

Advanced Hydrogen Fueling Station Supply : Tube Trailers

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Air Products and Chemicals, Inc.

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Project ID #
TV028

Overview

Timeline

- Project Start Date: 09/01/2014
- Planned Kick-Off Date: June 2016
- Project End Date: 09/30/2018
- Project Duration: 32 months

Budget

- Total Project Budget: \$1,943,765
 - Total Recipient Share: \$1,006,249
 - Cost Share 52%
 - Total Federal Share: \$937,516
 - Cost Share 48%
 - Total DOE Funds Spent*: \$0

Barriers

- Barriers addressed
 - **Gaseous Hydrogen Storage and Tube Trailer Delivery Costs** from central production
 - **Cost of Gaseous Hydrogen Compression** at retail hydrogen forecourt

Partners

- US DOE
- Air Products
- Worthington Cylinders

* As of 3/31/16

Relevance

- Develop and validate advanced hydrogen tube trailers to support hydrogen and fuel cell market.
 - Conduct engineering design of new composite over-wrapped pressure vessel (COPV) to increase the pressure capability of tube trailers beyond DOE Technical target(s) and current industry benchmark

| Gaseous Hydrogen Tube Trailers | | | |
|--------------------------------|--------------------|--------------------|--------------------|
| Current targets* | <u>2011 Status</u> | <u>2015 Status</u> | <u>2020 Target</u> |
| Payload (kg) | 560 | 720 | 1100 |
| Pressure (bar) | 250 | 250 | 500 |
| Capital (\$/kg) | 930 | 720 | 600 |
| Lifetime (yrs) | - | 30 | 30 |

- Increasing hydrogen delivery pressure ≥ 586 bar (8500 psig) will increase capacity of hydrogen deliveries and can reduce the need for compression at hydrogen fueling stations and lower overall hydrogen delivery cost

*DOE Technical Targets for Hydrogen Delivery <http://energy.gov/eere/fuelcells/doe-technical-targets-hydrogen-delivery>

Approach

Task 1: Preliminary Study, Modeling, and Analysis (Duration: 6 months)

Goal: Confirm Viability of Higher Pressure Storage Solution

Go/No-Go

Task 2: Develop 586 bar (8500 psi) Or Higher Vessel (Duration: 11 months)

Goal: Complete Vessel Design, Fabricate, and Test; Receive DOT Approval

Go No-Go

Task 3: Design, Fabricate, and Test Delivery Trailer (Duration: 9 months)

Goal: HAZOP and Operability Review of Tube Module and Trailer; Test Unit

Task 4: Deploy Delivery Trailer and Collect Data (Duration: 6 months)

Goal: Measure Operational Performance At Hydrogen Stations

Task 5: Project Management and Reporting (Quarterly and Annual AMR)

Goal: Project Progress Technical and Financial Reporting to DOE

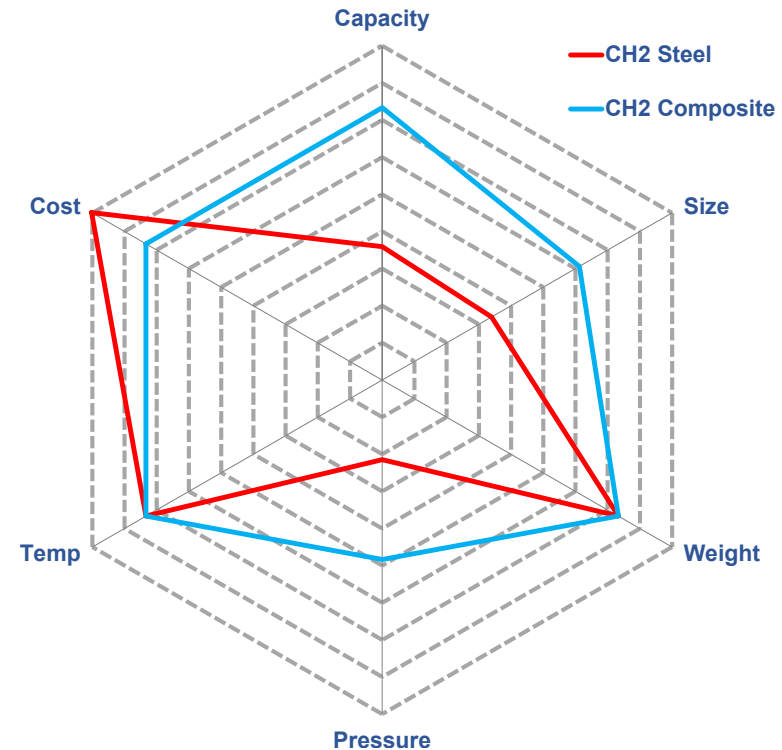
Approach- Milestones

- **Task 1.0** - Preliminary Study, Modeling, and Analysis
 - **SubTask 1.1:** Develop a preliminary design for storage vessels with consideration for vessel thickness, weight, length, and higher pressure \geq 586 bar (8500 psi)
 - **SubTask 1.2:** Air Products will consider various configurations for tube storage with consideration for trailer chassis size and tube configuration within the storage module frame

Go/No-Go Decision: Preliminary design analysis must prove the technical and cost viability of \geq 586 bar (8500 psi) hydrogen storage tubes and an appropriate frame and chassis configuration for a complete trailer

1- United States Department of Transportation (USDOT)

2- Hydrogen Refueling Station (HRS)



