Fuel Cell Application in a New Configured Aircraft

PUBLISHABLE REPORT

Document Reference	CELINA Publishable Report	
Contract Nr.	AST4-CT-2005-516126	
Version/Date	Version 1.3	January 2009
Issued by	Airbus Deutschland	
Project Coordinator	Ch. Schilo	
Project Deliverable	CELINA Final Technical Report	
Project Period	1January 2005 – 30 June 2008	
Release status	public	
Distribution	European Commission	

Edited by Ch. Schilo, Airbus Deutschland, Hamburg
>>> Restricted Release <<<

This document has 6 pages

Publishable Report

Contract N°:	AST4-CT2005-516126
Project N°:	516126
Acronym:	CELINA
Title:	FUEL CELL APPLICATION IN A NEW CONFIGURED AIRCRAFT
Project Co-ordinator:	AIRBUS Deutschland GmbH
Partners:	- Airbus France SAS - Air Liquide - CNRT INEVA – L2ES - Dassault Aviation - Diehl Aerospace (DAs), former Diehl Avionik Systeme - European Aeronautic Defence and Space Company - Energy Research Center of Netherlands - German Aerospace Center - Germanischer Lloyd - IRD Fuel Cell A/S - Joint Research Centre-Institute for Energy - Jozef Stefan Institute - KID Systeme - INP Toulouse (INPT)-Laboratoire d`Electrotechnique et d`Electronique Industrielle - THALES AES Avionic Electrical Systems - University of Applied Science Hamburg - University of Hannover - University of Patras
Reporting Period:	1 January 2005 - 30 June 2008
Project Start Date:	1 January 2005 DURATION: 42 month
Date of issue:	Issued by Airbus Deutschland
Release Status:	public

Project funded by the European Community under the Sixth Framework Programme

Project Overview

Fuel cell systems allow converting a variety of fuels used in aviation such as hydrogen, natural gas or Jet A fuel into electrical power. This makes them cleaner and quieter than most other power supplies. Fuel cell systems are an ideal alternative for conventional on-board power sources used in airplanes such as Auxiliary Power Units or Ram Air Turbines. In fact, they are considered as ideal power source for the all-electric aircraft of the future. However, before fuel cell systems can be installed into aircraft, a number of technological challenges remain to be solved.

CELINA started out to investigate the operational behaviour of the complete fuel cell system including kerosene reformer, fuel cell stack, air supply and all subsystems based on simulation models and tests. In view of the aircraft's operational conditions, the electrical load conditions, the thermal management, the mass flow and the performance of fuel cell system are investigated. Relevant safety and certification requirements have been developed including a preliminary safety assessment for on-board application.

Early in the project it became obvious that commercially available fuel cell system components are not suitable for aircraft application because e.g. of their present power-to-weight ratio. This finding required CELINA to place an extra effort into changing of objectives regarding to installation concept definition.

CELINA demonstrated that fuel cell systems are suitable for airborne use if properly integrated into the aircraft's electrical network and if safety and cooling aspects as well as the power management are organised appropriately.

The investigation of the fuel processing showed that kerosene reforming onboard aircraft is a long-term research topic. Today, all known reformer projects in Europe are running only on laboratory level requiring a significant financial investment and time for reaching airworthiness levels.

Similarly, Solid Oxide Fuel Cells (SOFC) are at present operated only on laboratory level. Application to flight conditions requires huge investments and technical solutions for safely managing the up to 800°C of operating temperature onboard of an aircraft.

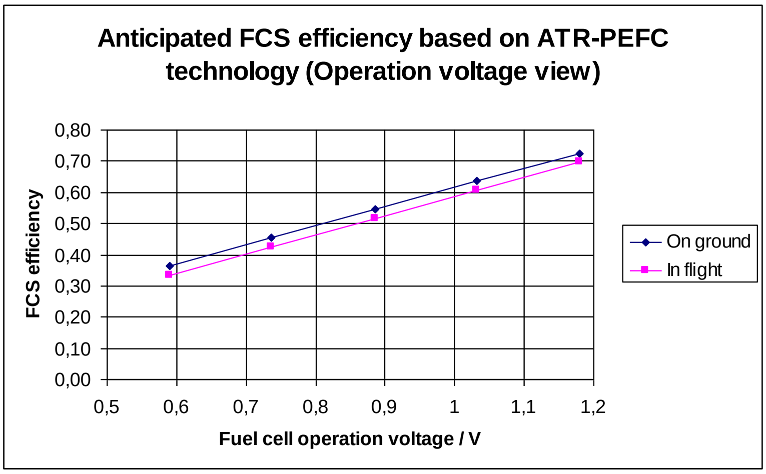
Originally, a 50 kW_{el} system architecture as replacement for the Ram Air Turbine was designed and simulated as intermediate step for 500 kW_{el} system as future Auxiliary Power Unit replacement.

However, it became obvious that in the near to mid term such complex fuel cell system architecture would not be suitable as standard design and that based on state-of-the-art technology it would be far beyond what is acceptable in commercial aircraft.

The major obstacles are the high specific system weight, the high space requirements of cooling equipment and the complex fuel processing technology. As a consequence, pure Hydrogen might be the preferred fuel for the first commercial in-flight application of fuel cells.

In order to optimise the system efficiency all by-products as heat, water and inert gas need to be utilised aboard an aircraft allowing the fuel cell system to take over additional services on ground and during flight in addition to Ram Air Turbine and Auxiliary Power Unit replacement.

Influences of type of fuel processing, fuel cell technology and flight mode on the fuel cell system efficiency have been analysed within CELINA. The figure below shows the development targets for the efficiency of Polymer Electrolyte Fuel Cells in order to meet aircraft requirements.



