

Safety Implications of Bio-fuels in Aviation (SIOBiA).

A Brief Synopsis of EASA Research Project EASA.2008/6.

1. This research task was undertaken by a consortium of industrial and academic resources led by the Aachen University of Applied Sciences. Industrial contributors included Bosch, Total, Rotax, ISP, Ludwig Bolkow and Petrolab.
2. The project was supervised by an EASA steering committee, which consisted of EASA personnel, assisted by representatives from LBA (the German CAA), Europe Air Sports, and LAA UK.
3. The final report, EASA report No. EASA.2008.C51 (279 pages) was compiled on 7th July 2010 and was issued by EASA in September 2010.
4. The research programme was divided into various sections to evaluate the potential scale of Mogas usage within Europe, and to investigate the technical difficulties associated with its use. The following work packages and investigations were undertaken;
 - Literature scan and statistical data gathering, (pp17 to 37 & 154 to 159)
 - The Phase Separation mechanism, (pp38 to 43 & 64 to 67 & 72 to 74))
 - Water and alcohol detection methods, (pp126 to 136)
 - Long Term Storage, (pp67 to 72)
 - Vapour Locking, (pp43 to 47 & 80 to 93 & 205 to 212)
 - Carburettor Icing, (pp47 to 49 & 76 to 80)
 - Materials compatibility, (pp48 to 51 & 93 to 125)
 - Failure Mode and Effects Analysis, (pp51 to 62 & 161 to 195)
 - Life Cycle Analysis of Ethanol blended Gasoline. (pp137 to 143 & 213 to 276)

5. Literature scan and statistical data gathering

6. Looking into the scale of Mogas usage throughout Europe created a number of problems for the research team since data availability from most of the European Countries was difficult or impossible to obtain. However a fairly good statistical base exists in Germany and in UK, and steering committee members were able to supply basic data for those two countries. Since these two countries contain 60% of the GA fleet between them it was resolved to use the data available and extrapolate proportionally for the remaining countries.
7. Throughout Europe there are a total of 38,324 powered aircraft of less than 2.25 Tonnes. From the statistical data in Germany it was found that approx 57% of hours flown by these aircraft were by those already approved for operation on mogas, or for types, which were potentially approvable for operation on Mogas.
8. Like all statistical data there are many ways to analyse the figures, and huge assumptions need to be made on the hours flown and fuel consumption for the various types in order to assess the total fuel consumption. The team concluded that the number of aircraft operating or potentially operating on Mogas was of the order of 20,000. If the vast majority of these types are used for training and recreational purposes the potential usage of Mogas is around 12,000,000 litres per year (my estimate, not in the report). Whilst this may sound like a lot of fuel it is a tiny drop in the ocean of European Hydrocarbon fuel use, but from a safety point of view 20,000 aircraft

potentially under threat from the technical problems with Ethanol blended fuels, this is a significant problem.

9. Most of the aircraft cleared for Mogas use were approved prior to the recent introduction of Bio-Fuels into the hydrocarbon motor fuel supplies. The reason for the introduction of Bio-fuels originates in the desire to reduce the emissions of Greenhouse Gasses into the atmosphere by introducing renewable content to the fuel stream. Previously within Europe this was achieved by adding ETBE (which has a 47% renewable content), but more recently this has changed and suppliers are now tending to add Bio-Ethanol to fuel supplies. European legislation was introduced in 2003, which made the introduction of renewable content compulsory, along with financial penalties for companies who fail to achieve the target levels. This European legislation was enshrined in UK law as the Renewable Transport Fuel Obligation (RTFO), and currently the requirement is for 3.25% v/v of the total fuel sold to be a renewable. Ultimately this will increase to 5 % v/v by 2012. This is the maximum allowed under the current fuel specifications EN 228 in the case of Mogas. Further European legislation is on the way and a recent EC directive 2009/30/EC will encourage (but not compel) suppliers to add up to 10% v/v of renewable content.
10. The effect of all this is that presently the vast majority of fuel outlets are selling Mogas, which contains up to 5% v/v of ethanol. Operators of aircraft within the certificated world that have been approved to operate on Mogas have purchased an STC (Supplemental Type Certificate), and modified their aircraft to suit. The currently available STCs all preclude the use of fuels with greater than 1% alcohol. These aircraft are therefore unable to use ethanol blended Mogas.
11. Aircraft within the UK Permit-to-Fly fleet may be operated on Mogas if so approved by LAA or BMAA. Most of the lighter aircraft, particularly the Rotax powered types have a preference for Mogas as the lead content of Avgas 100LL causes oil fouling problems etc. with these engines.
12. CAA has confirmed that light aircraft may use Mogas to EN228, provided that it does not contain alcohol. (CAP 747, GC No. 5). However Microlight aircraft are exempt from this condition and are therefore free to use Mogas with alcohol.

