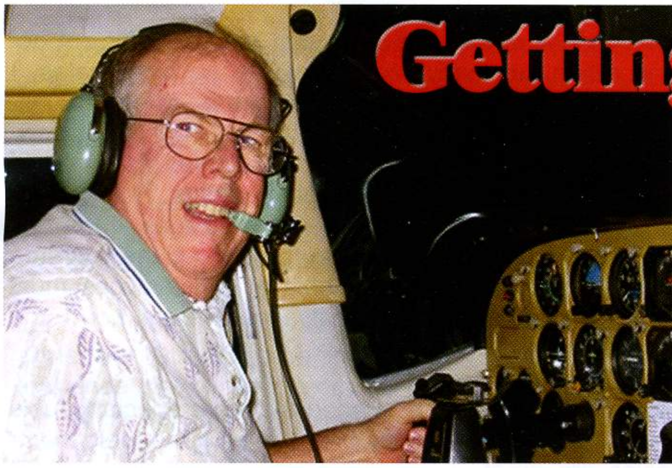

Getting The Lead Out

Dealing with 100LL issues

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Jim Rickey took his first small airplane ride at the age of 5. Not long after, he was getting into dad's toolbox while dad was at work. At age 7 he put his hands on the controls during the family's annual flight to Kansas and became an airport bum by age 12 when his parents opened a flight school. Jim did tune-ups and a brake job on mom's '59 VW before he could legally drive it but didn't solo until his 24th birthday. With solo cross country flights done, Jim put flying away to enter the teacher-prep program at Cal Poly Pomona. A move to Hanford CA to start a career teaching kindergarten through fifth grades settled him down enough to buy a house, etc. That essential stuff taken care of, he obtained his private pilot certificate in his father's Cessna T210, driving 4 hours each way to fly it. When dad gave up being PIC, but had no luck selling the plane, Jim took over the 210 instead of buying his own. Dad got to enjoy the 210 an extra 16 years.

Shortly after moving to Hanford, Jim met Debby, also a teacher, and the rest is history. The 25-34 students they had each day were their kids, and they never had any of their own. Debby enjoys riding in the plane and has soloed a 172. Now retired and done with care-taking for family, they hope to use the plane more often.

In the 23 years the 210 has been Jim's, he has done the majority of the work on it, and still rolls along on a creeper to clean a plane's bottom and up on a ladder to get the top. Jim is the newsletter editor for the Hanford EAA Chapter 1138 and in a recent issue, he published the following article that he wrote.

After the March meeting I heard a couple of members griping about the push to ban leaded avgas, and then about the cost of 100 Low Lead. This article is not to explore the politics of getting the lead out of 100LL--you guys can do that quite well on your own! It is well past the time to get the lead out of avgas-- not just for environmental reasons.

This article is directed more to those of us in the certified aircraft world, as you with experimental aircraft are free to experiment to your hearts' content, burning any fuel, even choosing any means of propulsion you want.

Lead-free avgas has been talked about since the mid-1980s, and talked about again...and again. Nothing has happened. Arguments against removing the lead all remind me of the arguments I heard in the 1970s against removing lead from automotive fuel. Valves were going to wear out, performance was going to go down the tubes; etc. Automobile performance did get pretty poor around 1980, but it wasn't just due to the removal of lead. I don't think any of us would want go back to carburetors in our autos after experiencing oxygen sensors, electronic fuel injection, and catalytic converters.

Lycoming and Continental have both been putting hardened valve seats in their engines for a while. Yes, our aircraft engines have substantially different operating parameters than auto engines, but by now there are enough aviators who have run exclusively with unleaded autogas for enough years, that fears of premature valve wear should be put to rest.

Cleaning the spark plugs on my plane over the years I have rarely observed more than the very lightest of carbon deposits. Lead deposits are a different story. While lead deposits have never come close to fouling a spark plug in my engine, it has been a problem for some cool-running motors. I see lead when I scrub the belly of my plane. I see lead when I change the oil; it settles in the recess of the drain plug and in the grooves of the filter. When I removed the prop for overhaul I saw a coating of lead inside the crankshaft, and I have never run synthetic oil which caused so many problems for some operators with lead-plugged oil galleries a few years back, or even a semi-synthetic oil. Lead is detrimental enough to engines that a lead scavenger is added to avgas, and this lead scavenger is corrosive to our engines and some consider it worse for the environment than the lead that is getting all the attention.

