Specialty Vehicles

History

The first fuel cell vehicles were specialty vehicles.


Allis Chalmers fuel cell tractor, 1959

Allis Chalmers built and demonstrated a tractor in 1959 utilizing an alkaline fuel cell that produced 20 horsepower.

During the 1960s, Pratt & Whitney delivered the first of an estimated 200 fuel cell auxiliary power units for space applications. Union Carbide delivered a fuel cell scooter to the U.S. Army in 1967.

PEM fuel cells were invented in the 1960s for military applications and have been used since the 1970s in submarines.

Engelhard developed a fuel-cell-powered forklift about 1969.

Since fuel cells are modular, scalable, and fuel-flexible, they remain excellent candidates for a wide range of specialty vehicle applications. Fuel cells are currently being demonstrated on land, in the sea, and in the air.

Bicycles and Scooters

Fuel cell bicycles and scooters are being developed for markets in Europe and Asia. Densely populated cities, particularly in India, rely heavily on bicycles and scooters for personal mobility. There are an estimated 100 million motorized two-wheel vehicles in use worldwide. These vehicles are inefficient and polluting. In Bangkok, scooters produce more hydrocarbon and particulate emissions than buses, trucks, and cars combined.

Electric bicycles are becoming more and more popular, in part as a result of government incentives and restrictions on two-stroke engines. Major Asian cities, such as Shanghai, have recently adopted policies to phase out gas mopeds and bicycles. Most companies working on fuel-cell-powered scooters project market introduction in 2004, although that target appears very ambitious.

Asia Pacific Fuel Cell Technologies

Asia Pacific Fuel Cell Technologies (APFCT) showcased a proof-of-concept Zero Emission Scooter (ZES) scooter in April 2000, working with Kwang Yang Motor Co., Taiwan, Taiwan Institute of Economic Research, and the W. Alton Jones Foundation. The scooter's development began at the Desert Research Institute (DRI).

The second-generation scooter, the ZES II, appeared in November 2000. The ZES III was redesigned from the ground up and debuted in July 2002. It uses an APFCT 1-kW PEM fuel cell stack. ZES III has a top speed of 58 km/hour and a range of 120 km at 30 km/hour. A pre-commercial prototype, the ZEV IV, was completed in September 2003. It weighs 109 kg.

APFCT, DuPont Fuel Cells and DuPont Taiwan, Ltd., have agreements in place to commercialize PEM fuel cells for the Taiwan electric scooter market by 2005. The Taiwan Institute of Economic Research is exploring infrastructure options, such as collecting and refilling pressurized hydrogen canisters at 7-11 or Super K stores.

Palcan Fuel Cells Ltd.

Palcan Fuel Cells is developing small fuel cells (100 W and 5 kW power range) for bikes, scooters, and forklifts. Palcan and Shanghai Forever unveiled a fuel cell bicycle at the Asia Pacific Economic Cooperation (APEC) TechnoMart Exhibition in China.

In 2000, Palcan established Shangai Palcan Fuel Cell Ltd. with three Chinese partners to develop a Chinese market for fuel cells. Palcan's marketing strategy is to enter joint venture agreements with OEM's worldwide, providing access to system integration, manufacturing, sales, and distribution and service capability. In 2001, Palcan signed a memorandum of understanding (MOU) with both the Chuang Yuan Group Company, Ltd., and Shanghai Forever Company, Ltd., for the manufacturing and integration of Palcan's PalPac portable fuel cell system into electric bicycles and motor scooters.

Palcan Fuel Cells has successfully integrated its 2 kW fuel cell system into a scooter, using its own metal hydride hydrogen storage technology.

PEM Technologies, Inc.

PEM Technologies, Inc., is focusing on small- to medium-size fuel cell power systems (<10 kW) for portable power, light/personal electric vehicles, and non-road industrial electric vehicles. In July 2002, PEM Technologies introduced the PemPower-02, a PEM fuel cell scooter, and in 2003 unveiled the PemPower-03, a two-wheel motorcycle and the PemPower-04, a three-wheel motorcycle. The range for both the 03 and 04 was increased by more than half.

Manhattan Scientifics

In 2003, Manhattan Scientifics, Inc., issued a non-exclusive patent license of its NovArs mid-range fuel cell technology to Ballard Power Systems, providing unlimited use rights to Ballard for its proprietary technology and systems.

In 1999, Manhattan Scientifics acquired global intellectual property rights to the advanced fuel cells, materials, and concepts technology of NovArs and is working with Italian bicycle manufacturer Aprilia to incorporate units made by NovArs into scooters and bicycles.

Its most recent prototype was shown in 2002. The Mojito FC uses a Manhattan Scientifics/NovArs 3-kW PEM fuel cell stack fueled by compressed hydrogen. Top speed is 35 miles per hour, and the range is 120 miles.