13. The Phase Separation mechanism

14. The SIOBiA team investigated the mechanism of phase separation in great detail, as this is seen as potentially the greatest threat to light aircraft operation on Ethanol blended Mogas.
15. Phase separation occurs when a fuel blend of petrol and ethanol is contaminated by the addition of water. Up to a point the mixture can remain in equilibrium with all three constituents, but if the water content is raised above a critical value it will suddenly separate from the mixture, taking most or all of the ethanol with it. Since the ethanol rich water is of greater density than the base fuel it will settle to the bottom of the tank. Greater concentrations of ethanol will allow higher content of water before separation occurs. Similarly for any given concentration of ethanol, higher temperature will allow higher content of water before separation occurs. (see fig 35 page 73)
16. Here we have a problem, because there is presently no specification limit for the water content of fuels at the service station forecourt. The only requirement is that the fuel must be clear of liquid water. Further there is no practical method of determining the water content of a sample that could be used by pilots pre-flight.

17. The SIOBiA team identified a number of ways that this mechanism can occur, potentially producing a flight safety problem;
 - Fuel purchased with a high water content remains safe at ground level temperature, but cooling in flight results in separation,
 - Fuel is contaminated in storage due to rain water intake through fuel caps, or breathers,
 - Fuel is contaminated in storage due to moisture absorption from the humid atmosphere via the breather,
 - Fuel is contaminated in flight by the addition of moisture via the breather,
 - Fuel with a high moisture content losing ethanol content in storage.
18. The team investigated each of these scenarios, by theoretical and experimental work under laboratory and flight test regimes. The theoretical work and some laboratory experiments have led to a much clearer understanding of the saturation limits for water contamination in fuel samples of various ethanol concentration. This gives a good indication of the safe limits for water content.
19. The flight testing regime was interesting in that it confirmed the expected fuel cooling during climb and high level cruise. (See pages 64 to 67) This effect will of course be exaggerated the higher and longer the flight proceeds. A further point was noted during this test where the cold fuel remaining in the tank can be below the dew point of air entering the vent during the subsequent decent through lower, warmer, higher humidity levels of the atmosphere. This could lead directly to moisture contamination from the air entering the tank through the vent. (See fig 29 page 67)
20. Our understanding of this mechanism is now much better, but we are still totally unable to determine the safety of any particular fuel sample, since there is no practical method for checking the moisture content of the fuel, either at source, pre-flight, or on line in flight. Samples of fuel were obtained from various fuel outlets in Germany and moisture content was found to vary between 190ppm to 750ppm. (See fig 13 page 41)

21. Water and alcohol detection methods

22. The team looked at the currently available alcohol detection methods that could conveniently be used by pilots to check the presence and/or quantity of alcohol in the fuel to be used. These are the colour change method available through Airworld UK which indicates a positive/negative test for alcohol, and the water test method promulgated by most Aviation authorities (including CAA).
23. The colour change test was assessed and found to give good results down to approx 2% alcohol with confidence, but gives no quantitative analysis for alcohol. However as a go/no go test this gives a quick result from a simple to use test kit.
24. The water test is very difficult to use as promulgated, with very small liquid level change for quite large changes in alcohol content. However a test kit available from Maul (see fig 72 page 128) uses a novel method to give a large level change indicated in a small test tube, from a large fuel sample. The down side of this test is the wasted 500ml of fuel after each test.
25. The team identified a number of potential methods for determining the moisture content of fuels such as;

