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# A CASE FOR BIOFUELS IN AVIATION

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## Abstract

In the last 15 years, the technical and the economic feasibility of biomass based fuels for general aviation piston engines has been proven. Exhaustive ground and flight tests performed at the Renewable Aviation Fuels Development Center (RAFDC) using ethanol, ethanol/methanol blends, and ETBE have proven these fuels to be superior to aviation gasoline (avgas) in all aspects of performance except range. Two series of Lycoming engines have been certified. Record flights, including a transatlantic flight on pure ethanol, were made to demonstrate the reliability of the fuel. Aerobatic demonstrations with aircraft powered by ethanol, ethanol/methanol, and ETBE were flown at major airshows around the world.

The use of bio-based fuels for aviation will benefit energy security, improve the balance of trade, domestic economy, and environmental quality. The United States has the resources to supply the aviation community's needs with a domestically produced fuel using current available technology. The adoption of a renewable fuel in place of conventional petroleum-based fuels for aviation piston and turbine engines is long overdue.

**Key Words:** Ethanol, ETBE, Biodiesel, Renewable Aviation Fuels, Renewable Aviation Fuels Development Center (RAFDC).

## Introduction

Mandates of the Clean Air Act Amendments of 1990 banning lead from all motor fuels have prompted an effort to find an unleaded alternative to the existing aviation fuel. Avgas is today the single largest contributor of lead in the atmosphere in the U.S. Environmental regulations have forced oil companies to use dedicated systems for the production and distribution of avgas. As a result of its special handling requirements and low sales volume, it is predicted that the oil companies will eventually quit avgas production. For this reason, pilot organizations, the Federal Aviation Administration (FAA), engine manufacturers, and some of the producing companies, are all searching for a replacement aviation fuel.

The main difficulty in manufacturing an unleaded gasoline for aviation is the high octane needed by many aircraft engines. The American Society for Testing Materials (ASTM) has formed committees to direct the search for an unleaded fuel suitable for aviation. Guidelines on the specifications of the fuel were suggested by the General Aviation Manufactures Association (GAMA), but progress has been slow. Results obtained from testing various blends of fuels have been presented to the ASTM committee, but none of them, as of today, completely satisfies the requirements set for the new fuel.

Because of these difficulties, the current consensus among the organizations involved in the research is to settle for a fuel of between 96 to 98 octane. Accordingly, the FAA Technical Center is testing various fuels in various engines, trying to determine a minimum octane rating which will meet the needs of the general aviation fleet. The development of a fuel with a lower than 100 octane rating could satisfy the requirements of about 70% of the general aviation aircraft in the U.S. fleet. However, the remaining 30% of the fleet requires 100 octane fuel, and it uses 80 % of the aviation fuel sold in this country.

There is also a need to find an alternative to Jet A which is used throughout the world in all turbine powered aircraft. This need is prompted by environmental concerns about particulate pollution caused by this fuel. Particularly vulnerable to this pollution is the region of the tropopause along the heavily traveled North Atlantic corridor. Pollutants in this fragile environment have a much longer residence time than at lower altitudes and consequently have a magnified impact. Studies have shown that blends of biodiesel into Jet A decreases these emissions. It is expected that ETBE will have the same effect. RAFDC is in the process of conducting both ground and flight tests to determine performance and emission levels of blends of biodiesel and ETBE in Jet A.

**Technical Considerations: Outcomes of the "First International Conference on Alternative Aviation Fuels"**

In November 1995, RAFDC hosted the "First International Conference on Alternative Aviation Fuels" at Baylor University in Waco, Texas. Major support for this conference was granted by the U.S. Department of Energy, the FAA, Baylor University and Texas State Technical College. Aviation experts from Brazil, Canada, France, Greece, Italy, Sweden and the United States gathered to discuss the future of aviation fuels. Government agencies, oil companies, academic institutions, aircraft manufacturers, state energy offices, state aviation organizations, and media were represented. Organized to reflect all viewpoints, the speakers and panelists included both supporters of unleaded petroleum based fuels and those who favored renewable biomass alternatives.

Although disagreeing on the solution, everyone agreed on the problem -- the days of 100 Low-Lead aviation gasoline (100LL avgas) are numbered.

At the conference, the proponents of the "petroleum solution" enumerated both real and alleged problems with biomass fuels. A "legitimate problem" is the loss in range caused by the lower energy density of biomass fuels. Petroleum fuel proponents assume that the loss in range in an aircraft powered by ethanol is directly proportional to the caloric content of ethanol when compared to gasoline's (40% less). But, extensive ground and flight tests have shown that the range loss varies from a maximum of 25% with 7:1 compression ratio engines, down to 10% range loss for engines with 10.5: 1 compression ratio. Brazil's experience has shown that automobile engines using ethanol achieve optimum mileage at a compression ratio of approximately 12.2:1. RAFDC, under a contract with the FAA, will be testing aircraft engines with compression ratios as high as 13:1.

Many of the petroleum fuel proponents at the conference were not aware of the substantial increase in performance when operating on ethanol. The higher latent heat of vaporization results in an increase in volumetric efficiency which produces more power and lower operating temperatures. The wider range of flammability produces smoother combustion and decreases the likelihood of inappropriate combustion. Additionally, it causes less internal engine buildup of combustion byproducts. All of these factors combined to prompt the FAA Designated Engineering Representative (DER) who witnessed the certification of the Lycoming IO-540 to estimate that the time between overhaul (TBO) for engines operating on pure ethanol could easily be increased by 100%.