Design Constraints and Objectives

Capacity – Maximize H2 trailer payload (kg)

Size – Maximize to USDOT¹ limit and HRS² access

Weight – Maximize to USDOT limit

Pressure – Maximize to reduce or eliminate HRS compression

Temperature – Minimize to increase H2 density

Cost – Minimize cost per kg H2 delivered

Approach- Milestones

- **Task 2.0** - Develop New Tube Size for 586 bar (8500 psi) Vessel, Fabricate Tubes For Test Units, Perform Testing, and Submit Testing Results for DOT Special Permit
 - **SubTask 2.1:** Develop vessel suitable for hydrogen storage at ≥ 586 bar (8500 psi)
 - **SubTask 2.2:** Perform pressure cycling tests on an initial prototype vessel and identify potential optimization of vessel design.
 - **SubTask 2.3:** Manufacture vessels for US DOT certification testing
 - **SubTask 2.4:** Test high pressure units in accordance with International Organization for Standardization (ISO) 1119-2 criteria for hydrogen transport vessels
 - **SubTask 2.5:** – Submission of Special Permit application to US DOT
 - **SubTask 2.6:** Manufacture trailer cylinders after receipt of US DOT Special Permit

Go/No Go Decision: Project moves forward if DOT approval is obtained for use the ≥ 586 bar (8500 psi) vessels over the road

Approach- Milestones

- **Task 3.0** – Design, Fabricate, and Test a Delivery Trailer Unit
 - **SubTask 3.1:** Design manifold for delivery of hydrogen from the trailer unit to a hydrogen station
 - **SubTask 3.2:** Conduct Hazard and Operability Reviews On Completed Trailer Design
 - **SubTask 3.3:** Design Tube Module to Support Storage Vessels Designed in Task 2.0
 - **SubTask 3.4:** Select Chassis for Carriage of Tube Module
 - **SubTask 3.5:** Assemble and Test Complete Trailer Unit
- **Task 4.0** – Deploy Delivery Trailer to Hydrogen Station(s) and Collect Data

Approach- Milestones

- **Task 5.0** – Project Management and Reporting
 - **SubTask 5.1:** Progress/Technical and Financial Reporting Quarterly
 - **SubTask 5.2:** DOE Project Kick-Off and Review Meeting and DOE Annual Merit Review

Accomplishments and Progress

- Task 1.0 – Work has begun with Worthington Cylinders in support of the project objective of increasing hydrogen delivery pressure ≥ 586 bar (8500 psi)
 - Once project is officially kicked-off the work will explore hydrogen delivery pressure(s) greater than 700 bar (10000 psi)
 - Tube trailer cost model developed to support conceptual vessel design(s) and trailer configuration(s)
- Air Products is leveraging work outside of this project through commercialization of hydrogen distribution trailers with 520 bar (7500 psi) operating pressure at hydrogen stations in California and Europe
 - The work serves as important building block in further advancing light-weight composite tube trailer to the next level in the hydrogen energy market
 - The Learning by Doing experience helped identify and address technical challenges related to high pressure trailer design, components, and construction, along with high pressure trailer filling, trailer operability, and hydrogen fueling station interface. This project will directly benefit from this experience.

Accomplishments and Progress: Responses to Previous Year Reviewers' Comments

- This is a new project with expected official start in FY 2016 Q3
- The project was not reviewed last year at the 2015 DOE Annual Merit Review

Collaborations

- **DOE Hydrogen Safety Panel (HSP)** - Safety serves as the #1 Priority and project plan includes HSP review
- **Worthington Cylinders** - Composite vessel supplier and pressure vessel technology developer serves as the key project partner
- **National Renewable Energy Laboratory (NREL)** – Performance data pertaining to project will be provided to the National Fuel Cell Technology Evaluation Center (NFCTEC) at NREL for independent review and analysis

Remaining Challenges and Barriers

- Agreement among project partners on intellectual property rights that may develop under the program

Proposed Future Work

- **FY 2016:**
 - Develop a preliminary design for storage vessels with operating pressure of ≥ 586 bar (8500 psi)
 - Conduct feasibility analysis on new storage vessel and tube trailer design
 - Pending feasibility analysis, initiate manufacturing of proto-type vessels and conduct performance testing to validate engineering design
- **FY 2017:**
 - Complete new pressure vessel US DOT certification testing
 - Submit Special Permit application to US DOT
 - Pending DOT Special Permit manufacture vessels for new high pressure tube trailer

Technology Transfer Activities

- Air Products is committed to commercialize the new tube trailer supply across amenable hydrogen energy markets
- Advancement of tube trailer distribution to higher pressure under this program enables “compression-less” fueling at fill pressures greater than 350 bar (5000 psi) and result in providing greater fuel cell driving range
- Patents will be pursued on all new inventions discovered under this program



Summary

- **Objective:** Design, procure, construct, and demonstrate US DOT approved composite tube trailer with ≥ 586 bar (8500 psi) delivery pressure
- **Relevance:** This project aims to meet or exceed DOE's 2020 Delivery targets for tube trailer hydrogen distribution and has the potential to reduce the cost of hydrogen fueling stations
- **Approach:** Gated project approach with early project Go/No-Go decisions that will avoid wasteful spending and ensure likelihood of commercial success
- **Accomplishments:** A significant amount of preliminary work and learning have been accomplished by the project team prior to official project kick-off
- **Collaboration:** Strong team with good working relationship and support from DOE