- Chemical detection methods (page 129)
 - Optical detection methods (page 131)
 - Electrical detection methods (page 132)
 - Molecule-specific adsorption methods. (page 133)
26. Chemical methods included the MLR Quick-Check Solution and test kit. This kit claims to test the alcohol and water content at the same time. The colour change solution is said to be equally reactive to water and ethanol and so the sum of the abundances is measured. Since the danger content of water is about one order of magnitude smaller than the ethanol content there is no sensitivity for water content, therefore the test has no significance with respect to danger assessment. However the direct measurement of alcohol content is possible using this kit.
 27. Macherey-Nagel “Watesmo” indicator paper was tested but found to give a false positive test in the presence of ethanol.
 28. Karl-Fischer titration. (See fig 72 page 130) This is a very complex chemical analysis technique requiring special substances, some of which need to be prepared immediately prior to the test procedure. The process is accurate even in the presence of ethanol, but is suitable only for specially equipped laboratories.
 29. Various optical methods were investigated including three types of spectroscopy and small angle scattering, but once again these all fall down when looking for solved water in a solution containing ethanol. The molecular similarity of water and ethanol tends to limit the usefulness of these techniques. There is it would appear some potential in new optical techniques, but none of these are likely to produce a practical low cost portable sensor in the near future.
 30. Electrical detection methods rely upon the change in the dielectric constant and resistivity of the sample with changing water content. A number of sensor manufacturers were contacted and all but one confirmed that the presence of ethanol would confuse the results. One manufacturer did provide a sample sensor, but this showed a marked temperature dependency in the output and later failed under test in the presence of ethanol. (See fig 73 page 132)
 31. One side effect of this part of the study, which was not highlighted by the team, was the significant change in dielectric constant and resistivity of fuels with variable ethanol and water content. Presently there are a number of fuel gauges used in light aircraft, which use the capacitance of the fuel to check the fuel tank contents. These devices rely upon a single fixed dielectric constant for the fuel for calibration purposes and their output will be significantly affected by both ethanol and water content, potentially leading to erroneous fuel level indication.
 32. Water detection by molecule specific adsorption relies upon the property of Zeolite to exclusively adsorb water molecules into its structure. Zeolite beads of a known mass are added to a solution of petrol water and ethanol of known mass, and shaken to ensure complete adsorption of the water. The zeolite is then removed and petrol and ethanol allowed to evaporate leaving the moisture laden zeolite. This is then weighed to give the mass of water removed from the fuel. The method sounds simple, but its accuracy could not be assured even under laboratory conditions, so this is not seen as a practical test. (See pages 133 to 135)
 33. The conclusion for this part of the study was that there are no low cost, simple, effective, portable methods for checking the moisture content of fuels in the presence of ethanol. The only

really effective laboratory test is the Karl-Fischer Titration method, which will give accurate, results, but is time consuming and expensive requiring specialist facilities.

34. There are no online test devices for installation in the aircraft fuel system. This is a problem, since our understanding of the prevention of phase separation relies upon the knowledge of the fuel moisture content. However an unreported line of enquiry by the University led to the conclusion that in reality the water content is not the real point of concern, so much as the turbidity-temperature of the fuel. In other words the temperature at which moisture will be released from solution as the fuel cools in flight. If the actual turbidity temperature of the fuel can be shown to be well below the possible temperature that it could be cooled to in flight then the moisture content is irrelevant. The University demonstrated a prototype of such an instrument at the final SIOBiA group meeting in Cologne. A small sample of fuel (1ml or so is put into a small receiver in the instrument, and sealed. A thermo-electric refrigeration system cools the fuel until an optical detector senses that turbidity occurs, and the fuel temperature at that point is reported. (This is very similar in principle to common industrial air dew point detectors). The instrument was not noted in the report as it is in prototype stage and patent application could be affected, but it is understood to be under continuing development.