The issue of materials compatibility was also raised during the conference. RAFDC had experienced problems caused by the interaction between ethanol and aluminum. The problem was solved by allodizing all fuel wetted aluminum parts. However, the ethanol industry, experiencing the same problem with its storage tanks, began adding an anti-oxidant to the ethanol. This additive prevents the reaction between ethanol and aluminum thereby eliminating the need for additional alterations.

To ensure that there are no other materials compatibility problems, RAFDC conducted soak tests of elastomers and metallic components. In addition, RAFDC had Southwest Research Inc. (SWRI) of San Antonio conduct materials compatibility, luminosity and lubricity tests on denatured ethanol, a 50/50 blend of ethanol and methanol, and avgas. This extensive testing showed no adverse effects on any materials (besides aluminum), acceptable luminosity characteristics, and slightly better lubricity properties than avgas (it should be pointed out that the difference between the lubricity of ethanol and avgas was so slight as to fall in the range of experimental error, consequently, we assume the lubricity of ethanol and avgas to be about the same). The lubricity test results were a surprise, as even ethanol proponents believed that it would be necessary to add a top lubricant when using ethanol as a neat fuel. The results of all these tests were corroborated during the 150 hour engine test stand certification of the IO-540. On all measured components (as part of the procedure certain components are measured before and after the test), equal or less wear was measured than is usually detected during similar tests on avgas. This was probably due to a combination of smoother operating characteristics, adequate lubricity, cooler operating temperatures and less internal combustion byproduct buildups.

RAFDC has obtained FAA certifications for two series of aircraft engines and certification of a training aircraft and an agricultural aircraft are expected to be completed shortly. One series of aircraft engines certified is fuel injected while the other is carburated. Thus, FAA approval has been received for engines whose delivery systems cover all the range of those in use. This experience will considerably simplify and shorten the process in pursuing further engine certifications.

During the conference, most of the issues raised in opposition to biofuels by the petroleum fuel faction were refuted. A Brazilian participant related his country's experience with ethanol, pointing out that in Brazil, 4.3 million vehicles operate on neat ethanol and there are no unsolved technical problems whatsoever.

Even if there was no consesus at the conference among the attendees as to what the next fuel for general aviation will be, at least there was dialogue. The main purpose of the conference was to exchange information, and this was accomplished. Everybody at least agreed that general aviation is facing a serious problem.

## Market Potential: Reciprocating and Turbine Engines

The piston engine fleet in the United States uses approximately 305 million gallons of avgas per year. In the next few years, as stated above, due to a variety of regulatory and economic reasons, 100LL avgas will have to be replaced. Development of other unleaded petroleum alternatives is underway, but none of these, as of today, has an adequate octane rating to satisfy the needs of the 30% of aircraft that burn 80% of the avgas. The octane number of a fuel is a measurement of its resistance to detonation. Ethanol exhibited during the FAA certification tests better detonation resistance than avgas. Consequently, at the very least, ethanol should be the fuel of choice for the aircraft requiring a high octane fuel which consists of a market of 240 million gallons of fuel.

The turbine fuel market in the United states consists of 16.4 billion gallons per year. RAFDC is planning to test blends of 20% biofuels in Jet A. The adoption of such a blend would result in an enormous expansion of the renewable fuels industry and a reduction of over 3 billion gallons a year of imported oil. The potential environmental benefits are a powerful impetus for the development of a biofuel blended turbine fuel.

## Implementation Strategy

There are two major impediments to the commercial success of ethanol in general aviation. The first is not surprising. It is the opposition of the petroleum industry. The second is the lack of public education and general complacency concerning the issue of alternative fuels. Lack of knowledge among organizations and agencies also results in insufficient support for this program and consequent slow progress in implementing ethanol as an aviation fuel.

Since distribution of ethanol for general aviation could initially represent a problem, RAFDC intends to initially target flight schools and agricultural operations since the aircraft engaged in these activities almost always refuel at a single location.

RAFDC has conducted flight demonstrations, forums, and workshops in conjunction with aviation events for the past 15 years. With the imminent certification of a training aircraft and an agricultural spray aircraft, RAFDC will continue to concentrate on these types of activities to encourage operators to use ethanol and help them to convert their fleets.

It is expected that the current placement of E85 pumps around the country, as part of the National Ethanol Vehicle Program, will greatly benefit the implementation of ethanol as an aviation fuel.

## Conclusion

The necessary technology to establish the adoption of a biobased fuel for piston engine aircraft is available.

This is a market for which ethanol has distinct performance advantages and is competitive at today's ethanol prices. With the demise of 100LL avgas on the horizon, and the competitive economic position of ethanol versus even the existing aviation fuel, the potential success of this program is unquestionable.

Aviation gasoline represents a potential market of 305 million gallon per year. Organizations representing the farming interest and ethanol producers should seriously consider supporting this effort. Gaining the aviation market could, in addition to providing a substantial expansion in the ethanol industry, contribute to a public acceptance of ethanol as a general transportation fuel.