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WORKING PAPER

CONFERENCE ON AVIATION AND ALTERNATIVE FUELS

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Agenda Item 2: Technological feasibility and economic reasonableness

SUGAR CANE BIOMASS AND AVIATION: THE EMBRAER/NEIVA "EMB-202A IPANEMA POWERED BY ETHANOL" CASE

(Presented by Brazil)

SUMMARY

This paper presents a description by AIAB[1] of the development and certification of the EMB-202A Ipanema, the first aircraft in serial production to be certified for operation with a biofuel (*ethanol)*. It brings into discussion technical aspects involving the use of a biofuel in aviation and the overall achievements considering the environmental, economical and technical advantages. Additional visions are mentioned in the Conclusion: the need to promote cultural and operational changes due to the implementation of a new fuel, the concerns regarding fuel standardization and the fostering of sugar cane biomass usage as a feedstock for 2nd generation aviation jet fuels.

Therefore, the conference is invited to approve the conclusions and recommendation in paragraphs 6 and 7.

1. INTRODUCTION

1.1 In 1979, the first ethanol-powered car was sold in Brazil. Since then, the use of this biofuel has been spread through many different applications, including an important initiative, in the beginning of the 80's, conducted by the *Centro Técnico da Aeronáutica – CTA* (Brazilian Air Force's Aeronautical Technical Center). CTA tested a Lycoming engine operating with ethanol (Hydrous Ethanol). Acting to support this initiative, Neiva Aeronautic Industry, an Embraer subsidiary, was responsible to run material compatibility tests with aeronautical fuel system materials. A wide range of materials was evaluated at that time, but due to the ethanol supply shortage, this development was interrupted. More than ten years later the ethanol industry in Brazil grew strong and organized itself in the beginning of the 2000´s, resulting in a more efficient distribution network and cost framework. This

[1] Aerospace Industries Association of Brazil - AIAB is the national trade association that represents the Brazilian aerospace industries, networking, promoting and supporting their common interests and objectives, in Brazil and worldwide.

combination motivated automotive OEMs to develop the flexible fuel vehicle (running ethanol, gasoline or their blends).

1.2 The growth of sugar cane business in Brazil created a new demand to the Agricultural Aviation, a segment of aviation business that realized some important advantages of the ethanol over the Aviation Gasoline: **a.** the possibility of a piston engine to deliver a higher power output, **b.** reducing operational costs due to the use of a cheaper fuel, even though a higher fuel consumption was considered, and **c.** reducing the greenhouse gas (GHG) emissions using a fuel with a better carbon life cycle, and especially the absence of tetra-ethyl lead.

1.3 As the major player in the Agricultural Aviation in Brazil and motivated to attend this demand, EMBRAER/Neiva elected the EMB-200 Ipanema family to create a derivative aircraft fed with ethanol. In 2004, the EMB-202A Ipanema was certified as the first ethanol-powered aircraft for serial production in the world.

2. DEVELOPMENT OF THE ETHANOL CONVERTED AIRPLANE

2.1 The development tests started in 2002 and revealed the possibility of using a promising fuel and many technical solutions were developed, especially in the fuel system, in order to make fuel tanks, fuel pumps, hoses and other components resistant to the corrosivity of the ethanol fuel. The protection of the structure was mainly evaluated by a very specific bench test using a corrosive fluid, a specifically prepared “version” of the hydrous ethanol in order to test the reaction of materials against the corrosive attack. The research team understood that there was not a corrosion standard procedure good enough to properly evaluate the materials and surface treatments against the ethanol fuel. A special corrosion test needed to be developed. Some materials were changed, surface treatments tested, rubbers evaluated considering swelling and chemical compatibility. Considering the ethanol properties (volatility), It was necessary incorporate a cold start system in the aircraft that was developed in order to make the engine start in cold weather conditions.

2.2 An engine bench test campaign was conducted so all the operating parameters could be evaluated and some immediate results came up: possibility of increasing the overall power output of the piston engine and the need for recalibrating the fuel system considering different line pressures and fuel flows. Additional tests involving detonation in “hot weather” condition brought much interesting results which were used into the final technical solution, later used in the Certification Process.

2.3 An extensive analysis of the hydrous ethanol was conducted to check the requirements met by the “automotive” fuel specification since it would now be compared to aviation quality standards. At this standpoint Embraer/Neiva was facing a strong technical challenge: **a.** to decide whether it should impose restrictive solutions in the project of the fuel system, capable of withstanding some variability in the quality of the fuel (considering the in-service reality of the Agricultural Aviation in Brazil) but still keep all the safety issues required by a certified aeronautical solution versus **b.** trying to impose the creation of a specific “aviation ethanol” which, in counterpart, would facilitate the technical solutions adopted to the EMB-202A Ipanema but would also make the fuel price to be higher. The first option involved the possibility of keeping safety standards but with some very restrictive solutions that would make Certification tests to be more difficult. The second would probably lead to a more expensive fuel since a very unique specification would need to be developed. Embraer/Neiva chose to work with the first option, so in the design of the fuel system, ensuring the proper safety standards. This decision proved to be the best, mainly due to the operational cost reduction achieved by the EMB-202A Ipanema, a competitive differentiation comparing to its competitors.