35. Long Term Storage

36. Long-term storage of fuel in vented aircraft fuel tanks was investigated to determine the potential change in content of the fuel with time, for various starting fuel compositions, and under various storage conditions. The tests were carried out using E0 and E10 fuels, in specially manufactured vented aluminium fuel tanks. Some were painted in dark colour some left bright, some stored in open daylight, others under cover. (See fig 31 page 69) The tests were carried out over a period from July to December 2009.

37. The tests concluded that there is no significant change in fuel composition in terms of ethanol content over the period for any of the tank types or locations. The fear of preferential evaporation of ethanol therefore does not seem to be a problem. (Top of page 71)

38. The dark coloured tank containing E10 stored outside suffered the highest weight loss of 22% over the period, the dark tank with E0 lost 18%, and the bright tank with E10 lost 16%. The two tanks stored under cover lost 7% over the same period. (See fig 32 page 70)

39. The moisture content of the fuels in the various tanks showed some interesting results. (See fig 33 page 71)

- E10 outside in a dark tank rose from 1100ppm to 2700ppm,
- E10 outside in a light tank rose from 1100ppm to 2200ppm,
- E0 outside in a dark tank fell from 400ppm to 200ppm,
- E10 inside fell from 1100ppm to 700ppm,
- E0 inside fell from 400ppm to 200ppm.

The first two results with increasing moisture content offer no real surprise. The moisture content at the end of the period was still well below the saturation level, and no phase separation took place. The surprise result was the reducing moisture content of the E10 stored inside. Presumably this is as a result of the falling atmospheric water vapour-pressure as winter approached.

40. One point that is interesting to note, is that at the start of this test all three E10 tanks had a moisture content of 1100ppm whereas the E0 tanks were both 400ppm. The difference is not

explained in the report, but could be because the ethanol was not totally dry when mixed with the petrol blendstock. Alternatively the water content test was influenced by the presence of ethanol.

41. The reassuring conclusion of this programme is that the degradation of fuels during long-term storage does not seem to be a problem. Aircraft kept under cover in a hangar are not likely to suffer moisture absorption, and preferential evaporation of the ethanol content does not appear to occur. For aircraft kept outside the preferential evaporation of the ethanol would not appear to be a problem. Water absorption does occur but apparently not to a dangerous degree. The most likely fuel contamination hazard would appear to be physical introduction of water either condensation or rain water by-passing fuel filler caps and vents, rather than via absorption.

