CONFERENCE ON AVIATION AND ALTERNATIVE FUELS

Rio de Janeiro, Brazil, 16 to 18 November 2009

Agenda Item 3: Measures to support development and use

NON-DROP IN FUELS AND ADVANCED AIRCRAFT SYSTEM POWER TECHNOLOGIES

(Presented by the International Coordinating Council
of Aerospace Industries Associations)

SUMMARY

This paper gives a snapshot of current knowledge and past experiments associated to non drop-in fuels. It does not pretend to draw an exhaustive list of them but shows that the requirement for drop-in fuels is actually based on sound technical arguments and data.

1. INTRODUCTION

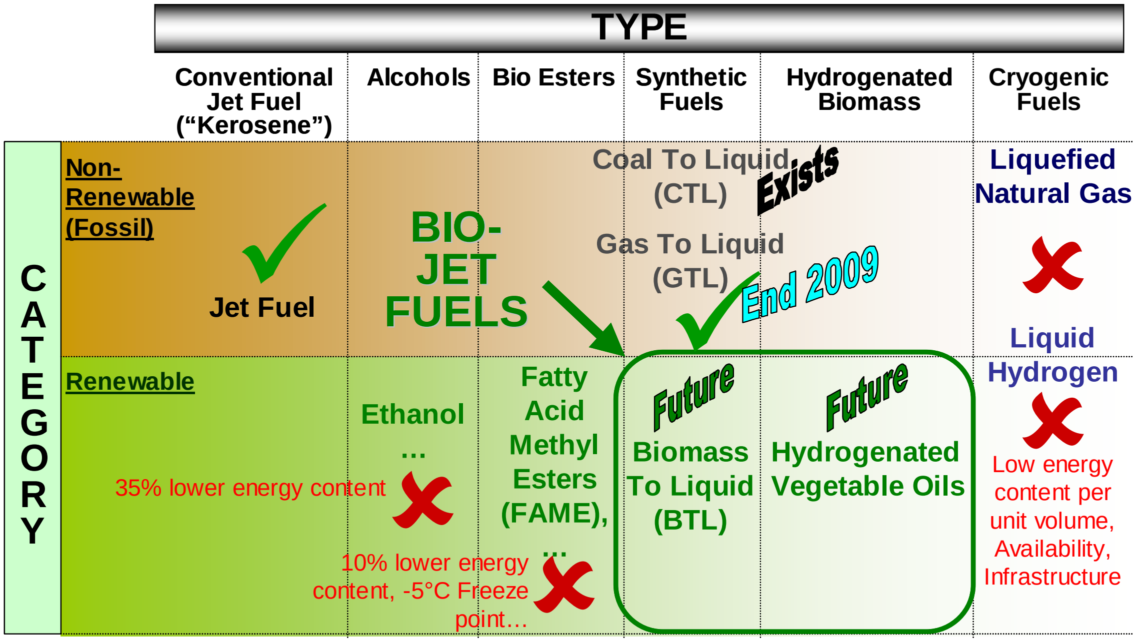
1.1 Whereas the focus is now almost exclusively on drop-in fuels, some past experiments have tried to find out alternative sources of energy for aviation, as it was the case for other sector. This paper gives a snapshot of these experiments. It does not pretend to draw an exhaustive list of them but shows that the requirement for drop-in fuels is actually based on sound technical arguments and data.

1.2 The paper summarizes the various experimentations performed in the past decades on non drop-in alternative fuels.

2. EXPERIMENTATIONS OF NON DROP-IN FUELS

2.1 Far before the first oil crisis in 1973, when the environmental awareness was far lower than to its current level, some civil and military projects have been initiated and carried further to evaluate the potential of alternative sources of energy for aviation, from non drop-in liquid bio-fuels to nuclear and cryogenic fuels. This paper does not consider drop-in fuels that are extensively covered through the other documentation for the rest of the conference.

