"Solid Oxide Fuel Cell Diesel Auxiliary Power Unit Demonstration"

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DELPHI
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Sponsor: U.S. DOE – Hydrogen, Fuel Cells and Infrastructure Technologies

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Partners: PACCAR, TDA Research, Inc , & Electricore

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Project ID: H2RA002

This presentation does not contain any proprietary, confidential, or otherwise restricted information

Overview

Timeline

- September 2009
- January 2012
- 63% Complete

Budget

- Total project funding
  - DOE - $2,400,000
  - Delphi - $2,400,000
- $ **0** obligated in FY10 (DOE)
- $ **0** planned in FY11 (DOE

Barriers

- Barriers to address:
  - System Vibration Robustness
  - Packaging / size (Form factor)
  - System Weight
  - System Cost
  - System Manufacturability
  - System durability / reliability

Partners

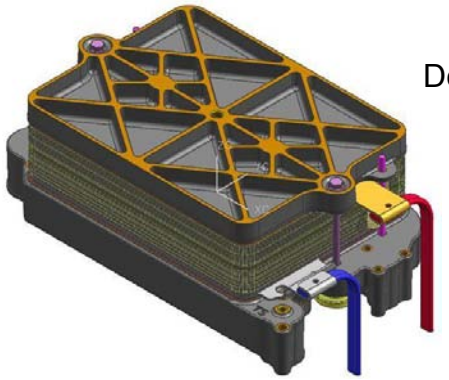
- PACCAR, TDA Research Inc.

Relevance: Objectives

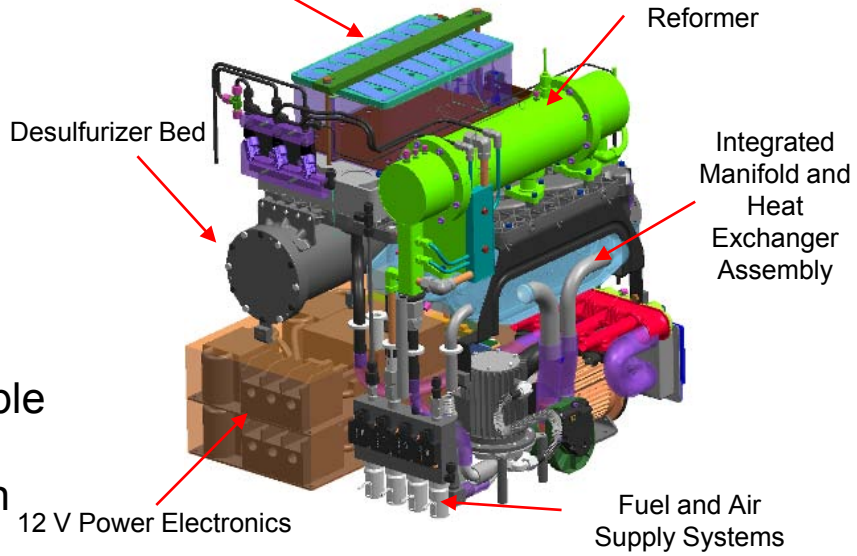
- DOE's support of Solid Oxide Fuel Cells Development will:
  - Support Delphi's continued investment in the Fuel Cell Technology
  - Accelerate the commercialization and high volume manufacture of SOFC Auxiliary Power Unit (APU)Technology
  - Augment the US's long term energy policy by enabling the development and commercialization of alternate energy technology
  - Provide immediate job creation / retention during the Development Phase
    - Jobs created / retained: **18**

