



# Fuel Cell Vehicle Infrastructure Research and Demonstration

## Cooperative Research and Development Final Report

**CRADA Number: CRD-16-601**

NREL Technical Contact: Matthew Post

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Contract No. DE-AC36-08GO28308

**Technical Report**  
NREL/TP-5400-73382  
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**Cooperative Research and Development Final Report**

**Report Date: 9/19/18**

In accordance with Requirements set forth in the terms of the CRADA agreement, this document is the final CRADA report, including a list of Subject Inventions, to be forwarded to the DOE Office of Science and Technical Information as part of the commitment to the public to demonstrate results of federally funded research.

**Parties to the Agreement:** Hyundai America Technical Center, Inc. (HATCI)

**CRADA number:** CRD-16-601

**CRADA Title:** Fuel Cell Vehicle Infrastructure Research and Demonstration

**Joint Work Statement Funding Table showing DOE commitment:**

<b>Estimated Costs</b>	<b>NREL Shared Resources a/k/a Government In-Kind</b>
Year 1	\$ 100,000.00
TOTALS	\$ 100,000.00

**Abstract of CRADA Work:**

In support of NREL’s mission, which includes preparing technologies and markets with “speed and scale,” HATCI will loan up to two fuel cell vehicles (collectively, the “vehicles”) to NREL. Operation of the vehicles enables NREL to provide education of the vehicle technology and research renewable hydrogen production, fueling equipment, and hydrogen energy system integration in real-world conditions and use. These vehicles provide an opportunity for NREL to evaluate the Hydrogen Infrastructure Testing & Research Facility (HITRF) using a variety of vehicle types, which provides a balanced portfolio of this technology and represents real world conditions more accurately.

**Summary of Research Results:**

Throughout this project, HATCI provided NREL with two different fuel cell versions of the Hyundai Tucson to support ongoing research at the HITRF. Hyundai has released the Fuel Cell Tucson in limited markets within the United States, therefore the vehicles themselves are commercially available. NREL is doing research associated with fueling infrastructure reliability, optimization, and implementation. Having fuel cell vehicles on campus provides NREL researchers with real world fueling data into commercial vehicles that would otherwise need to be done only by simulation. The two vehicles were provided back-to-back without any overlap. The newer vehicle that replaced the first vehicle had the 2017 model year improvements.

The majority of this project was intended for demonstration and data collection. Concurrent projects were implemented to support Task #2, involving utilization of the shared resources described in this CRADA.

## 1) Hydrogen Fueling System Equipment Interaction

In the time that the vehicles were on campus, there were more than 90 fuelings into vehicles or the vehicle simulator which accounted for more than 300 kilograms of hydrogen dispensed. Projects that directly benefitted from having vehicles fuel at the dispenser include:

- Component Validation
- MC Method Validation
- Stack Test Bed Electrolysis Research

In figure 1, an example of data obtained from the vehicle fuelings is shown in which the Tucson is the second vehicle fueled. In this test sequence, two different fuel cell vehicles were fueled in succession which shows how fast light duty vehicles can be fueled with hydrogen.

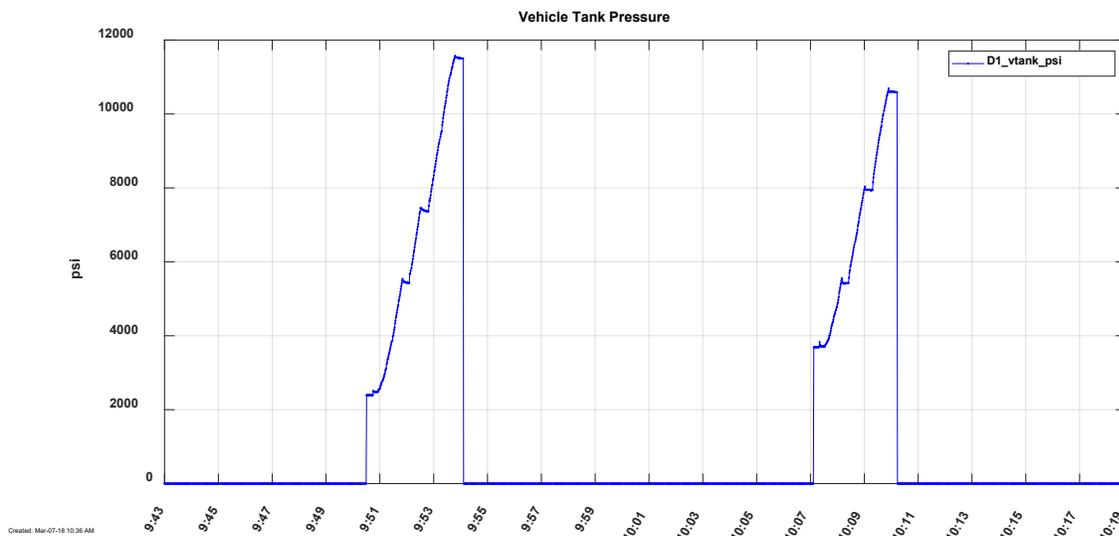


Figure 1: Vehicle fuelings at the HITRF performed on March 15, 2017.