2.2 As a first stance, the various categories of fuels can be described in the table below:



2.2 Liquid bio-fuels can be grouped into two categories. Biomass To Liquid (BTL) fuels and Hydro treated Biomass Oils Synthetic Paraffinic Kerosene (HBO SPKs) can be considered as candidates for drop-in fuels and will not be discussed in this paper. Oxygenates (ethanol or Fatty Acid Methyl Ester (FAME) also most commonly known as bio-diesel) encounter several technical challenges such as lower energy content compared to traditional jet fuel (thus significantly reducing the operating performance of the aircraft in terms of range or payload), high temperature freeze point and poor high thermal characteristics in the engine, moving them away from the list of candidate alternative fuels for aviation.

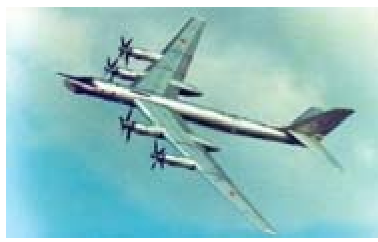
2.3 Nuclear energy: nuclear energy is highly dependent on fossil resources, mainly uranium. These resources are quite substantive and with the existing number of nuclear plants worldwide, it is estimated that the resources are there for about a century[1], and could be extended in the event of the fusion technology become mature. Nuclear energy can demonstrate various advantages, such as very high power density (about 1 Million times more than chemical energy from oil for instance), which would allow and aircraft to fly long distances with a small amount of resource and generating energy through nuclear technology does not emit any CO2 emissions. However, the energy generated by unit of resource is quite low, at about 33% for a nuclear plant to 22% for nuclear-driven submarine ships. In addition, the nuclear energy generates a lot of heat, so the place where the energy generator is located would need to be importantly insulated and refrigerated, thus implying an additional weight penalty for these reasons. Moreover, the problem of waste generated by this technology, together with the radiation generated are clear drawbacks of that technology

2.4 Two main aircraft projects were carried out in the 60’s:

- The US NEPA/ANP project (1946-1964): consisted in the development of on-board nuclear reactors (AEC) coupled with turbojets (General Electric for the direct cycle, Pratt & Whitney for the indirect cycle). A bomber NB36H has carried on board a nuclear reactor to study the emitted radiations; 47 flights over Texas and New Mexico between July 1955 and March 1957 were carried out; and

[1] Paul Kuentzman – ONERA – Air Transport and the Energy challenge – Toulouse - 2006

- The soviet bomber project: A Tupolev 95M bomber has been modified to carry on board a nuclear reactor coupled with two turboprops NK14A, replacing two conventional turboprops NK12MV 40 flights over Kazakhstan were performed from 1962 onwards



2.5 These programmes have demonstrated that it is technically feasible to consider nuclear energy as a potential alternative fuel for aviation. However, the investment needed to match the challenges of such a technology (heat, radiations, waste) is quite high and probably not to be considered for aviation. In addition, the acceptability of such type of aircraft flying over land is very limited as society is not ready to accept the consequences of a possible accident of such an aircraft type. In conclusion, nuclear energy cannot be kept as a potential alternative source of energy for aviation.

2.6 Liquefied gaseous fuels such as liquid methane (extracted from methane hydrates) and liquid hydrogen (to be produced as hydrogen does not exist per se in the nature) were envisaged. Hydrogen has for long been considered as a potential source of energy for various applications, including air transport. As early as 1937, an experimental turbojet engine on hydrogen[2]. In 1957, the US Air Force performed flights with a B57 bomber aircraft. After several studies, carried out in the 1970's and to which the US NASA was very much involved, some other initiatives were launched in various parts of the word. A German-Russian cooperation was initiated in 1990, including DASA, Tupolev, Kuznetzov and others. In 1995-1998, some German/Russian studies were performed for a Demonstrator aircraft on the basis of a Dornier 328, and in the late 90's, the cryoplane project (on the basis of an A310 aircraft) was launched, covering configuration, systems and components, propulsion, safety, environmental compatibility, fuel source and infrastructure, transition.

