

## Fuel Cells - Flying High!

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Future aircraft will likely need to meet enhanced emissions reduction requirements, necessitating new, clean energy technologies to improve both ground and airborne performance. Current RD&D is exploring the use of more electrically-driven components to replace hydraulic and pneumatic systems. Fuel cells are a promising technology to help meet this challenge.



The International Air Transport Association (IATA) states that air transport contributes 2% of global manmade CO<sub>2</sub> emissions and is predicted to grow to 3% by 2050. Gas turbines used to power a plane's electronic systems when operating on the ground also emit CO, NO<sub>x</sub>, hydrocarbons, and noise pollution. Because of these challenges, IATA has created a vision is for the industry to attain carbon-neutral growth from 2020 and reach a 50% reduction of emissions by 2050, and has also set a long-term goal for zero air transport emissions. Accordingly, major aircraft manufacturers Boeing (in conjunction with Sandia National Laboratory), and

Airbus (in conjunction with German national aerospace agency DLR) are conducting research into promising fuel cell applications on future aircraft that can assist with emissions reductions and improve energy efficiency.

DLR, and Airbus - whose Aerotec Fuel Cell Test Center opened in Hamburg in August 2009 - have identified a number of fuel cell applications and are investigating them for use in research aircraft. Fuel cell systems can potentially be used to provide power, emissions-free ground operation (autonomous taxiing, maintenance bus supply and cargo reloading), electrical main engine start, electrical environmental control system supply (air conditioning), water generation (potable water and water for toilets), heat generation (icing prevention and hot water generation), explosion and fire prevention and suppression (inerting of tanks, cargo and electrical bay compartment), and cockpit and cabin air humidification. The multiple fuel cell applications may be able to reduce a plane's payload, lower maintenance costs and reduce emissions, potentially justifying the present higher cost of fuel cells compared to current technologies.

Boeing has examined conceptual SOFC-micro gas turbine hybrid configurations and found a large benefit in their use. These high temperature systems attain a high level of energy efficiency and operate at a similar temperature as in the fuel reforming process. The company is presently working on a SOFC system that operates using Jet A fuel.

Boeing, however, believes that SOFC technology is not yet mature enough for use in aircraft and anticipates that PEM fuel cells will be deployed sooner. In collaboration with Sandia National Laboratories, Boeing is exploring the use of PEM fuel cells to provide backup power for critical subsystems in emergency situations, such as dedicated battery power, in-flight operation of the auxiliary power unit, ram air turbine, or other technologies.

In 2008, Boeing conducted three test flights of a manned, two-seater motor glider airplane powered by an Intelligent Energy PEM fuel cell, operating in a hybrid configuration with a Li-ion battery. The system was used to power an electric motor coupled to a conventional propeller. The hybrid system was used during take-off, but once the plane reached a cruising altitude of 3,300 feet the battery power was disconnected and the plane flown for 20 minutes using solely fuel cell power (you can check out Boeing's video of the flight at [http://www.boeing.com/news/releases/2008/q2/080403a\\_nr.html](http://www.boeing.com/news/releases/2008/q2/080403a_nr.html)). While Boeing does not anticipate using fuel cells for primary power on larger aircraft, the company is examining the use of fuel cells to improve environmental performance.

DLR is also developing PEM fuel cells for auxiliary power unit (APU) applications. When on the ground, an aircraft's main engine is shut down and auxiliary power, compressed air and hydraulic pressure are delivered from gas turbine APUs located in the plane's tail end. The gas turbine APU can also be used to operate avionics (aviation electronics, such as communication systems and navigation systems), environmental systems (air conditioning) and de-icing equipment, and is used in starting the plane's main engines. These gas turbine systems operate at quite low efficiencies - less than 20%, and only around 10% efficiency when idling - and are also a source of CO, NO<sub>x</sub> and noise emissions at the airport. Replacing gas turbine APUs with fuel cell power would allow a gain of up to 50% efficiency, as well as elimination of noise and polluting emissions.