NREL and Hyundai studied the differences in filling performance for SAE J2601 table-based and MC Formula dispensing protocols. Two fills were performed within 20 minutes of each other with both vehicles starting at the same pressure and same ambient temperature. The MC Formula dispensed 107 g more and completed the fill 15 seconds faster.

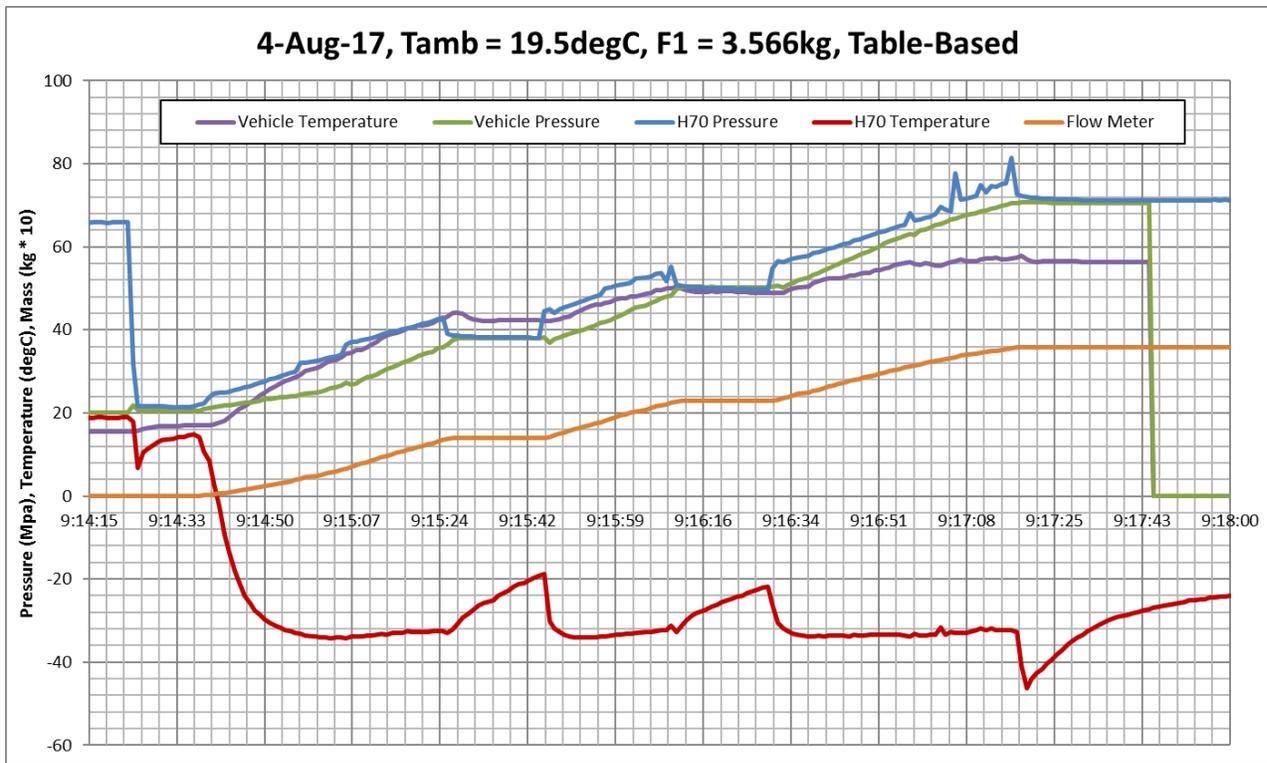


Figure 2. Vehicle and dispenser data shown for a SAE J2601 T40 table-based fueling