Relevance: Objectives

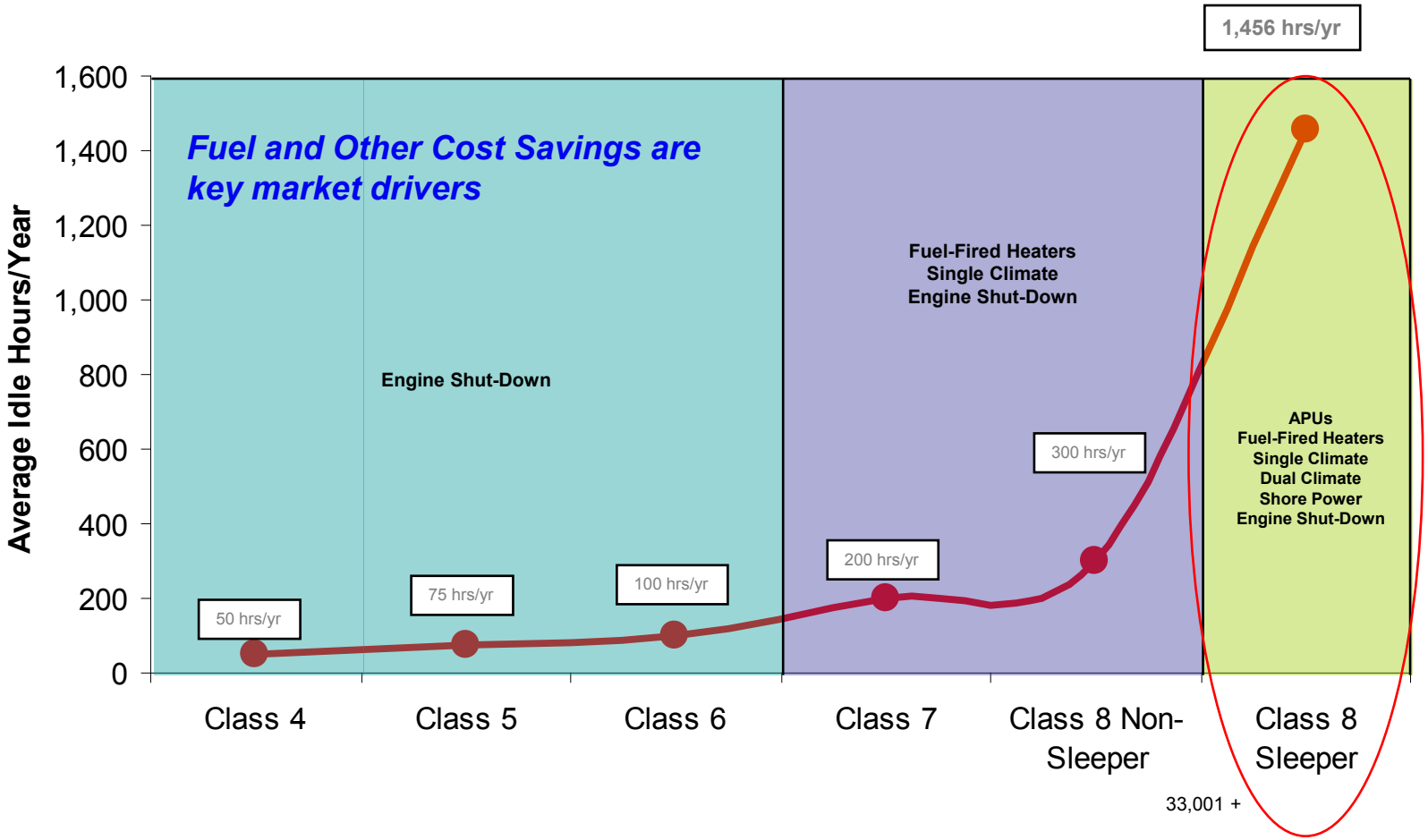
- **Market Drivers**
  - 30-states currently have Anti-Idling Regulations
  - SOFC APU Meets 2012 EPA Emissions Regulations
- **Benefits Compared to Diesel Engine APUs**
  - Fuel Efficiency: 40-50% higher
  - Emissions: Meets current emission standards with no aftertreatment
  - Noise: Very low noise
  - Durability: Significant improvement expected
- **Delphi is:**
  - Meeting budget forecasts
  - Behind schedule for long term fleet test due to balance of plant components
  - Designing components and subsystems capable of meeting production requirements
  - Committed to developing SOFC and a solution for the heavy duty truck market



Delphi Gen 4 Stack



Relevance - Heavy Duty Truck Market Idling Time



Relevance - Heavy Duty Truck Market Drivers

Increasing Cab Electrical Loads

Truck load profiles identify potential power requirements of 2.5kW and 4.0kW

In-Cab Appliances Include

- CB Radios
- Cell Phones
- Televisions
- Refrigerators
- Stereos
- Lamps
- DVD / VCR Player
- Computer
- Microwave
- Coffee Maker
- Electric Blankets
- Electric AC / Heater

Approach - Objectives

Complete a 30-month contract with the DOE EERE:

1. Define System Specifications and Commercial Requirements
   1. Define Subsystem requirements
   2. Develop subsystem requirements document
2. Design, Build and Test the Diesel APU system
   1. Verification testing of APU subsystems
   2. Form and packaging re-design
   3. APU System vibration analysis
3. One year vehicle demonstration and data analysis

Meeting these objectives will dramatically increase both the technical and commercial viability of fuel cell APU technology

Approach - Safety

Project Safety Plan:

- As an initial task, Delphi has reviewed, updated and provided DOE with a comprehensive “Safety Planning Guidance for Hydrogen Projects” document.
- All Delphi’s test facilities, including Delphi’s Metro Park test facility, are required to meet Delphi’s stringent safety requirements which are in alignment with the Safety Planning Guidance documentation specified by DOE.