The fuel cell bicycle made by Manhattan Scientifics, designed by Aprilia S.p.A. with a NovArs fuel cell, was named one of Time Magazine's "Inventions of the Year" in 2001. The bicycle stores compressed hydrogen in a 2-liter canister in the frame and has a range of about 50 miles and top speed of 20 miles per hour.

Prior to working with Aprilia, Manhattan Scientifics released the Hydrocycle, a fuel-cell-powered concept bicycle. The hydrogen fuel is stored in a 2-liter carbon fiber pressure vessel located behind the seat. The bicycle has a range and top speed comparable with those of the initial Aprilia unit.

Other Developers

Yamaha Motor Company has developed a fuel cell for motorcycles, powered by methanol. Yamaha is also working with battery maker Yuasa Corporation to develop fuel cells for 50 cubic centimeter (cc) -class motor scooters. A prototype reached 40 kilometers per hour (25 mph), with an output of 500 watts, which is generally equal to the performance of standard 50-cc scooters.

With support from the South-North Institute for Sustainable Development (SNISD), **Beijing Fuyuan Century Fuel Cell Power Ltd.** has joined forces with Suzhou Small Antelope Bicycle Company and jointly manufactured a fuel-cell-powered scooter in China.

Golf Carts/Forklifts/Utility Vehicles

Astris Energi, Inc.

Since 1983, Astris Energy has been pioneering the development of alkaline fuel cell electric generators and now has three such power systems "fully tested and ready for commercialization." Astris is concentrating on 1-5 kW systems.

Astris unveiled its first fuel-cell-powered golf cart in 2001. The fuel cell runs on compressed hydrogen gas — enough for more than three days on the golf course or about eight hours of continuous driving. The golf cart has a maximum speed of 25 mph and a range of more than 250 miles.

Astris Energy's principal strategy is to form joint ventures with leading manufacturers of golf carts and recreational vehicles. Astris recently terminated its agreement with Care Automotive, Inc.

Astris also manufactures a 4-kW fuel cell, which it hopes to market as a generator for recreational vehicles. The 4-kW unit can also be incorporated into yachts and boats.

Deere & Company

Deere & Co. has purchased six Hydrogenics 10-kW HyPM-LP2 fuel cell power modules for integration and evaluation in off-road vehicles, including grounds equipment and utility vehicles. The collaboration produced a prototype (Deere's second) in 2003 — a modified John Deere Pro-Gator™ Utility Vehicle. The Gator has a speed of 50 km/hour and a range of "four hours." It is currently being demonstrated across the United States.

Deere & Co. is also part of a consortium of technology and end-user partners planning to develop, demonstrate, and "pre-commercialize" fuel-cell-powered forklifts.

Sustainable Development Technology Canada (SDTC) has approved a proposal to outfit two Class-1 forklifts with 10-kW fuel cell propulsion systems and metal hydride hydrogen storage systems, develop fueling infrastructure, gather market information, and demonstrate the forklifts to industrial end users. Consortium members also include Hydrogenics, FedEx Canada, General Motors of Canada, HERA Hydrogen Storage Systems, NACCO Materials Handling Group, and the City of Toronto.

Siemens/KWU demonstrated a fuel-cell-powered forklift several years ago. The 10-kW PEM fuel cell uses hydrogen, stored in titanium-based hydride tanks. The tanks hold 23 standard cubic meters of gaseous hydrogen, which is enough to run the forklift for eight hours.

Locomotives

The **Fuelcell Propulsion Institute** in Colorado built a fuel-cell-powered mine locomotive using a Nuvera PEM fuel cell stack. It has been working in regular mucking operations since October 2002 in Ontario and has performed well, pulling five loaded cars (20 tons) without difficulty.

The Fuelcell Propulsion Institute is also part of an international consortium funded by the U.S. Army National Automotive Center (NAC) to develop and demonstrate a 109-metric ton, 1-mW fuel cell locomotive for military and commercial railway applications. Plans call for refitting a 1,200-horsepower switch engine with a fuel cell. Funding for Phase 1 of the five-year project is $1 million.

Boats, Yachts, Submarines

Marine engines are among the highest contributors of hydrocarbons (HC) and nitrogen oxides (NO_x) emissions in many parts of the world. An outboard motor can produce more than 100 times the emissions of the average car per hour of operation. An increasing number of lakes in Europe and the United States ban motor boating. Fuel cells are being evaluated as an alternative engine for boats.

A report by John J. McMullen Associates, Inc., concluded that the marine market potential (commercial and military) for fuel cells could be tens of thousands of units by 2015.

MTU Friedrichshafen unveiled the first fuel cell powered yacht, with a propulsion system manufactured by Ballard Power Systems.

The 12-meter- yacht, named “No. 1,” will operate in Lake Constance in Kressbronn, Germany.