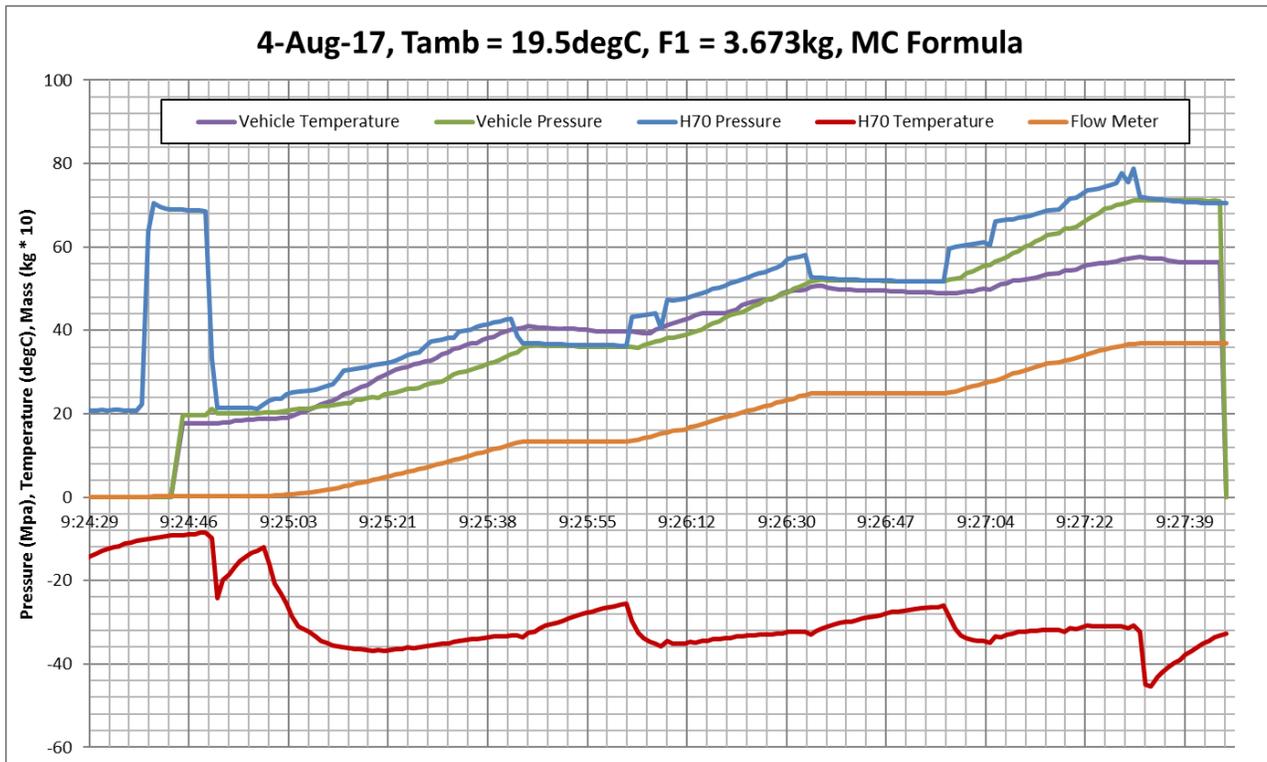


Figure 3. Vehicle and station data shown for an MC Formula fill

## **2) Integrated Renewable Energy Station (IRES)**

The hydrogen-based integrated Renewable Energy Station, capable of servicing many different needs beyond vehicle fueling was not validated under this project.

Due to lack of funding and other priorities, activities under this task were limited to the vehicles using fuel made by simulated renewable electrolysis. The fueling of the vehicles provided data that fed into the analysis of potential station capacity. In connection with this, NREL determined that there is no standard method for calculating station capacity, and will need to perform further work in this area outside of the CRADA to accomplish this.

This information did assist NREL in building a system that simulates multiple vehicle fuelings back to back and to understand how much hydrogen would be available in the station for a potential energy storage system.

## **3) Driver Behavior**

While the vehicles were on campus, NREL implemented a check-out system. After a short training, NREL employees could check out the vehicle and use it throughout the day for work related or non-work related travel.

HATCI also had the vehicles outfitted with data loggers that transmitted vehicle use characteristics back to them. Other than times when the HITRF station was down for research and testing purposes, there were no instances of fueling being unavailable. There were also no instances of the vehicles running out of fuel in normal use.

Although originally planned, a survey to the staff to capture driver input was not administered under this CRADA.

## **4) Driving Performance Assessment**

NREL researchers demonstrated mountain and high altitude driving conditions with a drive up to the continental divide and back. The car was fueled before and after the trip to show similarities to current gasoline fueling. The trip is documented in a video located here:

<https://www.youtube.com/watch?v=V0etWuZKY7w>.

