III.17 FY 2009 SRNL Hydrogen Delivery Project—Hydrogen Permeability and Pipeline Integrity/Fiber Reinforced Composite Pipeline

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Objectives

Fiber Reinforced Composite (FRP) Pipeline

- Focused evaluation of FRP piping for hydrogen service applications.
- Assessment of the structural integrity of the FRP piping and leakage of existing commercial available FRP joint designs and joint components.

Technical Barriers

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

(D) High Capital Cost and Hydrogen Embrittlement of Pipelines
(I) Hydrogen Leakage and Sensors
(K) Safety, Codes and Standards, Permitting

Technical Targets

This project is focused on the evaluation of FRP piping for hydrogen service applications. Assessment of the structural integrity of the FRP piping and the individual manufacturing components in hydrogen will be performed. Insights gained will support qualifications of these materials for hydrogen service including the DOE 2012 delivery targets:

- Pipeline Transmission and Distribution Cost: $0.6 M/mile and $0.27 M/mile, respectively
- Hydrogen Leakage: TBD--<0.5% by 2017

Accomplishments

- Completed 9-month hydrogen exposures for FRP pipe sections, compression samples, tensile and dynamic mechanical analysis (DMA) samples.
- Completed commercial FRP joint leakage testing–established leak testing protocols and defined relevant testing conditions.
- Initiated FRP flexural load leak testing.
- Initiated FRP cyclic load leak testing.

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Introduction

The use of FRP materials for hydrogen service will rely on the demonstrated compatibility of these materials for pipeline service environments and operating conditions. The ability of the polymer piping to withstand degradation while in service, the fiber strength wrapping to resist hydrogen attack, and the fiber-resin interface to remain intact are all critical to the successful implementation of these materials for hydrogen pipeline. The goal of the overall project is to successfully adapt spoolable FRP from oil and natural gas use to high-pressure hydrogen use. As such, the current research effort has been focused on two aspects: 1) long-term exposures of FRP piping sections and materials to gaseous hydrogen for subsequent materials property testing, and 2) evaluation of leakage behavior of existing commercially available FRP joints and joint components.

Approach

SRNL has performed environmental exposure testing under accelerated conditions to simulate aging effects on FRP piping materials. This testing involves exposures of short piping sections to pure hydrogen environments at both ambient and non-ambient temperatures (140°F) and pressures of approximately 1,000 psig in order to evaluate hydrogen compatibility.

Additionally, a testing program has been initiated to evaluate current existing metallic joint components for FRP piping. Commercially available joint types are being leak tested and leakage rates recorded. The leak rate data for the joints will be applied to determine the acceptability of existing metal joints available for FRP pipe and will also aid in the development of new joint materials and designs if necessary for hydrogen service.

Results

Testing of FRP materials in Fiscal Year 2008 has focused on two major areas: 1) environmental exposure of FRP pipe section and materials of construction to gaseous hydrogen, and 2) leak testing of commercial FRP joint components. SRNL has completed the 9-month environmental exposures in support of Oak Ridge National Laboratory's (ORNL's) FRP materials testing effort. Multiple 4-ft sections of 2.5" outside diameter (OD) FRP pipe and materials test samples–tensile dog-bones, compression rings, DMA test strips–have been exposed to 99.9995% hydrogen gas at nominally 140°F and 1,000 psig in the newly designed, fabricated, and installed SRNL FRP hydrogen exposure station. Following exposure of these materials to gaseous hydrogen ORNL will work with a commercial FRP vendor to subject the 4-ft pipe sections to commercial standard product quality tests in addition to internally conducting materials evaluation testing on the exposed test samples.

In addition to the hydrogen exposure testing, leakage testing of commercially available FRP joint components has been initiated. Samples of 2.5" OD FRP piping with attached end fittings and joint fittings from two major FRP piping vendors–Fiberspar and Polyflow–have been procured. The Fiberspar technology makes use of an O-ring compression mechanical system to maintain seal integrity while the Polyflow uses a high pressure hydraulically crimped technology.

Leak tests for these typical joint/end-fitting components were conducted using two approaches. The first approach used conventional helium detection technology with a leak sensitivity of 1×10^{-9} cc/sec. Results from the helium leak rate determination for the Fiberspar O-ring compression system and the Polyflow hydraulically crimped system are as follows: 1) Fiberspar--> 1×10^{-4} stdcc/sec @ 1 atm and room temperature and 2) Polyflow--> 1×10^{-5} stdcc/sec @ 1 atm and room temperature. Evaluation of these He leak rate values was higher than expected, however, from previous research effort it was known that He leakage rates can be higher than actual hydrogen leak rates due to the He molecule being smaller than the diatomic hydrogen molecule.

As a result, pressure decay testing using gaseous hydrogen at 1,000 psig was initiated for both joint/end-fitting designs. Results from this testing have indicated leak rates on the order of $> 1 \times 10^{-2}$ stdcc/sec for 1-hr durations. Additional testing of the FRP pipe materials under flexural load to simulate trench earth movement has also been conducted. Leakage rates from these test indicate only minor increases in leakage for test conducted at a 2" deflection (Figure 1).

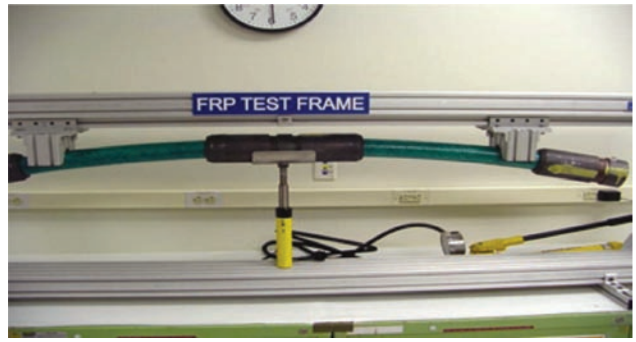

FIGURE 1. Flexural Load Leakage Testing of FRP Piping

Finally, in order to evaluate the stability of the hydraulically crimped end fitting for one of the FRP manufacturers tested as part of this project, cyclic load leak testing was conducted. The cyclic load leak testing consisted of subjecting a 4-ft section of FRP piping with hydraulically crimped end fittings to 100 cycles of pressure load from 0-1,000 psig followed by pressure decay leak testing previously described. Results from this cyclic loading showed no indication of increased leakage for the hydraulically crimped end-fittings after 100 pressure cycles.

Conclusions and Future Directions

Conclusions

- Critical issue for demonstrating the feasibility of FRP pipeline for hydrogen service is development of the technical basis to demonstrate structural integrity by defining FRP susceptibility to hydrogen embrittlement.
- Qualification of existing commercial FRP joint components with respect to leakage identified in the Department of Transportation gap analysis report as one of four major needs for demonstrating composite FRP piping feasibility.
- Leakage results indicate acceptable leak rates for FRP joint fittings.
- Initial leakage rates for FRP flexural load testing indicate minor increase in leakage rate under flexural load for a 2" deflection.
- Cyclic load testing of crimped FRP end fittings indicate no increase in leakage rate.

Future Work

- Initiate FRP life management methodology development.
- Initiate flaw tolerance/third party damage testing for FRP.
- Evaluation of environmental degradation of FRP.

FY 2009 Publications/Presentations

1. SRNL FRP Piping Project, Presentation to Hydrogen Delivery Pipeline Working Group, Sandia National Laboratory, February 21, 2008.

2. SRNL FRP Piping Project, Presentation to Hydrogen Delivery Pipeline Working Group, Jackson Hole, WY–Post Hydrogen Effects Conference, September 5, 2008.