An important share of CELINA was dedicated to generate test measurements of a fuel cell stack and the verification of it. Simulating and testing possible components including the fully functional fuel cell stack have significantly advanced the state-of-art on flight-worthy fuel cell systems.

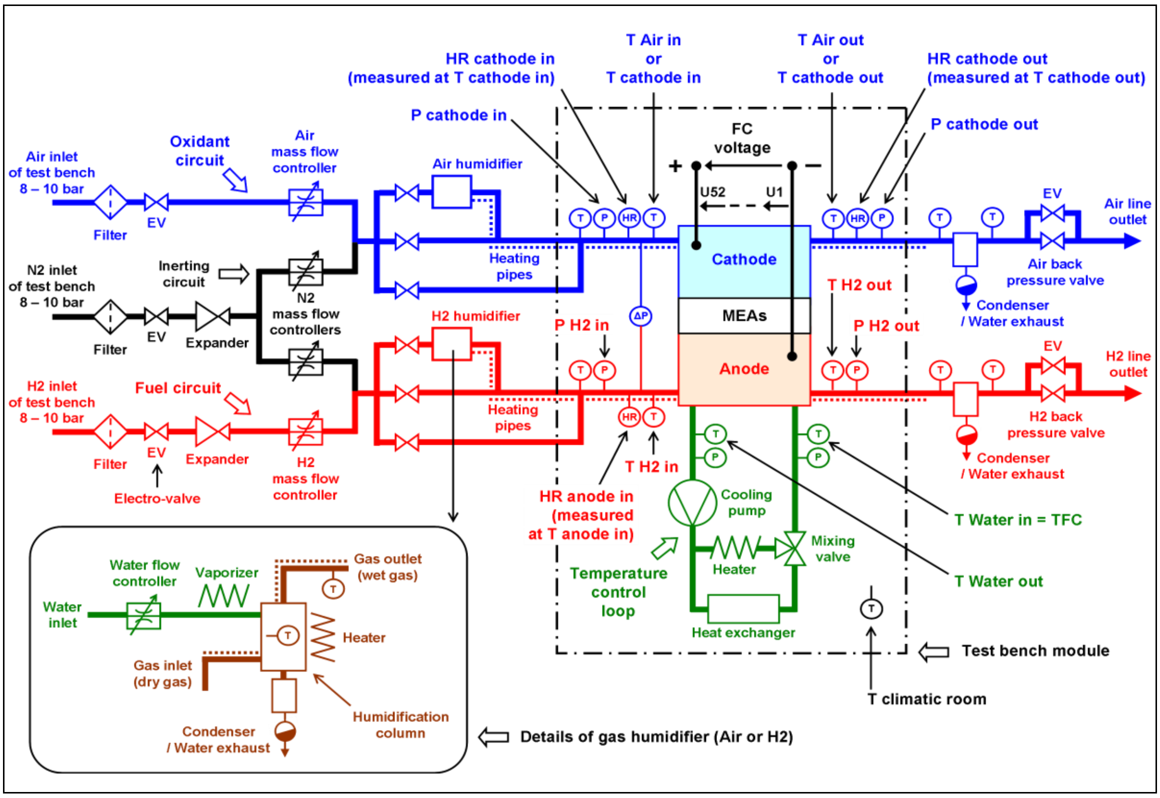
The monitoring of critical process parameter is a key driver of the fuel cell system application in an aircraft, e.g. monitoring of hydrogen supply.

In support of the numerical simulation activities reference tests and dynamic tests have been performed with two different fuel cell stacks investigating gas pressure and humidity rates as well as climatic and vibration tests. Several practical problems were encountered including the break down and repair of the 2,5 kW stack during the climatic tests.

The low pressure tests showed no significant decrease of the power output while changing the pressure between 1000 and 500 mbar, but a dramatic loss can be observed with lambdas of 2.5 and pressures lower than 500 mbar.

Operating at low surrounding temperatures of -18°C the power output reached 1500W at 40A when failures occurred associated to anode – cathode leakages. Vibration tests conducted under realistic aircraft conditions were performed without problems.

The diagram below provides an overview on the basic test bench designed and operated in CELINA for performing the numerous tests.



The consortium faced many challenges and finally had to re-adjust several objectives with respect to the application readiness of fuel cell systems. But many lessons have been learned. The difficulties have been in definition of consistent interfaces between the corresponding modules between different partners while on the other hand the fuel cell system models were modelled partly too detailed.

In general, the original envisaged improvements were validated with the potential benefits which are depending on the respective type of aircraft.

Future fuel cell research for flight applications should consider the following recommendations:

- Main off-the-shelf fuel cell system components need to be modified and re-designed for aircraft application
- In order to reach maximum efficiency all by-products (heat, water, exhaust gas) have to be utilised aboard the aircraft allowing the fuel cell system to take over additional services on ground and during flight in addition to Ram Air Turbine and Auxiliary Power Unit replacement.
- The power-to-weight ratio and the structural volume of present fuel cell systems need to drop below today's standards given by conventional Auxiliary Power Units and Ram Air Turbines.

- The reliability and durability of system components under all flight conditions including vibrations over long operating live times need to be investigated with respective aircraft requirements to be specified.

- Redundant fuel cell system architectures have to be developed to guaranty reliable and safe operation in major failure scenarios.

- To improve the long-term performance of the SOFC running on commercial hydrocarbon fuels, research should address the development of kerosene/diesel reformer and the development of advanced sulphur and carbon tolerant anode materials with superior catalytic and electrical properties.

Acknowledgements

The CELINA consortium thanks the European Commission for supporting the project.