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Unleaded Avgas

The avgas that we use in most of our Mooney engines has an interesting history. It was developed during the Second World War to enable designers to get high power to weight ratios from aircraft engines. To do this the fuel required a very high resistance to knock and this was achieved through the addition of lead compounds. Avgas remains a high quality specialty fuel that has better properties than the best available racing fuel.

The Australian Government, some decades ago, mandated the removal of lead from common products like petrol and paint because of the negative health impacts. New cars were required to use unleaded fuel from 1986 and the use of leaded fuel was phased-out by 2002. This has left our GA engines as, I think, the only permitted users of leaded fuel in Australia.

As previewed in the last newsletter, there are moves afoot in the USA to reduce and eventually eliminate lead from avgas and there has been much debate there about when that might happen and what fuel might replace it. This article lets you know the latest on the issue from discussions with the technical representatives of an engine company and avgas producers. It also outlines how avgas is produced and distributed in Australia and discusses what future changes in the lead content of avgas might mean for us as Australian Mooney owners.

Avgas – what is it and who makes it?

Like other fuels, avgas is blended from various hydrocarbon components to meet a specification. The blend can differ between refineries, and over time in the same refinery, depending on the types of crude being processed and the availability of particular blending components.

The most demanding specification to meet in making avgas is usually the octane rating. Octane is an index that indicates how effective a particular component is for avoiding knock in engines. Because aircraft engines need to have very high power to weight ratios they were often designed with high compression ratios, and therefore required fuels with very high knock resistance in order to avoid detonation and other unpleasant things that can spoil your day. The physics do not change whether your engine has a mechanical or a more sophisticated electronic engine control system, but those with electronic systems should be able to operate on fuels that have a thinner margin over the minimum octane requirement for the particular engine.

Relatively few refineries worldwide produce avgas – perhaps a dozen of the circa 150 refineries in the USA and only a few in Europe and the rest of the world[1]. Of the six refineries in Australia (once Shell Clyde closes) only two of them produce avgas – Shell Geelong (Victoria) and BP Kwinana (WA). Mobil Altona (Victoria) ceased producing avgas after the contamination problem in the 1990s.

Like most other products, the companies swap avgas produced at Kwinana for avgas produced at Geelong (and vice versa) to enable them to market across the country without going to the expense of shipping product around the country. This means that (whoever you buy it from) avgas sold in the east of Australia is likely to be from Geelong and in the west from Kwinana.

[1] http://www.hjelmco.com/news.asp?r_id=3871

While the different refineries manufacture to a specification, it is not necessarily the same specification. Geelong, like much of the rest of the world, produces 100LL (coloured blue) but Kwinana is one of the few refineries that still produces 100/130 (coloured green) since it is unable to economically produce 100LL. The 100LL produced at Geelong contains up to 0.56 grams per litre TEL (or 0.125%)[2] whereas the 100/130 produced at Kwinana contains up to 0.85 grams per litre. While the lead is necessary to meet the octane specification, there are also significant dis-benefits to using avgas with higher lead levels. Jabiru suggest that the use of 100LL (rather than 100/130) significantly decreases combustion chamber deposits and may significantly improve overhaul life[3] and there is solid evidence that the same is true for other engines. For example, Rotax recommend against using 100LL avgas in their engines "since the lead content is like cholesterol to your engine: it will accelerate wear on the valve seats, create deposits in the combustion chamber and sediments in the lubrication system and gearbox. Increased maintenance is necessary to compensate."[4]

Avgas represents a very small proportion of the products manufactured from the refining of crude oil in Australia - it was less than 0.4% in 1998[5] and is an even smaller proportion now. It is referred to in the refining business as a "minor product" or as a "specialty chemical" and tends to be classified with other small volume products like lighting kerosene and solvents. The volumes decrease each year as recreational flying declines and more of the commercial aviation market move to turbine engines.

