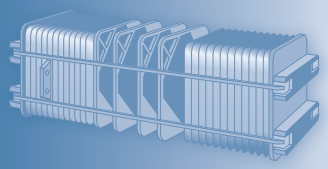


Fuel Cell Hybrid Bus Lands at Hickam AFB

A FUEL CELL HYBRID ELECTRIC BUS was unveiled at Honolulu's Hickam Air Force Base (Hickam AFB) in February 2004, becoming the first fuel cell vehicle in Hawaii and the first in the U.S. Air Force. The 30-foot flight crew shuttle bus will undergo 1 year of in-service data collection and evaluation, then will continue in routine service at the base.

NREL/PIX 13499

The U.S. Department of Energy (DOE) and its National Renewable Energy Laboratory (NREL) are participating in the bus evaluation as part of DOE's Hydrogen, Fuel Cells & Infrastructure Technologies (HFCIT) Program. This program integrates activities in hydrogen production, storage, and delivery with transportation and stationary fuel cell activities. The ultimate goal is a future in which hydrogen energy and fuel cell power are clean, abundant, reliable, and affordable and are an integral part of all sectors of the economy in all regions of the United States.

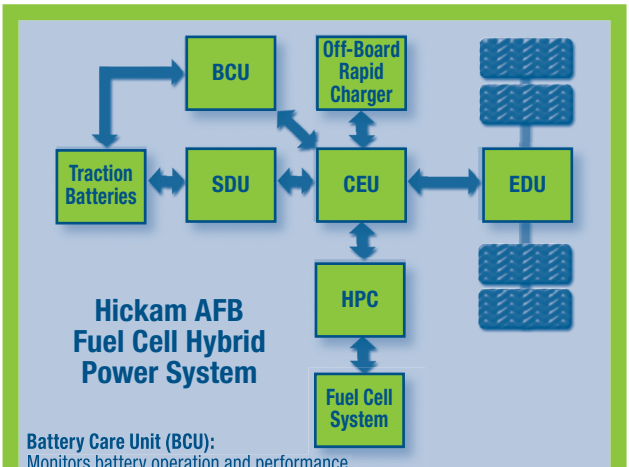
The Hickam AFB evaluation is one of several HFCIT projects that support the research and development of highly efficient, low- or zero-emission fuel cell power systems, which serve as alternatives to internal combustion engines. The U.S. Department of Transportation is also supporting this project through the Federal Transit Administration's (FTA) Hydrogen & Fuel Cell Bus Initiative.

THE HAWAII CENTER FOR ADVANCED TRANSPORTATION TECHNOLOGIES (HCATT) initiated the bus demonstration at Hickam AFB and is managing the project, with support from the University of Hawaii at Manoa. HCATT's goal for the project is to gain a better understanding of the fuel economy and performance of this fuel cell hybrid technology as well as the operation of the supporting infrastructure and hydrogen delivery. The Air Force Advanced Alternative Power Technology Transformation Office (A2PT2O) will use the results to help make future procurement and technology development and demonstration decisions.

Other project partners include power management technology developer Enova Systems and hydrogen and fuel cell technology developer Hydrogenics Corporation. Starting with an ElDorado National propane hybrid shuttle bus, Enova and Hydrogenics worked with HCATT and A2PT2O to design, develop, fabricate, and integrate the fuel cell hybrid shuttle bus. The collaborative effort was completed in 4 months at a cost of $1 million.

A BATTERY-DOMINANT SERIES HYBRID FUEL CELL SYSTEM powers the Hickam AFB shuttle bus. This system draws primarily on traction batteries to provide power for propulsion. A small (20 kW) fuel cell is used mainly to charge the batteries and extend the driving range. The small fuel cell may be economically advantageous in the future because fuel cells of this size may be the first to be commercialized for the transportation market.

The bus also has regenerative braking: the electric drive unit (EDU) converts kinetic energy (energy from the motion of the bus) to electrical energy while braking, and this energy is stored in the traction batteries. The power system diagram below shows the transfer of energy among the fuel cell hybrid system components.



Battery Care Unit (BCU): Monitors battery operation and performance.