42. Vapour Locking

43. Vapour locking is a phenomenon that will occur under certain circumstances in an aircraft fuel system, regardless of the fuel composition. The conditions required are simply that the fuel vapour pressure equals or exceeds the local pressure conditions in the fuel system. Under these conditions bubbles of vapour will form, and if this occurs in a part of the system where the bubbles cause a restriction to flow then fuel starvation can occur. This is most likely to be a problem if bubbles occur at the low pressure point of entry to a fuel pump. The resulting cavitation will reduce or terminate the pumping capability, and fuel starvation will occur.
44. The SIOBiA study looked at the increased potential for vapour locking with ethanol blended fuels caused by the increased vapour pressure of these fuels. Avgas to specification ASTM D910 or Def Stan 91-90 has a vapour pressure of 38 to 49 kPa at 38 degC (100 degF), whereas Mogas to EN 228 has a vapour pressure of 45 to 60 kPa for UK summer fuel and 70 to 100 kPa for UK winter fuel. (Winter fuels have a higher vapour pressure to improve low temperature volatility and therefore aid starting from cold). Providing the ethanol blended fuel is formulated to EN228 limits it will comply with these vapour pressures regardless of the ethanol content. The hydrocarbon blendstock composition will be adjusted to ensure the correct vapour pressure for the mixture at any time of the year.
45. Inadvertent mixtures of ethanol blended fuels and straight fuels can have an unusual effect, in that the vapour pressure will rise above the value of either of the two constituent fuels. The degree to which this occurs is dependent upon the make-up of the blendstock, but could be up to 5 kPa with an ethanol content in the mix at 2%. (See figs 15, 16 and 17, pages 44 to 46)
46. Vapour locking is increasingly likely when the local fuel temperature rises, or where the fuel pressure reduces. If these two occur together the effect is compounded. Fuel heating can take place in the fuel tanks when an aircraft is parked in bright sunlight and further still as the fuel lines pass through high ambient temperature areas under the engine cowlings in flight. The pressure of the fuel will drop locally whenever there is a restriction in the system at eg. fuel filters, valves, pipework fittings etc. Changes in hydraulic head also contribute to reduced pressures as fuel is raised from low mounted wing tanks etc. So in a low wing aircraft using winter Mogas where the fuel pressure at the inlet to the fuel pump is just below atmosphere, if the fuel has been heated to 38 degC on passing through the engine compartment the fuel will boil, and the engine will fail.
47. In order to evaluate this potential problem the SIOBiA team carried out a research programme to test the actual fuel temperatures and pressures prevailing in an aircraft fuel system in flight. The

universities Morane MS893 Rallye aircraft was instrumented and put through a series of full power climbs, cruise and decent periods to simulate multiple sorties on a hot day. The test results (See fig 43 page 83) showed that the fuel temperature reached at the inlet to the mechanical pump briefly exceeded 60 degC during this period. (These tests were undertaken using Avgas). Pressure drop measurements were also taken with the electrical fuel pump off or on using the Rallye (See fig 44 page 84). Further tests were conducted to determine if vibration levels were significant, and local accelerations could induce cavitation bubbles. This test indicated that the vibration levels in critical parts of the system were not significant. (See fig 45 page 86).

48. A simulator rig was then produced which mimics the construction of the aircraft fuel system, and sample blends of ethanol/Mogas were tested to determine the potential for vapour formation. (Pages 86 to 91 & 205 to 211)
49. The conclusion is drawn that for E0 fuel the temperature must be reduced by 5 degC compared to Avgas in order to stay clear of vapour formation. For E5, E10 and E15 fuels a reduction of 8 to 9 degC is required to stay clear of vapour formation. The higher vapour pressure fuels will boil at a lower temperature for any given pressure, and therefore must be kept cooler than Avgas to prevent vapour formation and potential engine stoppage. It is essential to minimise pressure reductions in the fuel system, as for each reduction of 0.1bar the fuel will boil 5 degC lower. The inclusion of an electric fuel pump as close as possible to the fuel tank outlet will assist with maintaining a higher pressure in the hotter parts of the fuel system in front of the firewall. (See figs 48 to 52, pages 88 to 91)
50. Aircraft of the certificated fleet which have been type assessed for issue of an STC for use of Mogas were required to carry out a hot fuel flight test in order to demonstrate freedom from vapour locking. Some further testing along these lines may be required for the certificated fleet in order to clear them for ethanol blended fuels.
51. The team were of the view that it would be beneficial for operators to be able to measure the fuel vapour pressure, by testing a sample before flight. In order to evaluate this they tested the only currently available, portable instrument for this purpose. This is the Hodges tester, which comprises a glass instrument rather like a large syringe (but without the hypodermic needle). A sample of fuel is drawn into the syringe and then a pressure (vacuum) gauge is fitted to the inlet. The plunger is then withdrawn to draw a reduced pressure on the fuel, and the pressure achieved is read from the gauge. This reading indicates the difference in pressure between atmosphere and vapour pressure. (See fig 53 page 92).
52. Unfortunately the results of the trials of the Hodges Tester were rather inconclusive. The team were attempting to identify the ethanol concentration for the fuels from measured vapour pressure and temperature, but found the results too imprecise. The Hodges tester could however be a useful tool for assessing the vapour lock margin for fuels particularly at the end of winter fuel periods when ambient temperature could be rising.