If you think that avgas is expensive compared with petrol, you are dead right. Since there is no excise on avgas, the capital city pump price of avgas is currently about double that of petrol. However, there are some good reasons for the higher price. Avgas is relatively costly for the refiner to produce and distribute. It requires a much higher level of quality control in production and the use of a large proportion of valuable high octane components in the blend. It is also much more expensive to store and distribute as it is supplied in small volumes and has to be segregated from other products due to the lead content. There is also a risk of major financial and reputation costs if you have a quality problem – just ask Mobil.

When I worked in the refining and marketing business in the early 1990s, avgas was one of our highest margin products … but our enthusiasm for it was always tempered by doubts whether we fully understood the cost of producing, storing and distributing it. So, while it is a high cost product, I suspect that the lack of competition means that the wholesale margin remains very attractive. The companies will be keen to continue selling it provided the returns are there. However, we should always remember that avgas accounts for a tiny (and decreasing) proportion of the volume and profit of any oil company and either of the companies could decide to exit the business at any time.

The distribution of avgas also appears to be changing with less of it being sold directly by the manufacturers and more via independent distributors. These companies appear to be picking up refuelling facilities as the major companies move out – which is good – but they also appear to be adding a larger retail margin to the pump price. Since there is usually no competition, there is nothing to prevent such distributors from charging what the market will bear. If we as owners want to avoid paying more than we should for avgas, then we had better develop a price monitoring scheme so that we can include pricing information in our decisions on where to fill. There is an

[2] Avgas 100LL MSDS, Shell Australia, 19Mar10
[3] Service letter JSL 007-3, Jabiru, 5Nov09
[4] http://www.rotaxservice.com/rotax_tips/rotax_feed4.htm
[5] Systemic Investigation into Fuel Contamination, ATSB, Mar01 p24

opportunity here for someone to create a system for collecting price information and an app that gives avgas prices at nearby airports.

What is the US Government position on lead in avgas?

Environmental groups in the USA have been seeking the elimination of lead from avgas for some years. In response to pressure from environmental groups the US Environmental Protection Agency, in April 2010, announced that it was considering whether it "…would be required, in consultation with FAA, to establish standards to control the emissions of lead from piston-engine aircraft" [6]. Lobby groups are continuing to push the issue, with one in California recently announcing that it was going to sue avgas sellers for violating certain Californian environmental statutes[7].

However, this is where we enter the murky world of US politics. The EPA can set limits on lead emissions but is not able to mandate removal since that power is in the hands of the FAA. As aviation fuel is a flight safety issue, only the FAA could ban leaded avgas and is unlikely to do so unless a safe alternative is available. The FAA is a US Federal agency and has jurisdiction over flight, so big legal issues would need to be resolved before one of the US States could override US federal statutes.

There are studies ongoing of lead concentrations around airports in the USA. Those studies should be complete during 2011, so we should await the next round with interest. It is by no means a foregone conclusion that such monitoring will identify high lead concentrations in the air around GA airports. Airport runways tend to be further away from housing than major roads and the frequency of aircraft movements is much lower than that of cars and trucks on major roads. What is certain is that the competing lobby groups will hail the results as supporting their position. Whether anything come of it will depend on the influence that the various groups have in the US Congress. Fortunately the GA lobby is far more influential in the USA than it is in Australia, so we can at least be certain that aircraft owners and manufacturers will get a fair hearing.

Is the lead in avgas a health risk?

This might appear to be a foolish question given the health risks known to be associated with lead, but let's explore it a little further. We live in a world where every day we encounter substances that could affect our health. Some of them are industrially produced - the methane produced by your domestic stove, sulphur in diesel, benzene in petrol, asbestos, etc. Others are naturally (even organically!) produced, like smoke from bushfires and methane from cows farting in paddocks. Whether any of these pollutants will shorten your life span depends on the concentrations that you expose yourself to.