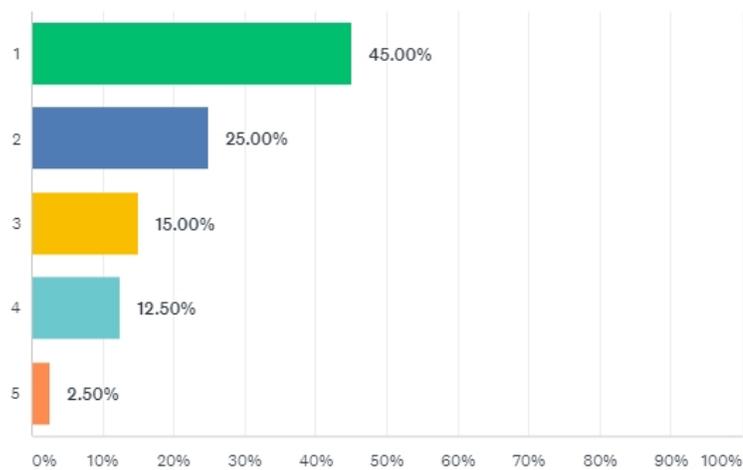
Instead of driver logs, drivers completed a survey via SurveyMonkey, which included name, number of people in vehicle, type of event, affiliation of non-NREL guests and odometer. Examples of usage documented by SurveyMonkey can be seen below. NREL employees used the car for on campus VIP tours and also took the vehicle to many high-profile events, and the vehicle was a great focal point for researchers to introduce people to hydrogen and fuel cell vehicles.

These events include:

- August 18, 2016 – Golden, CO – Executive Energy Leadership Academy August Meeting
- September 14, 2016 – Dacono, CO – Colorado Clean Cities 20<sup>th</sup> Anniversary Celebration

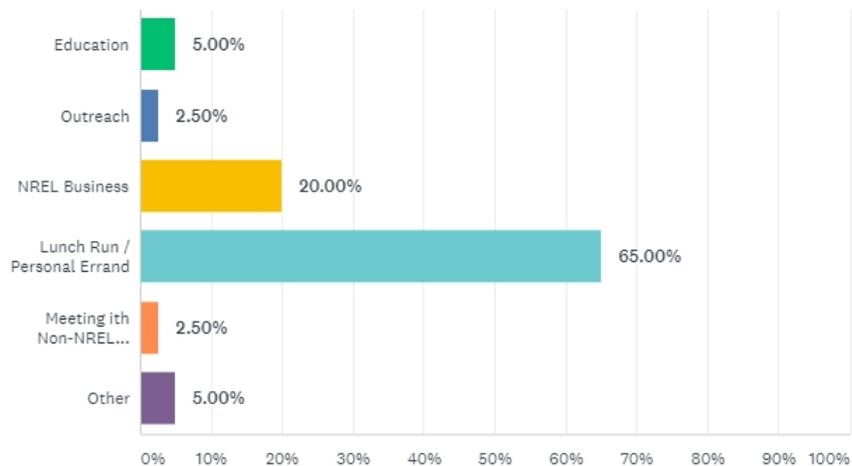
- September 14, 2016 – Boulder, CO – Boulder County Farmers Market National Drive Electric Celebration
- September 28, 2016 – Breckenridge, CO – Mountain Drive Demonstration
- October 3, 2016 – Denver, CO – National Hydrogen and Fuel Cell Day at the Capitol
- February 9, 2017 – Denver, CO – Alternative Fuels Program Kick-off & Stakeholder Meeting
- April 19, 2017 – Boulder, CO – National Alternative Fuel Vehicle Day ODYSSEY 2017
- July 13, 2017 – Golden, CO – NREL 40th Anniversary Staff and Family Celebration
- August 17, 2017 – Parker, CO – Cleantech Manufacturing Forum

**Number of people in FCEV (total, including you)?**



FCEV Usage

**What type of event is the FCEV being used for?**



FCEV Usage

Having the vehicles on campus was a very valuable component of performing research on hydrogen fueling infrastructure. Fueling the commercially available vehicles provided a baseline for all other research performed in the HITRF. Being able to bring a commercially available fuel cell vehicle to outreach events also gave NREL researchers a talking point that couldn't be reproduced by other means.

**Subject Inventions Listing:**

None

**ROI #:**

None

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**DOE Program Office:**

Office of Energy Efficiency and Renewable Energy Fuel Cell Technologies Office

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