XII.1 Solid Oxide Fuel Cell Diesel Auxiliary Power Unit Demonstration

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Subcontractors:
- Electricore, Inc., Valencia, CA
- PACCAR, Inc., Bellevue, WA
- TDA Research, Inc., Wheat Ridge, CO

Project Start Date: August 1, 2009
Project End Date: April 30, 2013

Objectives

- Design, develop, and demonstrate a 3-5 kW solid oxide fuel cell (SOFC) auxiliary power unit (APU) for heavy-duty commercial Class-8 trucks (Figure 1).

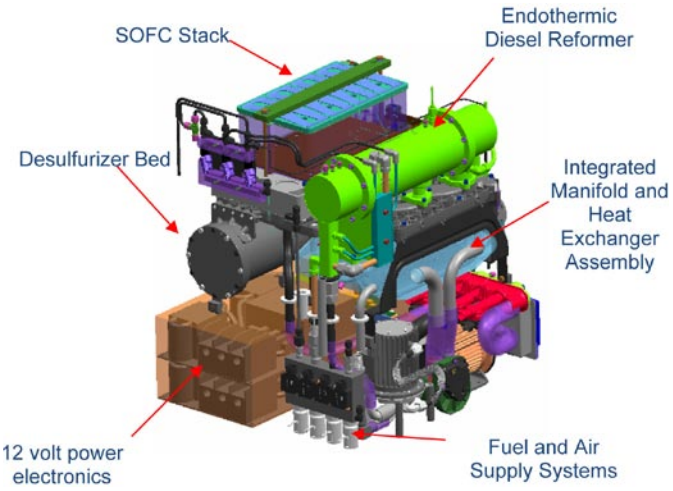

FIGURE 1. Delphi SOFC APU (A-Level Prototype) Schematic

- Utilize Delphi's next generation SOFC system as the core power plant and prove the viability of the market opportunity for a 3-5 kW diesel SOFC APU system.
- Test and demonstrate the diesel SOFC APU system in a high visibility fleet customer vehicle application that will support hotel loads and other real world operating conditions.

Relevance to the American Recovery and Reinvestment Act (ARRA) of 2009 Goals

- During this phase of the project, a total of eight jobs were created/maintained;
  - Delphi 6 jobs
  - PACCAR 1 job
  - TDA 1 job
- As a result of this project, Delphi will be able to install its SOFC APU on a high visibility fleet truck. This will provide Delphi, and its fleet customer, with real world use experience as well as the associated fuel consumption and emission data. This demonstration should increase the overall awareness of SOFC APUs and provide positive momentum in preparing to commercialize this product.

Technical Barriers

- As a result of the successful execution of this project, Delphi will have addressed:
  - System vibration robustness
  - Overall system packaging
  - System weight
  - System cost
  - System manufacturability
  - System durability/reliability
- During a recent SOFC APU system test, we discovered a significant issue with the desulfurizer during repeated thermal cycles. This issue needs to be resolved before the unit could begin fleet testing.

Technical Targets and Milestones

- Deliver the next-generation prototype (B-Level) SOFC APU for installation on fleet customer truck during the third quarter of 2012. Begin on-road, real-world application demonstration.
- Provide 3-5 kW of power during idle periods allowing for reduced fuel consumption and harmful emissions.
- Specific power: ≥15w/kg

- Power density: ≥10w/l
- Net system efficiency: ≥35%
- ≥2,000 hours of operation

Accomplishments

- B-Level SOFC APU mounted on Peterbilt Class-8 truck and driven on a local demonstration loop to gain durability and performance data. Current unit has more than 100 miles and 200 hours of demonstration (Figure 2). A second unit has compiled more than 1,500 miles and 200 hours of testing.
- B-Level SOFC APU completed more than 3,800 hours of lab testing on seven systems across typical start-up, power, and shut-down cycles. This testing includes 195 thermal cycles, start up, shut-down cycles.
- B-Level SOFC APU system validation testing:
  - Completed 19 thermal cycles of 416 planned on an accelerated thermal cycle test.
  - System and subsystem vibration testing completed.
    - System tested to the equivalent of 500,000 highway miles on a single axis vibration test.
    - Stack tested to the equivalent of 3.5 million miles on a vibration table with no measurable stack degradation noted.
- This testing has resulted in many improvements to the system calibration, reformer, stack, power electronics and air and fuel control systems.
- Integrated a sorbent bed for removal of hydrogen sulfide (H_2S) from the reformate. Above mentioned issue needs to be addressed.
  - Requirement is to remove H_2S to <0.010 ppm at a specified sorbent capacity.
  - Delphi continues to investigate an alternative, non-sorbent based solution.
- Launched the next generation endothermic reformer. Provides improved durability, heat transfer, and reduced manufacturing complexity.
- System level performance demonstrated to date:
  - 28% efficiency at 1.6 kW.
  - Less than 0.085 gallons per hour idle fuel consumption.
  - 2 kW of power for truck hotel loads, working towards a 3 kW system for production.