Much of the material published on the matter of lead in avgas is a lesson in how to lie with statistics. The reference by the US EPA to "Emissions of lead from piston-engine aircraft using leaded avgas comprise approximately half of the national inventory of lead emitted to air" illustrates their bias. It ignores the fact that the amount of lead released to atmosphere today is a very small fraction of what it was when the car fleet was largely powered by leaded petrol. For example, the Swedish EPA says that lead emissions in Sweden are today only a few percent of what they were in the 1970s.[8]

We should all be looking forward to the results of the further work that the US EPA is undertaking on lead concentrations in air around GA airports before reaching any conclusion on whether the lead in avgas is likely to do us any harm. Those people who live in airparks should pay close attention!

What are the engine and fuel manufacturers doing?

The direction of this issue is vital to the two main engine manufacturers – Lycoming and Continental. The direction of their business and their competitive position could change significantly depending

[6] http://www.epa.gov/otaq/regs/nonroad/aviation/420f10013.htm
[7] http://www.pacificflyer.com/2011/06/environmentalists-plan-to-sue-in-california-over-avgas/
[8] http://nvvextern.epi.nu/Webbinnehall/Tillstandet-i-miljon/Miljogifter/Metaller/Spridning-till-luften-fran-manga-kallor/

on the outcome of any move to replace leaded avgas with other products. Some engines might need to be redesigned and others might become obsolete.

So both companies have been vocal about the need for the FAA, the EPA and the fuel manufacturers to get the issue resolved. Lycoming has taken a strong public position[9] that any replacement for leaded avgas should have similar performance specifications to 100LL. This recognises the fact that the existing worldwide fleet outnumbers annual new aircraft production by a factor of 50. However, Lycoming do appear to be quietly working on certifying more of their engines to run on current grades of unleaded petrol[10] and to develop new engines that will run on lower octane unleaded fuels[11]. Continental, on the other hand, are more focussed on certifying some of their engines to run on 94 octane unleaded avgas and on developing a new line of Diesel engines[12].

We would all like to see the aircraft engine manufacturers doing the work to modify existing engines, and to develop new engines, to run on any replacement fuel for 100LL (not to mention taking advantage of modern car engine technology). However, if the replacement fuel is significantly different to 100LL, then we need be realistic about their capacity to do it. At a (very optimistic) guess, all aircraft piston engine manufacturers worldwide make a total profit of less than half a billion dollars each year. Even if they were to spend 20% of this on R&D, their total spend would be about a quarter of one percent of what the top four car companies spend on R&D each year. So, if there is a big change in fuel type, don't expect the engine companies to be able to instantly come up with modifications and/or new designs to replace the hundreds of engine types designed to run on leaded avgas.

The avgas manufacturers in the USA and Australia are waiting for the FAA/EPA to come to a resolution on the issue and will continue producing leaded avgas until told otherwise. I understand that the US refiners, based on some recent discussions that they had with the FAA, do not expect this issue to be resolved soon and expect to be producing 100LL for quite some time. Shell Australia are working on this assumption and (I understand) recently upgraded the handling facilities for lead additive at their Geelong refinery. It is also encouraging that Shell say, if BP were ever to decide to cease production of 100/130 at Kwinana, that they have the capacity to supply the entire Australian avgas market from their Geelong refinery.

There is only one company that manufactures the lead additive used in avgas - tetra-ethyl lead (TEL) - and both of the Australian refineries are supplied from a plant near Manchester whose owners are not prepared to make any further major investment. It is not clear what would happen to avgas production if that plant were ever to cease production.

What are the potential replacements for leaded avgas?

Making a high octane unleaded avgas is both an economic issue as well as a technical one. Any refinery chemist could create a small batch of unleaded avgas in the laboratory using components currently availably in Australian refineries but it is unlikely to be possible to achieve 100 octane while meeting all other aspects of the specification. The thing that enables 100LL avgas to be made at current price levels is good old TEL. Adding a small amount of it to the blend enables the refiner to meet the octane specification without additional investment to increase the "octane pool" in the refinery or importing exotic high octane components.

