Second-Generation Fuel Cell Stack Durability and Freeze Capability from National FCV Learning Demonstration[1]

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Abstract

The "Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project," also known as the National Learning Demonstration, is a U.S. Department of Energy (DOE) project started in 2004. The project is conducting an integrated field validation to examine the performance of fuel cell vehicles from four industry teams (Figure 1) and their supporting hydrogen infrastructure. The DOE's National Renewable Energy Laboratory (NREL) has now analyzed data from over four years of the five-year project, including 140 vehicles and 20 refueling stations, resulting in over 395,000 vehicle trips across 2,300,000 miles and over 110,000 kg of hydrogen produced or dispensed (Figure 2). Public analytical results from this project are presented in the form of composite data products (CDPs), which aggregate individual performance to protect the intellectual property and the identity of each company, while still publishing overall status and progress. In September 2009, NREL published the latest set of 72 CDPs, including many new analyses. Highlights include several new results for second-generation fuel cell stack performance and efficiency.

A key metric from the project is fuel cell stack durability. Most first-generation fuel cell stacks are still on the road and accumulating data, with more than one stack achieving over 2000 hours of operation without repair to the stack. In fact, out of 140 total fuel cell vehicles deployed, 109 are still in operation with only 31 retired. This has enabled an in-depth study of the durability of the first-generation stacks and some preliminary assessments of second-generation stacks. The existing method of projecting the best and fleet average stack durability for first- and second-generation stacks to a 10% voltage has been continued for comparison, with second-generation stacks showing improvements on all fronts. Additionally, five new CDPs have been generated to flesh out the complete picture of the performance and durability of the stacks. Specifically, relative to fuel cell stack durability, the following new results have been created:

- Histogram of fuel cell stack operating hours for first-generation and second-generation stacks separately, identifying how many of these stacks are 1) still in operation, 2) have been retired, or 3) are not currently accumulating hours (but not removed due to low performance)
- Histogram of power drop during fuel cell stack operation period with the same classifications described above

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- Graphs of the drop in the maximum power capability of the stacks as a function of their operational hours: separate results for first-generation and second-generation stacks
- Histogram of projected hours to low power operation limit

What these results indicate is that there is an initial power drop in roughly the first 200 hours and that after that there is a much lower degradation rate observed. Therefore, with much lower hours accumulated to date on second-generation stacks, current projections are expected to be lower than they will be after more data is accumulated (i.e., conservative).

Figure 1: Four Learning Demo Project Teams and Their Two Generations of Vehicles

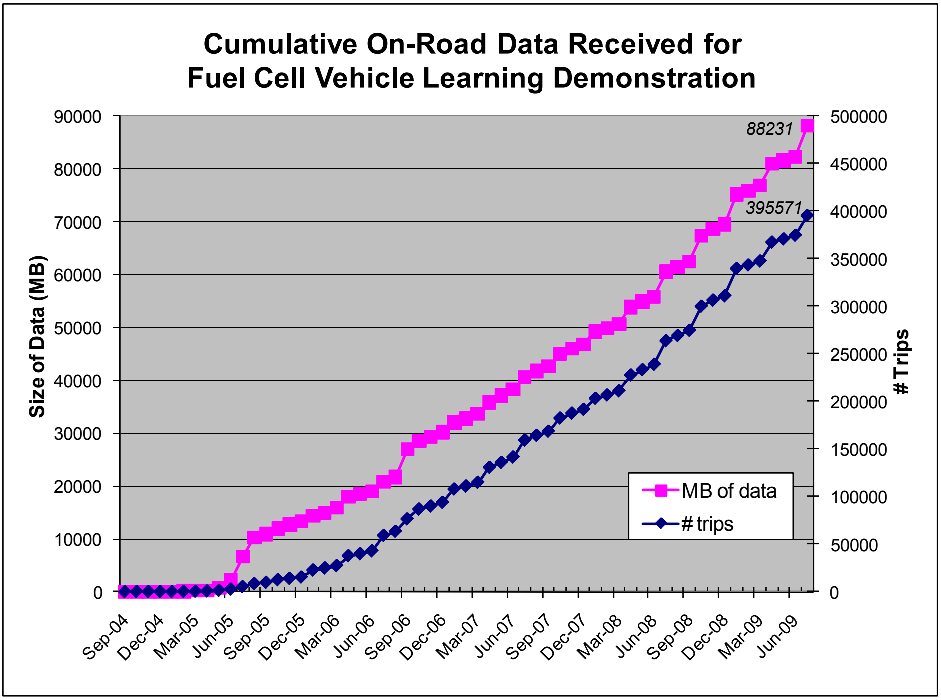

Figure 2: Cumulative On-Road Data Received from the Learning Demonstration

Freeze startup and tolerance is another metric that is new for this set of results that allows us to assess the current technology status. DOE has a freeze startup target of the time from a cold (-20 C) condition to 50% of rated stack power. The target is 30 seconds, however the soak time is not specified. Therefore, in requesting data from our industry partners, we specified two metrics that we felt were more customer oriented, which were the time to drive away and the time to maximum fuel cell power (both of which would be noticeable by a driver). We also gathered this information under two soak conditions: 12-hour soak (representing a typical overnight soak outside in a driveway from 6PM to 6AM) and an equilibrium soak (representing an extended time parked at an airport). We found a wide range of times to drive away and maximum fuel cell power reported, indicating both success as well as additional work needed. Finally, since second-generation stacks are now being exposed to freezing conditions on a regular basis during the winter in some sites, since we have not observed a negative impact of freeze on durability it appears as though the stacks have achieved freeze tolerance.

To allow an easy comparison with other powertrain systems that provide both power and energy for propulsion, such as PHEV batteries, we have created two new results that show the fuel cell system specific power and power density, including the hydrogen storage system, and compared these to DOE targets. Results indicate that the fuel cell system power density including hydrogen storage almost achieves the 2010 and 2015 FreedomCAR goal of 220 W/L and that the fuel cell system specific power of second-generation systems is still about 20% below target of 325 W/kg. Rapid progress continues to be made by industry, and recent announcements about third-generation systems indicate they may reach or exceed these targets.

We made a significant update to our published fuel cell system efficiency plot. Previously we only showed the range of efficiency at 25% of rated power and we have now expanded that to show the range of efficiency curves spanning from 5% to 100% power for both first- and second-generation stacks. Results indicate that efficiency has inched up slightly, but more importantly it has not gone down even while companies have focused on freeze tolerance, durability, manufacturability, and cost.

Most previously reported results have also been updated, and they are available on NREL's web site (http://www.nrel.gov/hydrogen/cdp_topic.html). The data collection is scheduled to continue for as long as vehicles are used on a daily basis as part of the project and data can be reported to NREL. Results will be published by NREL every six months with a final wrap-up report planned at the end of the project.