Approach – 2010 Milestones

Month/Year	Milestone and Go/No-Go Decisions (Immediate)	Complete
April 2010	**Milestone Review #1:** Requirements Document complete	**100%**
July 2010	**Milestone Review #2:** SOFC APU System Design Release Go / No Go	**100%**
October 2010	**Milestone #3:** System Integration APU Complete	**100%**
December 2010	**Milestone #4:** In-house Tests Complete Go / No Go .	**90%**
January 2011	**Milestone #5:** Deliver APU to Demonstration Site (now planned for Oct 15, 2011)	**0%**

Approach

Phase 1: OEM input Collection

- Delphi worked with PACCAR to establish the APU Application Specifications and specific Commercial requirements.
- Information was compiled into Delphi's "House of Quality" that then established the various Subsystem Requirements

Phase 2: Design/Build/Test

- 2010 Phase 2 effort is design and component verification period
- Late Phase 2 work will include system testing: both bench top and vehicle.
- Additional Desulfurizer development will be performed during this phase.

Phase 3: Site Demonstration / Analysis

- During 2011 and 2012, the APU System will be demonstrated on a Class 8 vehicle, as part of a controlled vehicle fleet.
- The data gathered during the demonstration will be analyzed and reported.

Technical Accomplishments and Progress

Major Design Efforts in APU Development

– A Level Vehicle Testing
  - A-Level SOFC APU hardware mounted on Peterbilt Class 8 Truck and driven 3000+ highway & secondary road miles
    – APU Air Inlet was modified based on data from road-test due to “slush” build up.

– A Level Laboratory Testing
  - A-Level SOFC APU completed > 50 thermal cycles of 250 planned thermal cycle at Rochester Institute of Technology (RIT)
  - System and Subsystem vibration analysis initiated
    – System tested equivalent of 17,000 highway miles equivalent on vibration table
    – Stack tested 3.5M mile equivalent on vibration table

Technical Accomplishments and Progress

SOFC APU Development – Vehicle Interface

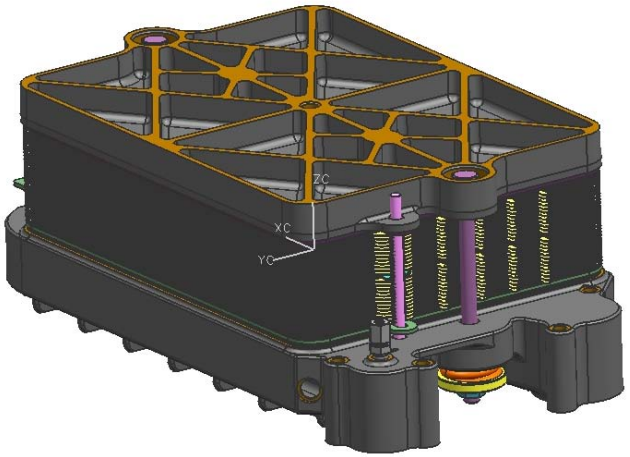
- Vehicle mounting requirements enhanced with specific focus on PACCAR assembly requirements
- Mounting concepts are evaluated / verified on the vehicle and with computer modeling