[2] Dr von Ohain rig tests He-S-2 experimental turbojet engines on hydrogen.

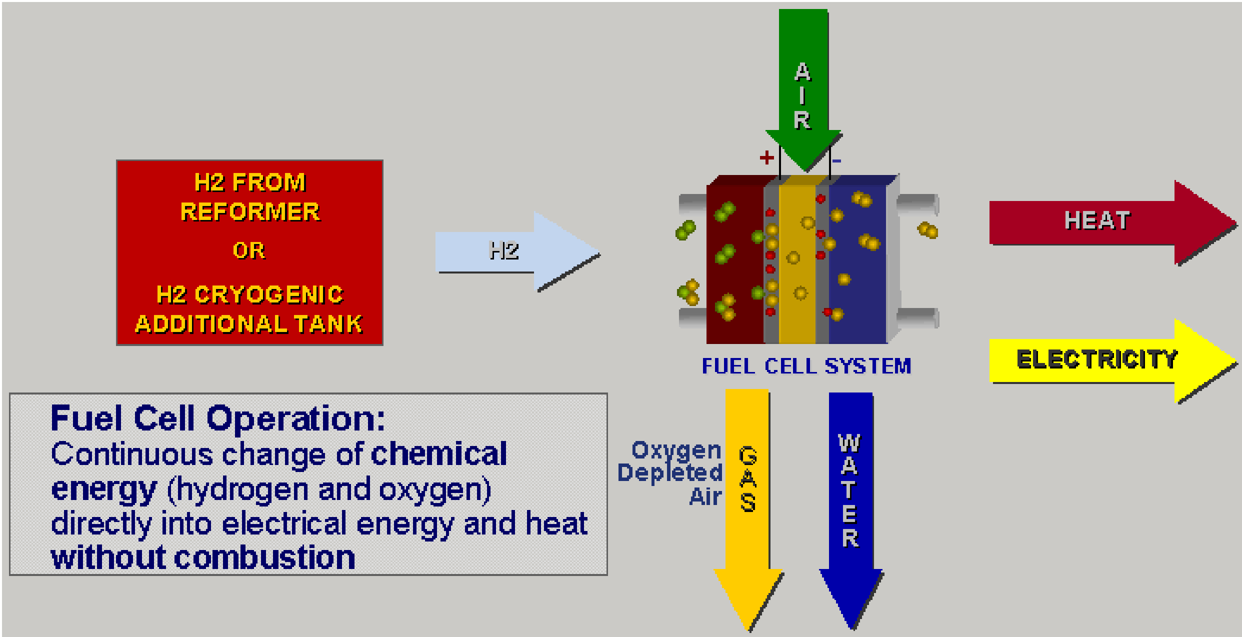
Cryoplane Project (Left) - Demonstrator aircraft on the basis of a Dornier 328 (Right)

2.7 Hydrogen offers a high energy density per mass, hence promising payload or range increase for aircraft. However, for aviation, hydrogen will have to be cooled down to the liquid state (LH2, 253°C), for reasons of volume and weight of tanks. Hydrogen (KH2) needs 4 times a greater volume than kerosene and the tanks in terms of insulation or pressure resistance would need to be re-designed and would no longer be able to be integrated in the airframe wings. The use of this technology has been envisaged for a small or standard regional aircraft as well as for unconventional aircraft types. The specific energy consumption is estimated to be 8 to 15% higher than with conventional fuel.

2.8 Hydrogen is not considered as a potential source of alternative energy today for several reasons: hydrogen does not exist in nature, and the energy needed to create it might be dissuasive and too much polluting although nuclear or solar technologies could be envisaged. Furthermore, the potential impact of flight environmental factors, such as increased water vapour emissions need to be better understood. Lastly, a complete, worldwide cryogenic fuel infrastructure (covering production, storage and transportation) has to be established.