Removing lead from avgas may produce some short-term pain for some aircraft, which can be worked around, but in the long run it will be beneficial to all. I personally think the boat was missed back in the late 1990s when a specification for 82UL avgas had been approved. If, upon approval, there had been the guts to say something like, "We'll give you 15-20 years to get your engines 82UL compliant, then there will be no more 100LL," we would not be worrying about getting the lead out today. But nothing changed. It is time to bite the bullet and move on!

CURRENT FUEL

Our special niche fuel is a very good product, but it really is doing us no favors. Little avgas is produced; out of the 137 operating refineries in the United States, only 10 produce avgas. Four companies control those 10 refineries. Several years ago I read that a six-month supply of avgas for the West Coast is satisfied with a 1-1/2 day production run. There is not much money to be made producing 100LL, because so little is consumed. Leaded fuel requires either completely different equipment, or cleaning of the equipment before the next product is refined. The presence of lead demands a completely separate method to get it from the refinery to us--it is trucked all the way from the refinery to the fuel island at the local airport. There is so little demand for tetraethyl lead that only one TEL manufacturer is left on the planet.

Looking at a chart of petroleum *Products Supplied* from the U.S. Energy Information Administration, the row labeled, "Finished Aviation Gasoline" shows that even in the U.S., with the healthiest general aviation in the whole world, avgas is a drop in the bucket. In 2009 avgas production was;

- 1/628th of "Finished Motor Gasoline,"
- 1/98th of "Kerosene-Type Jet Fuel"
- 1/254th of "Distillate Fuel Oil" and,
- 1/32nd of "Petrochemical Feedstocks."

Remember these numbers. Add the special handling and transportation required of our fuel, and suddenly it is no surprise that avgas costs significantly more than auto gas. The refineries that do produce it are doing us a favor, and we are paying for that.

ALTERNATIVE FUELS

Late 2009 and early 2010 had two alternatives to 100LL getting a lot of press, Swift Fuel and 94UL.

Swift Fuel, now designated UL102, sounded like a wonderful product. I had hoped it was as good as they said it was, plentiful, and at the $2.00/gallon price they were claiming they would be able make it for. However, from the very first press release, I felt Swift Fuel's claims were too good to be true. Swift Fuel has flown, but it has been real quiet with Swift Fuel the past few months--apparently the price per gallon they were talking was extremely optimistic--$10.00 per gallon is the latest number I read....Ouch!

General Aviation Modifications, Inc (GAMI, most known for their line of fuel injection *GAMIjectors*) has been heard from about a new drop-in replacement for 100LL, called G100UL. It also is not just in the lab, it has flown, and it works. According to General Aviation News' article, *G100UL: The future of fuels*, GAMI is wanting to pursue it by STC so they can keep the formula proprietary and patents can be controlled. The F.A.A. will allow this, but I have to wonder if fuel producers will want to license the fuel from GAMI.

Sunoco has some race fuels that have a sufficient octane rating, no lead, and some with no oxygenates. I have no idea what the vapor pressure is, or other qualities that we must be addressed for all the operating environments we fly in. I would not be surprised if they could adapt one of their fuels to our requirements. Trouble is, it is about twice as expensive as today's avgas. If the fuel is or could be made suitable throughout the extreme range of operating environments at which avgas must perform, production in quantity could likely lower the price difference.

All three of the aforementioned fuels are specialty fuels and will have two major problems even if the fuels themselves are great. 1) Ramping up of production and 2) Distribution of their unique product.

82UL specifications have been ratified by standards organizations and approved by the F.A.A. It would be pretty accurate to say it is 87 octane unleaded autogas, without oxygenates, and with strict quality control. It should be able to be tapped from the pipelines that carry fuels across this country. The same sources that supply fuel in third-world countries should be able to produce 82UL. The specification for 82UL is still with us, but 11 years after approval, none of it being made.

86UL is a fuel that has recieved little attention. The main difference from 82UL is that its base stock is the same as 91 octane autogas instead of the 87 octane autogas that forms the base for 82UL. There are no specifications for 86UL, but it should not be hard to come up with.

94UL. Early reports were that 94UL was simply the 100 low-lead fuel we have been using for decades, but without any lead in the mixture. It is not quite that simple, but there are no new ingredients in 94UL, just a little bit of adjusting the mixtures of 100LL's ingredients and the omission of lead. This is good; it should ensure that the fuel remains just as compatible with the materials in aircraft fuel systems as 100LL has been. 100LL has a proven track record from summer in Death Valley, to winter in the arctic circle, to well up into the flight levels, and it stores very well. If the changes in the mixture of the fuel do not require increasing the use of additional expensive components, removing the lead should result in a lower cost fuel, since the tetra-ethyl lead itself *is* quite expensive, and the fuel will not have to be so isolated from other fuels.