[9] http://www.lycoming.textron.com/news-and-events/pdfs/alternate-fuels-fa.pdf
[10] http://www.lycoming.textron.com/support/publications/service-instructions/pdfs/SI1070Q.pdf
[11] http://www.lycoming.textron.com/news-and-events/pdfs/iE2_Engine.pdf
[12] http://www.avweb.com/avwebflash/news/Continental_DieselEngineProject_202535-1.html

It may be that the clever chaps in the refinery research centres will come up with some new unit that produces high octane components at low cost. However, there are now health and environmental concerns[13] about the last one that was developed in the 1980s (Methyl Tertiary Butyl Ether – or MTBE to its friends) and it is now being phased out. Ethyl Tertiary Butyl Ether (ETBE) is used in Europe as an octane boosting additive but there may well be resistance from the green lobby in the US to the use of it (or any other new components).

You should ignore much of what you read about potential 100LL replacement fuels. While there are some good companies working on such options, there are other companies who are generating publicity as a means of securing research grants and subsidies. There is a lot of good work being done on these issues, but much of it is being done quietly by the engine manufacturers and refining companies. To be taken seriously, I think that any 100UL promoter needs to own their own production facility (or have firm supply contracts for the components) and to quote a price, and I'm not aware that any have done that yet.

Sweden is the one country where a local company (Hjelmco Oil) has been producing unleaded avgas for more than 30 years. However, it is a lower octane (91/96) product that is not currently certified for most for our Mooney engines and is priced about the same as 100LL at about A$2.80/litre (including about $1.00 of taxes). Hjelmco submitted a proposed 100 octane unleaded product (that included ETBE as one of its components) to the US standards authority (ASTM) in 2006 but have had no response as yet.[14]

One way to reduce overall lead emissions from light aircraft engines would be to introduce two grades of avgas – a lower octane unleaded for those engines that can use it and 100LL for those that can't. While two avgas grades (91/96 UL and 100LL) are available in parts of Europe, I doubt that the companies will be prepared to supply multiple grades to airport refuelling facilities in Australia. Due to the greater distances here, the freight cost of avgas is high and with two grades it would be prohibitive. One clever option being considered in Europe is to ship an unleaded avgas product to the final distribution terminal and then add the lead to make 100LL prior to final delivery. However, Iam sceptical that any of the major companies here would allow the lads at their remote distribution terminals to do this given liability issues.

So the big question for us is whether the agreed replacement product would have an octane equivalent to 100LL, or something less.

Implications for the Mooney fleet of a move to unleaded avgas?

Hamish Ramsay (the only Mooney agent on the East Coast of Australia) tells me that there is an STC to permit Mooneys with a carburettor (such as the M20C and M20G) to run on premium unleaded petrol, but that this is not the case for fuel injected Mooneys (M20F, M20J and onward).

So, if you own an M20C or such like, you have an option no matter what happens with avgas. If and when there is agreement on a replacement unleaded avgas, you can be pretty sure that your aircraft will run on it – whether it is an equivalent unleaded 100 octane product (100UL) or not.

If you have an engine that is permits use of petrol under that STC, there are some practical issues in using it in your aircraft at this time. Firstly, you can't actually buy petrol at most airports, so you have little choice but to use avgas unless you have your own fuelling facility. Secondly, ethanol will

[13] http://www.cancer.org/cancer/cancercauses/othercarcinogens/pollution/mtbe
[14] http://www.hjelmco.com/news.asp?r_id=37825

have a very bad effect on hoses and any rubber/fibreglass components in your fuel system. If you are going to use petrol, you must test it yourself to ensure that it does not contain ethanol. Thirdly, different blends of petrol may be supplied to different parts of the country to reflect different climatic conditions – you may find the petrol that you load in one part of the country will perform differently elsewhere. Last, but not least, one of the refiners that I spoke to said that would strongly recommend against using petrol in engines under older STCs due to the blend having changed very significantly between now and the time the STC was approved. I think the reason was the higher proportion on oxygenates in the blend increasing the risk of burnt exhaust valves. If, despite the other issues above, you are still keen to do it, then I'd suggest that you investigate this aspect further.