53. Carburettor Icing

54. Carburettor icing is a known problem for light aircraft operators, and most pilots will be familiar with the chart showing the relationship between air temperature and humidity where carburettor icing is expected to occur. (See fig 20 page 49) Under normal circumstances a temperature drop occurs in the air flowing through the carburettor as a result of the evaporation of the fuel.

Introduction of ethanol into the blend of Mogas slightly increases the drop in air temperature as it passes through the carburettor. This is due to the fact that ethanol requires a slightly greater amount of heat to evaporate than conventional fuel. The heat for evaporation is taken from the air stream passing through the carburettor and so the air is reduced in temperature slightly more than with petrol. The effect increases with increased proportion of ethanol in the fuel mix.

55. The research team used a Rotax 912 ULS engine fitted with a VP propeller on their test rig (See fig 91 page 203) at the University labs in Aachen. Runs at various loads with various fuel mixes were undertaken, and in each case the carburettor outlet temperature was measured in two places in each induction manifold. The results from the engine test rig showed that the carburettor temperature drop increases by 0.5 degC from E0 to E5, by 1.5 degC from E0 to E10 and by 3 degC from E0 to E15. (See fig 38 page 77). This is the worst case when the engine is set to approx 95% RPM at light load (decent conditions).
56. Further tests with a Lycoming O-320 engine fitted to the Rallye, but tested on the ground showed similar results, but with slightly larger increase in temperature drop of 5 degC under cruise conditions with the engine leaned to max EGT using E15. (See fig 40 page 79)
57. The conclusion here is that carburettor intake air heating systems will need to be slightly more effective when using ethanol blended fuels, and their use will be required at higher ambient air temperatures than current practice.

58. **Materials compatibility**

59. The compatibility of ethanol blended fuels with the materials of construction throughout the entire fuel system were investigated by the team. This consisted of metallic components, thermo-plastics, thermosetting compounds and elastomers.
60. Unfortunately rather little work was done on the investigation of compatibility with the various metals. Aluminium and its alloys were investigated but found to be in little danger below temperatures of approx 100 degC. The only areas under concern are therefore engine intake manifold connections within the cylinder head, which could be potentially wetted by the fuels. However these areas are generally quite massive and can be readily inspected at engine overhaul times. Engine manufacturers will be able to advise on this point.
61. Earlier work carried out by Concawe and published in their report 3/08 of 2008 offers more advice. The use of Zinc (including galvanized materials), brass, copper, lead/tin plated steel, and aluminium (but only a problem with E100) should be avoided. Materials such as steel, stainless steel, bronze and aluminium are recommended.
62. The work on the various polymers was extensive and has resulted in tables indicating the various compatibilities and incompatibilities over a huge range of materials commonly found in fuel systems. These are far too complex to deal with here, but one notable incompatibility appears to be NBR (as well as H-NBR and X-NBR). This is somewhat alarming as the vast majority of fuel system flexible tubing is based upon the use of this material. (See note at base of page 100 and conclusions on page 125)
63. A thorough study of the data will be required to assess the suitability of pipeline materials for use with ethanol blended fuels. It is thought that some cross check with motor industry standards could be useful in this context.

64. Thermosetting resins will also need to be carefully checked, as many light aircraft have GRP fuel tanks. It is understood that serious tank degradation and leakage problems have occurred in the vintage motorcycle world where early GRP tanks have failed, requiring total replacement with tanks constructed from more modern resins.
65. Thermoplastics are also extensively used in moulded components such as tanks and fuel filter cartridges. Again another area for extensive checks.
66. Sealants and glues are a further problem, as many aluminium tanks rely upon slop sealants or sealants installed at assembly for their integrity, and fuel filter cartridges use glues to retain the filter media in some cases.
67. Finally there are natural materials such as leather, paper and cork used in fuel systems. Unfortunately SIOBiA did not look at natural materials, but Concawe recommend paper and leather, but suggest that cork should be avoided. There are many aircraft with cork floats on fuel gauges, and with cork seals in fuel valves.