The German national project, ELBASYS, focuses on integrating fuel cells onto aircraft, beginning with the application with the easiest technology requirements, then adding additional applications to attain a multi-functional fuel cell system. In the first phase of the project, DLR, in collaboration with Airbus and Michelin, integrated a fuel cell system into a research aircraft (D-ATRA) to provide emergency power for the electric motor pump, the back up hydraulic circuit and the ailerons. Michelin provided the 20-kW fuel cell for the project. Several test flights were conducted in 2007 and 2008 in which the fuel cell showed "robust behavior" under high gravity loads ("g"s), as well as during turns and zero gravity aircraft maneuvers.

The current Ram air turbine (RAT) emergency power technology, which deploys from the plane's body to generate power from the airstream, is dependent upon air flow speed (greater air speed means greater power generation) and, once deployed from the body of the aircraft, cannot be retracted if main engine power is restored. The RAT system also experiences high maintenance costs. A fuel cell emergency power system used in place of a RAT would deliver maximum power independent of flight velocity, would also require less maintenance, and could be switched off if the main engine function was restored.

In the second phase of the ELBASYS project, further functions will be added to demonstrate the environmental and economic benefits of fuel cells. In addition to providing power, the fuel cell will provide water for toilets and the air condition system, reducing the amount of water to be loaded onto the aircraft, and provide low-oxygen

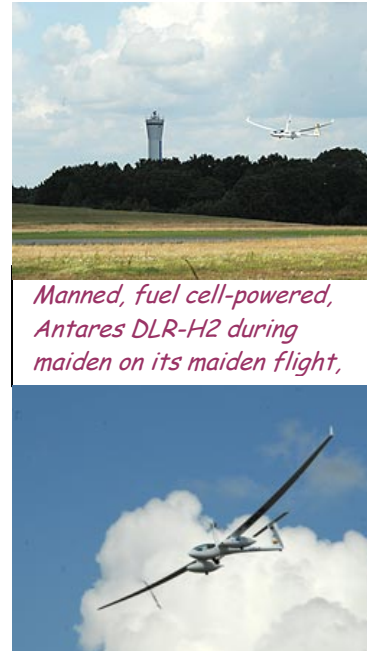
containing exhaust for inerting of the jet fuel tank (for fire retardation and suppression, or explosion prevention), eliminating the nitrogen-based inerting system. The fuel cell system could also potentially be used for heat generation and de-icing of the wings.

DLR has determined that the extra weight of the fuel cell can potentially be compensated by the multi-functionality of the fuel cell system, with weight benefits of over a ton, which increase further with mission duration, compared to a gas-turbine generator. These gains are attained by eliminating other technologies, and through payload reductions (such as carrying less water). Further weight benefits can be attained since less weight means less jet fuel is required, as well as other “snowball” effects.

The third phase of the ELBASYS project will demonstrate emissions-free ground operation, using four 12.5-kW fuel cells for ground taxiing of the Airbus A320 jumbo jet. Ground taxiing is usually performed by the main engines, but this project will instead use the fuel cell’s power for operation of the nose wheel.

DLR and Lange Aviation have developed a new fuel cell test bed, the Antares DLR-H2, a motor glider aircraft with two pods attached below the wings to carry the fuel cell system (left wing) and hydrogen tanks (right wing). A BASF fuel cell powers the plane’s electronics, electric motor and propeller, delivering up to 25 kW of energy. This new test bed permits testing of multiple factors at once, such as the effects of varying acceleration and vibration loads on the fuel cell. The Antares DLR-H2 made its maiden flight in Hamburg, Germany during July 2009. Learn more about Antares flight here:

[http://www.dlr.de/en/DesktopDefault.aspx/tabid-1/86\\_read-18278/](http://www.dlr.de/en/DesktopDefault.aspx/tabid-1/86_read-18278/).



*Manned, fuel cell-powered, Antares DLR-H2 during maiden on its maiden flight,*

DLR is also looking into other special requirements that fuel cells will need to meet for operation in aircraft. The agency’s laboratories are examining fuel cell performance under low pressure (equivalent to the pressure experienced at 30,000 feet), electro-magnetic compatibility and orientation. Researchers found that different orientations impacted fuel cell performance – a 30 degree angle decreased cell voltage, but this was successfully addressed by changing in the fuel cell’s water management configuration.

Fuel cells appear to be a promising technology for aircraft, yielding multiple performance and environmental benefits. Keep reading the Fuel Cell Quarterly and we’ll keep you posted on new aviation developments!