Insulated Pressure Vessels for Vehicular Hydrogen and Natural Gas Storage

Contractor: Structural Composites Industries (SCI), Lawrence Livermore National Laboratory (LLNL), SunLine Transit

Cosponsors: Department of Energy (DOE)

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Background

Hydrogen (H_2) differs from other fuels in that it can be produced (and used) without releasing the potent greenhouse gas CO_2, by simple decomposition of water (H_2O) using electricity and/or heat from solar, wind, fission, or fusion power sources. As a versatile and universal carbonless energy carrier, H_2 is a necessary element for future energy systems aimed at being free of air pollution, CO_2, and other greenhouse gases. If generated from renewable energy, H_2 becomes the crucial link in an inexhaustible global fuel cycle based on the cleanest, most abundant, natural, and elementary substances: H_2, O_2, and H_2O.

The physical and chemical properties of hydrogen make its utilization superior to fossil fuels. H_2 is a simple, non-toxic molecule that generates power cleanly and efficiently, even silently and without combustion, if desired. Widespread use of H_2 has been challenging, however, because of its low energy density relative to conventional (hydrocarbon) fuels. Energy density fundamentally drives the feasibility of H_2–fueled transportation by determining the capital, materials, volume, and energy needed for onboard storage.

Project Objective

Considering the importance of storage in achieving a smooth transition to the H_2 economy, and the serious technical challenges associated with H_2 storage, we have demonstrated the applicability of an alternative approach for vehicular H_2 storage: insulated pressure vessels.

In this work we have designed and built an insulated pressure vessel, developed a draft set of certification standards for insulated pressure vessels, and demonstrated the technology on a hydrogen fueled pickup truck and tested extensively by fueling it multiple times with liquid and compressed hydrogen and by driving the vehicle..

Technology Description

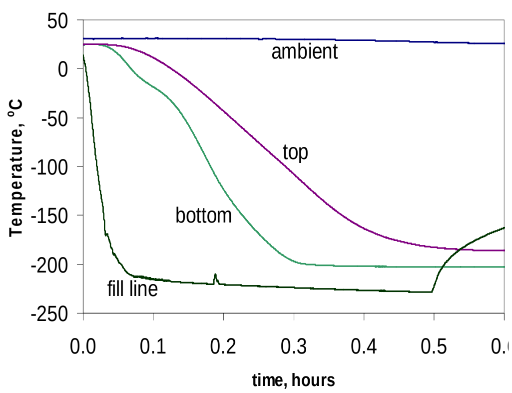
The proposed alternative to vehicular hydrogen storage consists of storing fuel in an insulated pressure vessel that has the capability to operate at cryogenic temperature (20 K), and at high pressure (240 atm or higher). This vessel can be fueled exclusively with LH_2, or it can be fueled flexibly with LH_2, cryogenic GH_2, or ambient temperature GH_2. In both modes of operation insulated pressure vessels present advantages with respect to conventional LH_2 and GH2 vessels.

If the insulated pressure vessel is always fueled with LH_2, it becomes a compact vessel that goes a long way toward solving most of the problems associated with LH_2 tanks: evaporative losses after a short period of inactivity, high evaporative losses for short daily driving distances, danger of being stranded due to fuel evaporation and need for considerable (10-20%) ullage space. Compressed H_2 heats up considerably as it is pumped into a storage vessel, reducing the density of storage. At high pressure, H_2 is not an ideal gas, considerably reducing the increase in density that can be obtained by increasing the pressure. Insulated pressure vessels have the advantage with respect to compressed hydrogen of delivering a long vehicle range and no compression heating if fueled with liquid hydrogen.

Status
The project has been successfully completed. The insulated pressure vessel was built in March of 2004, installed in the pickup truck in June of 2004, tested at LLNL in July of 2004, and delivered to SunLine in August of 2004. The truck was tested in SunLine for 6 months. The test was successfully completed and the final report was written in September of 2005.

Results
In this project we have demonstrated the possibility of flexibly refueling an insulated pressure vessel. The insulated pressure vessel was refueled multiple times with no physical damage to the vessel. The figure shows temperature in the pressure vessel during the liquid hydrogen fill operation. The figure shows that the vessel cools down from ambient temperature in approximately 0.3 hours (18 minutes). The fill line is in direct contact with liquid hydrogen and therefore cools down very quickly.

The other two thermocouples are located outside the vessel, and therefore take more time to cool down due to thermal lag through the vessel wall. The thermocouple located at the bottom of the vessel cools down faster, since the liquid accumulates there first. The thermocouple at the top is not in direct contact with liquid hydrogen until the vessel is completely full, and therefore remains warmer.



Benefits
This project has demonstrated the benefits of insulated pressure vessels and their advantages with respect to LH_2 and GH_2 tanks. Insulated pressure vessels offer flexibility and savings, both in terms of energy and cost. From engineering and economic perspectives, insulated pressure vessels strike a versatile balance between the cost and bulk of ambient temperature compressed fuel storage, and the energy efficiency, thermal insulation and evaporative losses of cryogenic storage.

Project Costs
The AQMD contribution for this project was $350,000. The cost share was $200,000 from DOE and $100,000 from SCI. Total cost of the project was $650,000.

Commercialization and Applications
This technology applies to vehicular hydrogen storage, for automobiles as well as buses and trucks. In the near future we will further develop this technology and demonstrate it in another vehicle (a Toyota Prius), and develop cryogenic compatible vessels for hydrogen delivery trucks (with DOE funding).

Commercialization beyond demonstration projects will take some time, due to the futuristic nature of this project and of the hydrogen economy. However, we anticipate that this technology has a good future as a potential solution to the very challenging technical issues of hydrogen storage.

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