68. Failure Mode and Effects Analysis

69. A sub-group led in the main by Rotax carried out a detailed Failure Mode and Effect Analysis (FMEA). It should be understood at this point that the study was after all being done for EASA, and although Rotax engines power a huge fleet of homebuilt and microlight aircraft, these types are all Annex II and therefore of no interest to EASA. The study was therefore tailored to the typical operating practices of the certified fleet of EASA types. As a result they completely ignored the problems associated with the manual handling of fuels expected with homebuilts and microlights. The assumption was that fuels would be delivered by tanker from loading racks to an approved airfield storage facility where it would be tested and quality assured in a similar manner to Avgas.
70. Clearly the most failure prone part of the fuelling process for homebuilt and microlight aircraft is the transfer from forecourt storage tank of doubtful quality via fuel pump to jerry can of doubtful parentage, followed by the manual transfer via funnel of doubtful cleanliness into aircraft fuel tank, and all carried out in the rain. It is these areas that should have been investigated but this opportunity was missed.
71. However the FMEA was very thorough once the fuelling process was complete, and considered most aspects of operation with ethanol blended fuels. The process involved identifying a point of failure and assessing its Severity, Occurrence Probability, and Detection Probability. Each of these areas are scored on a scale of 0-10 and the Risk Priority Number produced by multiplying the three scores together. This is a standard industrial technique and shows the areas of particularly high concern. Each failure mode was then assessed and logged for analysis. The report lists:
 - those failure modes which are already covered in the SIOBiA study report,
 - those where additional research study is required,
 - those which can be resolved by an awareness campaign,
 - those requiring enforcement of operational/maintenance procedures,
 - those where there is a recommended regulatory action.

72. This is a massive piece of work, but there are some very useful pointers if aircraft are to be designed for use with ethanol blended fuels. (See pages 51 to 62 & 161 to 195)

73. Life Cycle Analysis of Ethanol blended Gasoline

74. The final part of the SIOBiA report relates to the life cycle analysis carried out by Ludwig Bolkow Systemtechnik. (See pages 137 to 143 & 213 to 276) This part of the report was produced as a result of the EASA Environmental Dept hijacking the study and attaching this environmental issue onto what is essentially a safety study for a safety agency. It is the authors view that this wasted time, effort and money that could have been better spent on the core activity.

75. The life cycle analysis looks at the environmental benefits of including bio-fuels into the aviation environment. Most Life Cycle Analysis is carried out as a Well-to-Tank, or Well-to-Wheel study. Here we are talking of a Well-to-Propeller study. Fortunately they were able to minimise the workload by using existing Well-to-Tank studies, and producing a Tank-to-Propeller study from scratch. These two together gave the Well-to-Propeller results.

76. The research was thorough and came to the startlingly obvious conclusion that there will be a reduction in green house gas emissions partly because of the biogenic origin of the fuel, but mostly due to a change in the combustion process where there is a slightly less fuel rich setting. However if engines are re-tuned to achieve the original power output then much of this benefit would be lost. It is also concluded that should light aircraft be prevented from using ethanol blended fuels and have to resort to the only alternative, Avgas 100LL then lead emission levels will increase by 50% relative to today's value.

77. Some points for future development (Subsequent to the SIOBiA report).

78. Looking at the individual technical issues associated with the use of ethanol blended Mogas, we must consider them in the light of current experience in the operation of Homebuilt and Microlight Aircraft. Presently there is no ban on the use of ethanol blended mogas in microlight aircraft, and most operators using Rotax engines prefer to use lead free fuel, The vast majority of fuel outlets now sell fuel containing ethanol, and it is therefore reasonable to assume that the microlight fleet is largely powered by ethanol blended fuels.