2.4 Additionally, a control quality kit for fuel test was developed to be delivered to each Ipanema´s operator, who would be able to check the fuel quality before refuelling his/her aircraft. This kit gave a fast field verification of key fuel physical properties and allowed the pilot to make such quality verification.

3. CERTIFICATION

3.1 The Certification Process was divided in two separate fronts: Engine (per RBHA 33 – FAA Part 33, CAR 13) and Airframe Certification (RBHA 23 – FAA Part 23). Additional compliances to the regular aeronautical requirements were verified, specifically considering the response of the engine to different fuel hydration levels and variation of the magneto timing. The first was analysed in relation to the Avgas engine and the latter in relation to the safety margins against detonation for an ethanol converted engine in “hot weather” conditions. Other tests involved: a propeller vibration survey (imposed a restricted rotation range for a certain type of propeller), flight tests (involved controllability, manoeuvrability and stability, which led to good results especially considering the influence of a stronger engine), engine detonation and calibrating bench tests and others as per the above mentioned requirements.

3.2 The capacity of evaluating the in-service reliability of materials of the fuel system was also an important challenge and Embraer/Neiva overcame it with a very aggressive testing specification. The technical aspects involving the tests of the materials were able to properly anticipate eventual problems the aircraft system could face while in in-service operation.

4. CONTINUING AIRWORTHINESS

4.1 The use of a new fuel in aviation required:

1) Continued acquisition of technical in-service data of both the airframe and the engine;

2) Need for altering cultural aspects of: maintenance procedures, engine and aircraft operational parameters;

3) A wide divulgation of factory standard maintenance and operational practices by, in many cases, *in loco* assistance;

4) Fast response rate to new or unexpected technical incomes, ranging from supplier developments (upstream) to operational issues (downstream);

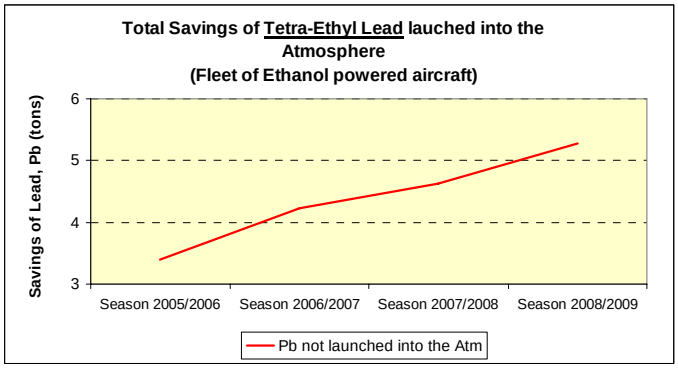
5) Capacity of fast response and proper divulgation of different types of technical publications;

4.2 Two aspects deserved special attention: storing / handling of the ethanol fuel and ensuring the correct engine operating parameters during start-up and cruising/aerial application. Compared to Avgas, Ethanol has different chemical properties and its higher corrosive characteristic demands special care for storing it. Improper storage with not recommended materials would lead to contamination of the fuel and future problems in the fuel system of the aircraft. New engine parameter

required the attention of the pilots in order to adequately run the engine during start-up and aerial application, especially taking into account the recommended fuel flow regimes.

5. ENVIRONMENTAL ACHIEVEMENTS AND OPERATIONAL ASPECTS

5.1 The ethanol conversion developed to the EMB-202A Ipanema brought the use of an environmentally friendly fuel into aviation and one of its contributions was regarded to the reduction of tetra-ethyl lead emissions into the atmosphere. The following illustration shows the overall reduction considering the newly manufactured EMB-202A Ipanema model and two other models that were originally manufactured in the Avgas version and that were afterwards converted to ethanol.



5.2 The use of the biofuel in the Ipanema aircraft added other important advantages: 7% increase of power output, increased in-flight performance, more than 30% reduction in fuel plus maintenance costs which made the operators to save an estimated USD 20 million, in current exchange rate, considering the entire Ipanema ethanol converted fleet up to now. Since the first Ipanema was converted to ethanol, more than 36 million litres of ethanol were burned by a fleet that has accumulated an estimated 360,000 hours of service operation by the end of the agricultural season 2008/2009.

6. CONCLUSION

6.1 The conference is invited to conclude:

b) That the development and certification of the ethanol converted EMB-202A Ipanema showed that the use of a biofuel in general aviation is a viable solution and may be incorporated with safety aspects being fully fulfilled;

c) That strong achievements may be reached, including: economical, environmental and technical advantages. As mentioned above in this paper, differentiated views of in-service practices must also be considered involving both cultural and operational changes.

7. RECOMMENDATION

7.1 The conference is invited to

a) Recommend that ICAO facilitate additional and wider technical discussions in a broad global view involving the use of an “aviation ethanol” in General Aviation, to include: specific mass and its effects in weight/performance of the aircraft, fuel consumption in reciprocating engines and its direct results in range, as well as the specific airframe modifications needed for ethanol running. Other topics include: distribution network, production plants and the quality control system, for example.

b) Encourage international standardization for an “aviation ethanol” fuel with specific consideration given to aircraft range.

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