Technical Accomplishments and Progress

SOFC APU Development – Stack / Cell

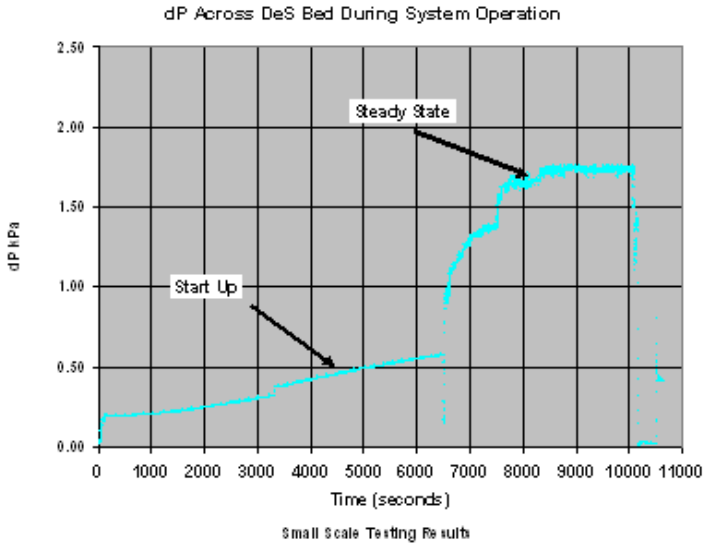
Integration of the larger cell / stack:

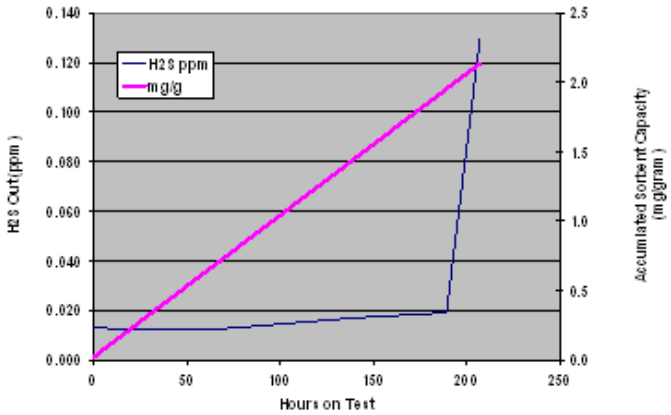
- Single, large footprint stack for improved efficiency and packaging
- 403 sq cm of active area per cell



Technical Accomplishments and Progress

- **Sorbent Bed for H2S Removal from the Reformate**
  - 4.6 liter Sorbent Bed
  - Removes H_2S to below 10 ppbv
  - Functional life of 6 months at normal APU operating conditions
  - Sorbent Cartridge is readily exchanged for fresh sorbent
  - Function has been demonstrated under steady state operating conditions on an APU system
    - Pressure drop requirements are met
    - H_2S is removed to less than 0.010 ppm





Technical Accomplishments and Progress

SOFC APU Development - Desulfurization Subsystem

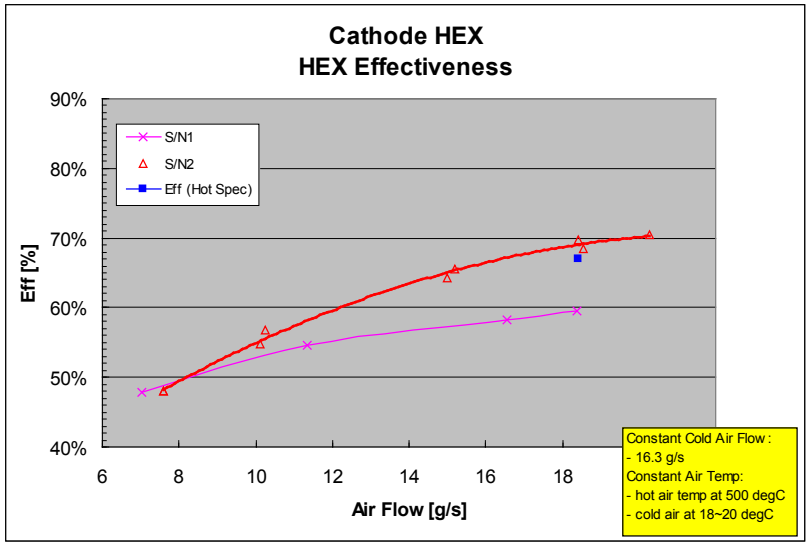
- Demonstrated capability to reduce Sulfur content of Hot Gas Reformate to 10 ppb, starting with US07 Diesel Fuel. (Ultra Low Sulfur Diesel)
- Discovered issues with operation of desulfurizer unit during repeated thermal cycles. These issues need to be closed before unit can start fleet testing.