If you own a fuel-injected Mooney, there is not currently an STC option to use petrol. This may be for two reasons: (a) the engine may require an octane equivalent to 100LL for detonation margin purposes or (b) the engine fuel delivery system may not be able to handle the higher vapour pressure of petrol. If the replacement for 100LL avgas is 100UL, then your plane will be able to run on it and give you similar performance. The main problem right now is that we do not know what the replacement for 100LL will be and what it will cost, and we may not know for a few years yet.

If the agreed replacement fuel does not match 100LL performance and your engine needs that level, then a whole bunch of other questions arise such as whether the engine could operate with sufficient margin to avoid detonation and other unpleasant things or would it need to be de-rated. In a worst case scenario, certain high compression engines might become obsolete if they can't be re-engineered or re-certified to run on a lower octane product.

The other complication is whether an STC would be required from the airframe manufacturer to permit the use of unleaded fuel - in addition to the approval from the engine manufacturer. This might be avoided if the regulatory authorities were prepared to grant a blanket exemption. For example, the European authorities permit[15] unleaded avgas to be used in engines where the manufacturer has approved it, without further approval being required from the aircraft type certificate holder. However, Lycoming believe that the FAA is unlikely to do that unless the specification of the replacement fuel exactly overlaps that of the original 100LL.

This aspect of the problem, along with many others, is being examined by the FAA and industry-owner representatives within the FAA's Unleaded Avgas Transition Advanced Rulemaking Committee (FAA UAT-ARC)[i16]. Let's hope that they do a better job than the folks managing the US national debt.

Where to from here?

If you own any aircraft, the future of 100LL is something that you should be interested in. My personal view is that the emotive arguments will trump any rational analysis and that there will be a move to unleaded avgas in the USA within the next decade. Australia, as with most else, will follow close behind. As owners of Mooney aircraft, I believe that we should:

a) support the transition to unleaded avgas being delayed as late as possible (provided the ongoing studies confirm that there is no clear health impacts);
b) keep a close eye on the relative costs of 100LL replacement fuels so that we can make an informed decision on which to back;

[15] http://ad.easa.europe.eu/eu/2010-31
[16] http://www.faa.gov/about/initiatives/avgas/

c) seek better information from engine manufacturers on whether STCs to permit the use of unleaded petrol can be extended to other engines in the fleet; and
d) prepare for a future where the owners themselves may have to band together to secure STCs to enable their aircraft to use a substitute fuel.

While the analysis and opinions above are my own, I had the benefit in researching this article of talking to a few people who are experts on various aspects of this issue. Avco Lycoming are heavily involved in this issue and I received helpful comments from Mike Kraft (General Manager) and Adrian McHardy (Regional Manager for Asia Pacific, Middle East and South Africa). Adrian has a pretty broad perspective on these things as his territory covers just about every place that there are significant numbers of avgas engines outside the US! For those who would like to hear more on this topic, there is an excellent presentation on this topic by Mike Kraft at Aero Freidrichshaven in 2010[17]. I also spoke with Murray Wilks of AeroShell who, in addition to being Technical Advisor Oceania, is also a LAME and an active pilot of a big turbo Cessna twin (so he has a personal as well as professional interest in where this issue is heading).

Lars Hjelmberg (Executive Director) of Hjelmco Oil also made a significant contribution to the article. Lars is passionate about unleaded avgas and rightly proud of his company's record of making and selling unleaded avgas in Sweden for more than 30 years. There is a much background material available at www.hjelmco.com.

Adrian McHardy (Lycoming) and Murray Wilks (Shell) hope to join us at our AGM Flyin in March 2012 to update us on this issue and to give us their perspectives on where engine and fuels technology is heading. So, this is yet another good reason to join us at next years' AGM flyin. This is an opportunity that you won't get anywhere else. We will finalise the date and place shortly but it is likely to be either at Aldinga (south of Adelaide) or on Kangaroo Island around 15-16 March 2012.

John Hillard

28 July 2011

[17] http://www.aopa.org/aopalive/?watch=JvMTNmMjqQ4CpxoIXM5TwR1ATuLuqGuh