A hydrogen-fueled public water taxi, powered by an Anuvu Power-X fuel cell/battery electric hybrid engine, was demonstrated at the World Maritime Technology Exposition in San Francisco. The 18-passenger boat was funded by California’s Center for the Commercial Deployment of Transportation Technologies, with Seaworthy Systems, Duffy Electric Boat, and Millennium Cell involved as project partners.

HaveBlue is developing hydrogen systems for recreational sailboats and powerboats. The company has begun testing components aboard the X/V-1, a specially-built 42-ft Catalina model 42 Mk. II sailboat, provided by sponsor Catalina Yachts. The boat is being fitted with a self-contained, onboard, zero- or ultra-low-emission power system that may utilize fresh or saltwater and electricity from renewable technologies to produce, store, and consume hydrogen as fuel.

A fuel-cell-powered U 31 submarine, developed by **Howaldtswerke-Deutsche Werft AG**, has begun testing in the western Baltic Sea. Tests are expected to continue into 2004.

Siemens AG has agreed to supply the Greek Navy PEM modules for use as APUs/range extenders in three class 209 submarines, with an option for a fourth unit. Siemens will supply the fuel cell modules, control and monitoring systems, control cubicles, control gear, and material packages to modernize the existing electrical equipment. Delivery is scheduled to begin in 2004.

Airplanes — NASA and Boeing

NASA

The National Aeronautics and Space Administration (NASA) conducted a feasibility study of fuel cells for aviation. The study found that a fuel-cell-powered craft was capable of a 140-mile flight carrying 270 pounds, with current state-of-the-art components. Fuel cells are an attractive option for aviation since they produce zero or low emissions and make barely any noise. The military is especially interested in this application because of the low noise, low thermal signature, and ability to attain high altitude.

Boeing

Boeing plans to test a fuel-cell-powered airplane in late 2004 or early 2005. The project will be led by Boeing's Research and Technology Center in Madrid, Spain. Other partners include Advanced Technology Products, Diamond Aircraft, Sener, and Aerlyper. The plane will be a modified version of Diamond's Katana Xtreme Motorglider, also known as the Super Dimona, running on a fuel cell, batteries, and an electric motor. The craft will have room for only one pilot, with some cockpit space taken up by the fuel cell.

Boeing strongly believes fuel cell auxiliary power units, or APUs will become a viable option for generating electricity while jetliners are on the ground, powering air conditioners and controls. Today's turbine APUs generate significant emissions.

Boeing has established a team of researchers working on a solid oxide fuel cell (SOFC) APU that will use Jet A fuel. Fuel efficiency of the fuel cell could save up to 40% of fuel during a flight.

Boeing is also designing a fuel-cell-propulsion system for a new unmanned aerial vehicle (UAV), under the Pentagon's Defense Advanced Research Projects Agency (DARPA) program.

NASA's Glenn Research Center has awarded a $524,999 contract to **Advanced Technology Products** of Worcester, Massachusetts, to design and build a fuel cell power system for a high-performance composite electric-propelled aircraft. Advanced Technology Products is also working on a two-seater fuel cell electric plane (E-Plane) with funding from both NASA and FASTec (Foundation for Advancing Science and Technology Education Curriculum).

The first flights ran on rechargeable batteries; the Phase II flights will be powered by a combination of Lithium Ion batteries and a hydrogen fuel cell. In Phase III, the aircraft will be powered totally by the fuel cell, with a range of more than 500 miles. The E-Plane is based on a high-speed, carbon composite DynAero Lafayette III, built and donated by American Ghiles Aircraft. The project is due for completion by 2004.

AeroVironment has been working with PEM fuel cells to provide nighttime power for its solar-powered unmanned NASA Helios aircraft. The goal is to make the Helios fly continuously for up to six months; during the day, the aircraft would have photovoltaic panels that run electric motors and electrolyze water into hydrogen. At night, the fuel cell would run the motors, converting the hydrogen and oxygen back into water.

Unfortunately, the Helios flying wing was destroyed when it crashed into the Pacific Ocean just 29 minutes into a functional checkout flight. NASA has formed an accident investigation team to determine the exact cause of the crash, and an interim status report by NASA's Mishap Investigation Board (MIB) reveals that the Helios experienced "undamped pitch oscillations," which led to a partial breakup of the aircraft at 3,000 feet.

The fuel cell system had not yet been turned on when the disaster occurred.

NASA Dryden Flight Research Center Photo Collection
http://www.dfrc.nasa.gov/gallery/photo/index.html
NASA Photo: ED01-0230-1 Date: August 13, 2001 Photo by: Nick Galante
NASA's Helios Prototype aircraft taking off from the Pacific Missile Range Facility, Kauai, Hawaii, for the record flight.