogen is transported by rail. Reasons include the lack of timely scheduling and transport to avoid excessive hydrogen boil-off and the lack of rail cars capable of handling cryogenic liquid hydrogen. Hydrogen transport by barge faces similar issues in that few vessels are designed to handle the transport of hydrogen over inland waterways. Lincoln Composites' ISO tank assembly will not only provide a technically feasible method to transport compressed hydrogen over rail and water, but a more cost and weight efficient means as well.

Approach

In Phase 1 of this project, Lincoln Composites will design and qualify a large composite pressure vessel and ISO frame that can be used for storage and transport of compressed hydrogen over road, rail or water.

FIGURE 2. Prototype Titan5 Trailer Delivered

The baseline composite vessel will have a 3,600 psi service pressure, an outer diameter of 42.8 inches and a length of 38.3 feet. The weight of this tank will be approximately 2,485 kg. The internal volume is equal to 8,500 liters water capacity and will contain 150 kg of compressed hydrogen gas. The contained hydrogen will be approximately 6.0% of the tank weight (5.7% of the combined weight.

Four of these tanks will be mounted in a custom-designed ISO frame, resulting in an assembly with a combined capacity of 600 kg of hydrogen. Installing the compressed hydrogen vessels into an ISO frame offers a benefit of having one solution for both transportable and stationary storage. This decreases research and development costs as well as the amount of infrastructure and equipment needed for both applications.

The large size of the vessel also offers benefits. A limited number of large tanks is easier to package into the container and requires fewer valves and fittings. This results in higher system reliability and lower system cost. The larger diameter also means thicker tank walls, which will make the vessel more robust and damage tolerant.

Phase 2 of the project was originally scoped to evaluate using the same approximate sized vessel(s) and ISO frame at elevated pressures. In the past year, Lincoln Composites determined that there are concerns with moving forward with higher pressure delivery modules. The market is difficult to forecast at this time and the cost to fully qualify a higher pressure module estimated at $5 MM to complete. Based on this, it was determined that Lincoln Composites would work with our current product and move forward with increasing the potential volume per load as well as improvements in safety. Other projects include the evaluation, testing and qualification of an improved fire protection systems as well a laboratory to begin looking at the effects of hydrogen on liner materials.

Results

Lincoln Composites has worked directly with DOE in determining the need to progress in the qualification of a 5,000 psi is not feasible at this time. The high cost to complete this qualification and lack of market needs has put this development on hold. Lincoln Composites is therefore concentrating efforts on the further development of our current module.

Lincoln Composites has designed a Titan5 trailer capable of increasing total payload capacity by 18% as compared with current Titan module that is in production, see Figure 3 for illustration. This new module will utilize the same four cylinders with the addition of a single 30' tank placed lower in the assembly utilizing space between the axels of the trailer.

Lincoln Composites has also began the design and evaluation of more robust fire protection system utilizing

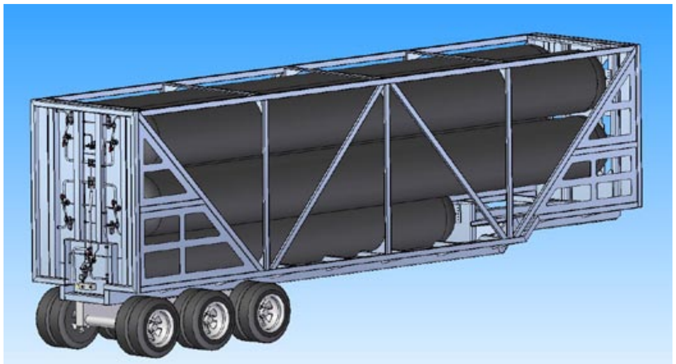

FIGURE 3. Drawing of Titan5

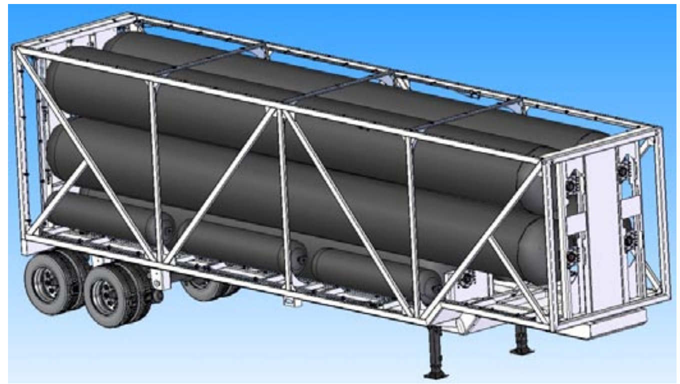

FIGURE 4. Drawing of Titan5 with Additional Capacity

memory metal as a trigger mechanism for de-pressurizing the tank in the case of a fire. This also greatly reduces the cost of the system in both components and labor for assembly. The reduction of components in the system affects the potential number of failure modes that could occur and thus making for a more reliable product.

The installation of a 100% hydrogen testing facility is nearly complete. This laboratory will be used to fully investigate new materials with the potential for them to be integrated into liners. Specifically, these alternate materials will be quantified and qualified as a means to reduce the permeation rates that are present in current Type 4 cylinders.

To further enhance product offering, the development/design of a Titan5 with additional capacity has been initiated. This design will utilize the Titan5 as a baseline with the addition of 6 smaller tanks on either side of the 30' single tank at the bottom of the module. See Figure 4 for illustration of this design. This configuration has the potential to increase capacity by 26% when compared to the standard 4 cylinder module. This translates to an overall payload of 775 kg of hydrogen.

Conclusions and Future Directions

- Proposed objectives for Phase 1 of this project were completed in the fourth quarter of 2009. This includes successful completion of a large 3,600 psi pressure vessel able to contain 8,500 liter water capacity. The successful qualification of an entire assembly into an ISO container was also completed. The delivery of a Titan5 trailer was realized that, when fully completed, will add an additional 18% capacity with respect to our current production module.
- Future work will consist of completing the prototype Titan5 trailer with pressure vessels, plumbing and fire protection to demonstrate a working module. Plans to perform testing with 100% hydrogen on liner materials will move forward as a means to reduce permeation. Completion of the testing of enhanced fire protection to be completed within the next nine months.
- Completion of the qualification and implementation of a safer and more reliable fire production system. This to include a new trigger mechanism for de-pressurizing systems in case of fire.

FY 2012 Publications/Presentations

1. 2012 DOE Hydrogen Program Annual Merit Review, May 17, 2012.