Control Electronics Unit (CEU): Incorporates a power inverter for motor control and 12 V and 24 V DC-DC converters to provide power to support all auxiliary systems; also includes a 6.6 kW on-board charger for the traction batteries.

Electric Drive Unit (EDU): Combines the electric drive motor and gear drive unit; allows for use of regenerative braking by converting kinetic energy from the wheels back into the CEU and ultimately back to the traction batteries.

Fuel Cell System: Provides power to the CEU for charging batteries and powering the rest of the propulsion system.

Hybrid Power Converter (HPC): Manages power between the fuel cell system and traction batteries.

Off-Board Rapid Charger: Charges traction batteries when the vehicle is not in operation.

Safety Disconnect Unit (SDU): Provides safe disconnection of the traction battery pack from the CEU and BCU.

Traction Batteries: Provide primary power; consist of 28 modules of 12 V Hawker lead-acid batteries.

HICKAM AFB BUS FACTS

Bus Chassis	ElDorado National RE-29E
Model Year	1994
Length/Width/Height	30 ft/96 in/116 in
GVWR/Curb Weight	29,000 lb/22,240 lb
Seats	23
Wheel Base	160 in
Service	Flight crew and other off-base transportation
Drive System	Hybrid electric
Vehicle Control System	Enova Systems integration and software; calibration set based on customer needs
Electric Propulsion	Series hybrid, battery dominant, charge depleting, induction motor, 120 kW max/60 kW continuous, 7,200 rpm max, liquid cooled
Power Control	Control electronic unit (CEU 120): IGBT power inverter, input 250-425 VDC, max output 120 kW; 12 V and 24 V DC-DC converters; liquid cooled
Power Plant	Hydrogenics proton exchange membrane (PEM) fuel cell, 20 kW
Fuel and Storage	Compressed hydrogen up to 5,000 psi, 2 Dynetek tanks, each holding 5 kg hydrogen
Traction Battery Pack	Hawker EP-70/lead-acid/70 A-hr (140 A-hr total), 28 modules in 2 packs/12 V/ 336 V nominal
Battery Management and Charging	Battery care unit (BCU) monitors battery operation and performance; safety disconnect unit (SDU) controlled by BCU for connect and disconnect of battery packs; on-board charging, 6.6 kW for traction battery pack
Off-Board Battery Charging	AeroVironment 60 kW rapid charger
Auxiliaries	Electric driven 12 V/24 V from CEU
Brakes	Standard brakes and regenerative braking
Emissions Equipment	Zero emissions

This hybrid configuration and control strategy are charge depleting, meaning that the batteries can be depleted even if hydrogen fuel remains. The batteries can be restored using any of three options: plugging into a wall outlet to use the on-board charger, plugging into an off-board rapid charger, or operating the bus for a time on an undemanding drive cycle to charge the batteries using the fuel cell system. Depending on the operation of the bus and its efficiency, supplementary charging may be required only every other night.

THE BUS WILL BE EVALUATED once it enters full operation. Full operation is expected to begin in summer 2004, when continuous access to compressed hydrogen is established. A2PT2O, the State of Hawaii, and HCATT will evaluate the bus for at least 12 months, and NREL will evaluate it for at least 6 months. NREL has evaluated numerous advanced propulsion systems in buses and trucks, with the goal of providing credible data and results in the form of publicly available reports.

Like all fuel cell propulsion systems, the Hickam AFB bus is a prototype in the early stages of technological development. The purpose of NREL's evaluation of this prototype bus is not to compare its performance with that of fully developed commercial products. Rather, the purpose is to record the experience of using fuel cell bus and hydrogen infrastructure technologies, show the progress of these technologies, and facilitate understanding of the work that remains to be done to make the technologies viable. The results also will be important for predicting performance and costs in the future, when expected technological advances have been achieved.

Project Partners

- **U.S. Air Force/A2PT2O:** Funding, demonstration leadership, and operating location
- **State of Hawaii:** Funding and management support
- **HCATT/University of Hawaii at Manoa:** Project management, technology development, and data collection
- **Enova Systems:** Hybrid electric propulsion system development and integration
- **Hydrogenics Corporation:** Fuel cell development and integration
- **FTA:** Funding and management support
- **DOE/NREL:** Evaluation support

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