79. Since many of the aircraft at the lighter end of the LAA fleet are Rotax powered it is a fair bet that many of the owners of these aircraft are ignoring the ban and using ethanol blended fuels. This is likely to be an increasing trend as supplies of ethanol free fuels progressively dry up, and owners see that "others are doing it without problems".

80. There does not appear to be a significant increase in the accident record associated with use of ethanol blended fuels, and we are not presently hearing of major airworthiness issues connected with their use.

81. **Phase Separation.** This would appear to be a very serious problem from the weight of research undertaken, and the fact that there is presently no way of assessing the water content of the fuel. It is unlikely that there will ever be a low cost, portable sensor for this purpose, and the only remaining course of action to prevent this becoming a problem will be through education and introduction of safe working practice in the handling of fuels. Scrupulous attention to detail is required to ensure that jerry cans are clean and dry, fuel caps are not allowing water into fuel

tanks, regular use of tank sump drains, no refuelling operations in the rain etc. A small glimmer of hope is emerging in the potential supply of a portable instrument to accurately measure the turbidity-point temperature of a small sample of a fuel blend. A spot check before flight could reassure that fuel turbidity and phase separation would not occur under the expected flight conditions for the forthcoming sortie.

82. **Long Term Storage.** This does not appear to be the major danger that it was thought to be prior to the study. This has been a pleasant surprise, and the threat of fuel deterioration by selective evaporation or moisture absorption during storage appears to be unfounded. Clearly the use of fresh fuel is good practice if aircraft are to be left out of service for long periods, and particularly for those left outside, but the previously feared dangers are now recognised as overstated. (Some further test work is underway locally on this topic).
83. **Vapour Locking.** This is a very serious problem with fuels of unknown but high vapour pressures being used in systems where high temperatures can be reached. Inadvertent mixtures resulting in further elevated vapour pressures also need to be considered when assessing system design and setting appropriate margins. If aircraft are to be cleared for use of ethanol blended fuels then the fuel system design needs careful attention to detail in order to prevent large pressure drops and significant heat gains to the fuel in transit to the engine. Flight testing of prototype systems may be required to confirm that vapour bubbles are not forming in the system (an LAA member has recently carried out some valuable work on the production of a sensor to detect the onset of vapour production, which could be used during such tests). The use of electric fuel boost pumps immediately adjacent to tank outlets may be a practical measure to offset system pressure loss. Insulation or direct air-cooling of fuel lines and components could be employed, as it is for example on some certified light aircraft. Very careful routing of fuel lines clear of heat sources such as cabin heater hoses, exhaust pipes or oil lines etc need to be considered.
84. **Carburettor Icing.** This well-known phenomenon continues to cause aircraft engine power loss in flight. The increased potential for carburettor icing is of a relatively minor nature in that the change due to the use of ethanol blended fuels is quite small. However the effect can be catastrophic and this should be treated as a serious problem. If aircraft are to be approved for use of ethanol blended fuels then the design of the carburettor intake air heating system needs to be seriously investigated. Flight tests to determine actual air temperature rise through home made intake heaters could be employed to determine suitability for use with ethanol blended fuels. Serious thought should be given to the development of alternative fuel delivery systems designed to overcome this problem once and for all.
85. **Materials Compatibility.** This is the really serious part of the SIOBiA study, and has identified a massive list of unsuitable materials, many of which are in current use. Fortunately the initial scare over the suitability of aluminium has been resolved. If aircraft are to be approved to use ethanol blended fuels then the materials of construction of the fuel system need to be evaluated in detail. Every seal, tube, valve, filter, tank, pump etc needs to be checked to ensure only appropriate materials are used to prevent system blockage or leakage. The list of prohibited materials will need to be developed in the light of the study, and in co-operation with the suppliers, such that a ready checklist is available. This should be made available to the membership.
86. **Other Concerns.** The use of capacitive fuel sensors needs to be investigated if these systems are to be used with ethanol blended fuels. Calibration for a range of fuel types may prove

impossible and this can only be determined by test. In the light of test work it may be necessary to review the use of these devices.

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6th October 2010