2.9 However, this current status may evolve as hydrogen production and infrastructure issues are addressed for ground transportation, thus providing new opportunities for air transportation. It is also considered as a high potential candidate in the particular application of fuel cells for aviation.

2.10 The technology of fuel cells is not new as it dates back to 1839. Fuel cells are electrochemical devices, which convert chemical energy directly into electrical energy (DC power). Fuel cells applications for aviation can be considered to provide on-board energy to supply several devices such as air conditioning, in-flight entertainment. If this technology develops, it can be envisaged as a replacement for Auxiliary Power Unit (APU) in the future.



Fuel cell principle

2.11 Currently fuel cell systems are at an early stage of research and technology, with the first in-flight test successfully demonstrated jointly by Airbus, Michelin and the German Aerospace Centre, the DLR, on an A320 test aircraft in February 2008. This innovative energy source powered the aircraft's back-up hydraulic and electric power systems. During the test, the hydrogen and oxygen based fuel cell system generated up to 20 Kilo Watts (kW) of electrical power. The emission free fuel cell system generates water as a "waste" product. The fuel cell system powered the aircraft's electric motor pump and the back-up hydraulic circuit and also operated the aircraft's ailerons. The system's robustness was confirmed at high gravity loads ("g" loads) during turns and zero gravity aircraft manoeuvres. During the flight test, the fuel cells produced around 10 litres of pure water.

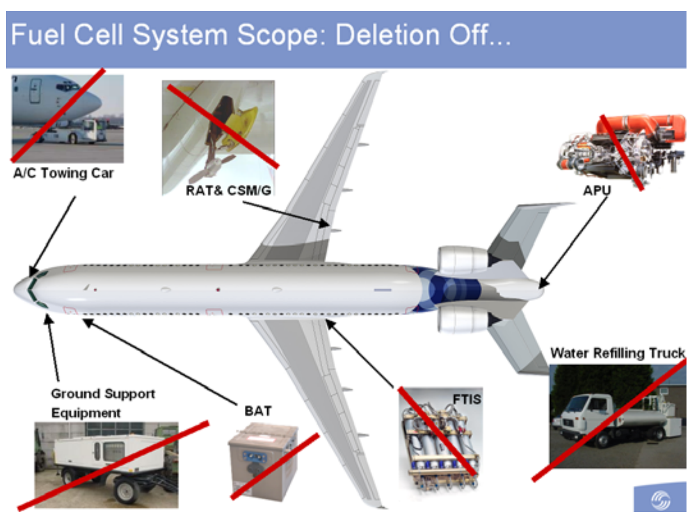
Fuel cell equipment for the A320 test aircraft from DLR in February 2008

2.12 At the same period, Boeing flew a manned airplane powered by hydrogen fuel cells. A two-seat Dimona motor-glider with a 16.3 meter (53.5 foot) wingspan was used as the airframe. Built by Diamond Aircraft Industries of Austria, it was modified by BR&TE to include a Proton Exchange Membrane (PEM) fuel cell/lithium-ion battery hybrid system to power an electric motor coupled to a conventional propeller. Three test flights took place in February and March at the airfield in Ocaña, south of Madrid, operated by the Spanish company SENASA.

2.13 Fuel cell technology potentially could power small manned and unmanned air vehicles. Over the longer term, solid oxide fuel cells could be applied to secondary power-generating systems, such as auxiliary power units for large commercial airplanes. However, the sector does not envision that fuel cells will ever provide primary power for large passenger airplanes.

2.14 Today, it is foreseen that the main challenge with fuel cell technology is the way hydrogen is made, together with the weight of the fuel cell itself. This weight needs to be reduced as the technology matures to become a suitable candidate for on-board applications.

2.15 These experiences could also pave the way towards emission-free ground operations, with fuel cell systems replacing aircraft functions that currently need the use of the APU or the engines long before take-off, such as main engine start and air conditioning. Substantial economics savings in and reduced environmental impact could be achieved when the related technologies are mature.



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