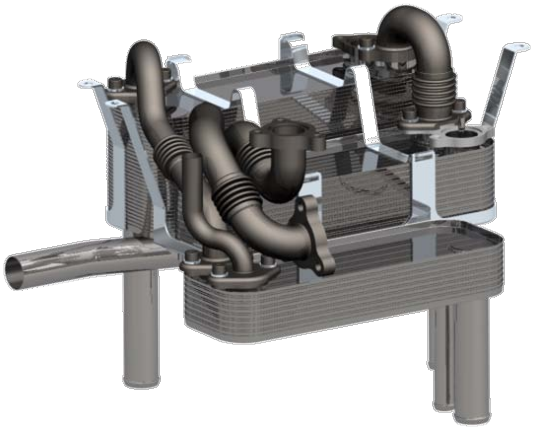
Technical Accomplishments and Progress

SOFC APU Development – Heat Exchanger w/ recycle cooling

- The Integrated Heat Exchange subsystem has been enhanced to address functionality and manufacturability concerns using a common footprint for 3 individual heat exchangers

- A more robust and cost effective design was developed based on a similar proven productive unit.

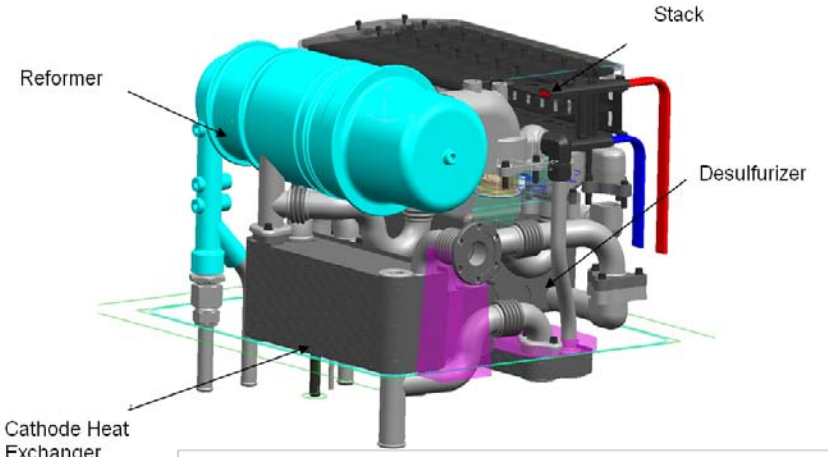


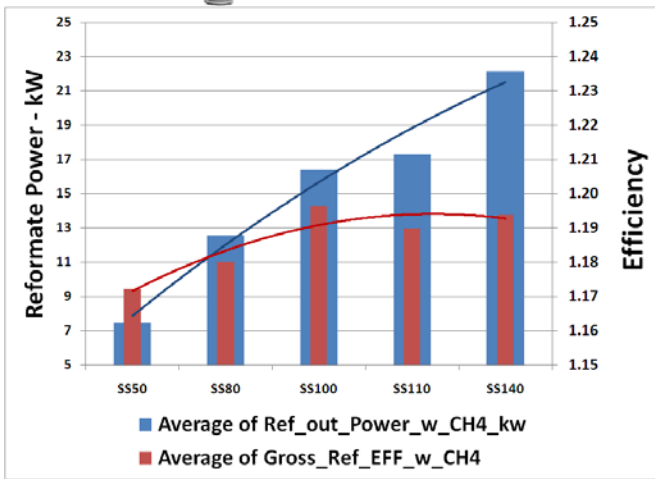


Technical Accomplishments and Progress

SOFC APU Development – Reformer Development

- The Next Generation Endothermic Reformer has been launched:
  - Low thermal stress reactor design
  - Improved Heat Transfer
  - Simpler Manufacturing Processes & Shapes
  - Reduced number & complexity of seal interfaces





Future Work

2011

- Address Desulfurizer issues / concerns
- Complete initial prototype builds
- Complete vibration analysis and thermal cycle verification
- Test Demonstration Unit prior to availability for on Vehicle Demonstration

2012

- Complete one year demonstration test

Summary

- **Delphi:**
  - Has Completed the Application Specifications and Commercial Requirements Documentation
  - Is completing System and Subsystem Modeling and Designs
  - Is meeting Budget forecast
  - Is behind on timing due to balance of plant components
  - Is Working to Introduce SOFC Diesel Technology in Full Scale Production for Heavy Duty Truck Applications

Collaborations

Delphi has teamed with OEM' PACCAR Incorporated to define system level requirements for a Fuel Cell (SOFC) based Auxiliary Power Unit (APU) for the commercial trucking industry and TDA Research, Inc. for desulfurization guidance and material/production development.

PACCAR
KENWORTH Peterbilt
DAF Foden Trucks

PACCAR, Mt. Vernon, WA

TDA Research

Wheat Ridge, CO