FIGURE 2. Delphi SOFC APU (B-Level Prototype) Installed on PACCAR Truck

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Introduction

Delphi's SOFC power system, installed on heavy-duty commercial trucks as an APU, addresses the growing concerns about emissions, fuel consumption, and noise. In the United States today, there are more than one million long-haul heavy-duty commercial trucks with sleeper cabs on the road. When drivers stop for their mandatory rest periods or loading/unloading, they often leave their engines idling in order to heat/cool their sleeping areas and operate other vehicle systems. This idling practice is costly to the driver, the fleet owner, and harmful to the environment. The Environmental Protection Agency's SmartWay Transport Partnership estimates that each year, long duration idling of truck engines consumes approximately 960 million gallons of diesel fuel and emits 11 million tons of carbon dioxide, 180 thousand tons of nitrogen oxides, and 5 thousand tons of particulate matter into the air. In addition to the consumed fuel and emissions, idling trucks create elevated noise levels. The SOFC APU has the potential to decrease idling fuel consumption by up to 85%, reduce exhaust emissions below federal regulation emission standards, and decrease radiated noise levels to less than 60 dBA when compared to the truck's main engine.

As a result of the on-road demonstration under this project, Delphi will be able to present user profile data from its fleet customer. This data will reinforce the lab-generated data showing that use of a SOFC APU as an anti-idling solution will provide drivers and fleets with reduced fuel consumption as well as reduced emissions and noise. This demonstration should increase the overall awareness of SOFC APUs and provide positive momentum in preparing to commercialize this product.

Approach

Under this project, Delphi is pursuing a 3-phased approach to conduct its research. During Phase 1, Delphi, working with its partner PACCAR, will establish the

applications specifications and commercial requirements for a SOFC APU. Phase 2 work will focus on design verification and system testing (bench top and on-vehicle). Phase 3 will include the demonstration of the SOFC APU on a heavy-duty Class-8 vehicle. The data collected during this phase will be analyzed and reported will respect to fuel consumption, emissions, and noise.

All Delphi facilities involved with this project are required to meet Delphi's stringent safety requirements which are aligned with the Safety Planning Guidance documentation specified by DOE. Additionally, there are no changes to the National Environmental Policy Act information submitted.

Results

During this report period, Delphi has completed several of the tasks necessary to provide a road ready SOFC APU to our fleet customer.

- Updated our requirements document.
- Completed SOFC APU B-Level system builds.
- Completed SOFC APU system integration into the truck including mounting the APU controls in the sleeper and adding data logging systems to the vehicle.
- Developed a user's manual and service procedures.
- Continued in-house subcomponent and system testing.
- Completed numerous small scale and full scale desulfurizer materials evaluations.
- Completed system level testing with US07 diesel fuel with no desulfurizer system.
- Completed system testing at elevated ambient temperatures.
- Evaluated and integrated anode protection and fire suppression systems.
- SOFC APU system installed on the vehicle is scheduled to be delivered to our fleet partner during the third quarter of 2012.

Specific subcomponent and system development achievements are described in the Accomplishment section above.

Conclusions and Future Directions

Delphi continues to make significant progress towards introducing a production-intent SOFC APU for use by heavy-duty truck manufacturers, fleets, and drivers. This leading-edge technology will provide users with the ability to run their hotel electrical loads during idling without the need to run their main truck engine or a diesel generator. As a result of using a SOFC APU, they will see reduced fuel consumption, reduced harmful emissions, and reduced noise.

Under this specific project, Delphi will next deliver its B-Level prototype SOFC APU to its fleet partner. After vehicle delivery and fleet/driver user training, the unit will be deployed in a real-world application. During this demonstration period, Delphi will be able to monitor the SOFC APU performance real time through a dedicated telematic connection.

Design direction has changed to reduce maintenance requirements by eliminating the desulfurizer in the near term. This requires delivering a 2-kW APU. We are redesigning the system to deliver 3 kW by taking advantage of the space available.

FY 2012 Publications/Presentations

1. May 2012 DOE Hydrogen Program Peer Review Presentation: "Solid Oxide Fuel Cell Diesel Auxiliary Power Unit Demonstration", Dan Hennessy.