Hjelmco introduced unleaded avgas in 1981 and their second generation *AVGAS 91/96* in 1991. From an Wikipedia article I read "In 1991 Hjelmco Oil introduced an unleaded *AVGAS 91/96 UL* meeting leaded grade 91/98 also in standard D910 with the exception of transparent colour and no lead. Engine manufacturers Teledyne Continental Motors, Textron Lycoming, Rotax and radial engine manufacturer Kalisz have cleared the Hjelmco *AVGAS 91/96 UL* which in practise means that the fuel can be used in more than 90% of the entire world piston aircraft fleet. *AVGAS 91/96 UL* has been produced in Sweden since 1991 and used in thousands of aircraft for many million flight hours." They do claim a long track record with unleaded avgas. But it is not getting much attention here in the U.S.

Ethanol. I was talking with fellow EAA member Richard Vandersteen about this article and he pointed out that he has some 104 octane unleaded fuel for his off-road vehicle. Of course, the 104 octane was achieved with Ethanol, which would work fine in an aircraft that was designed for it from the beginning, but very few aircraft in existence are. While the octane of ethanol is quite high, the BTUs per gallon are not as high as petroleum; aircraft range would go down.

As Richard pointed out, an aircraft built today could be designed to use alternative, non-petroleum fuels. There are aircraft flying around today that run great on ethanol. Greg Poe has been doing aerobatic routines in an ethanol-powered aircraft and the Vanguard Squadron has a 100% ethanol-powered team of RV-3s. But of course, these aircraft were built from the beginning with ethanol in mind.

My hope is that a fuel that is close to a mainstream product comes out of all of this. Whatever the regulatory agencies come up with, I hope they decide soon what is going to happen and then provide a long period for fuel suppliers and aircraft owners to get ready for it, and finally that the specifications can stay in place for decades to come.

ENGINE MODIFICATIONS AND ALTERNATIVES

Water Cooling; a great solution. Water cooling can eliminate the hot spots in the cylinder that force compressions to be lower and/or ignition timings modest. Even using a lower octane fuel, compression ratios could be raised in a water-cooled cylinder, so there would be a net gain of power even with a lower octane fuel. If I had an experimental aircraft, I would strongly consider *Liquid Cooled Air Power's* cylinders for Lycoming engines, or design my own Continental engine using their Voyager water-cooled cylinders, if they were available. There are several auto engine conversions that run on unleaded mogas and have great power-to-weight ratios.

But for those of us in the certified world, I am not holding my breath:

- When I had a valve leaking in early 1988 I talked to *RAM* about when the water-cooled Voyager Engine might be available, and was told it would be coming in a couple of years. 22 years later, still waiting.
- In April of 1988 at the Cessna Pilots Association convention, the Continental factory representative told us of the benefits and advantages of water cooling and how their Voyager engines would be so much better than air-cooled engines. I agree they would be better, but where are they?
- It has been 24 years since Rutan's Voyager circled the globe and the advantages of water cooling were shown to the world. Today, only a handful of certified light aircraft are flying with a water-cooled engine.

While I am obviously a proponent of water cooling, some existing airframes just wouldn't lend themselves to it. But the biggest roadblock I see is that manufacturers just don't seem to have the interest (or maybe don't see an economic incentive) in pushing it through. If general aviation manufacturing had not gone on the brink of extinction in the late 1980s, water cooling might have come of age. There may not be a viable economic model to retrofit the existing fleet. There are maintenance issues and loss of coolant concerns with water cooling but these concerns can be dealt with, and liquid-cooled engines could have better reliability than air-cooled engines which have some components running so near their thermal limits. Alas, I just don't see water cooling happening anytime soon. I hope I am wrong.

Advanced Engine controls. Most of these work around the principle of detecting pre-ignition and retarding the timing so that the engine does not self-destruct. GAMI.'s Prism is one of the leaders in this field. Their webpage says, "Certification is expected soon," but I believe I saw that same statement on that same webpage 3 or 4 years ago. I do not dispute any claims on the Prism webpage, but I have to ask, *"What happens to the power when the spark has to be retarded to prevent detonation?"* I drive a 1990 V6 Camry that says, "For best performance use 91 octane fuel." 99.9% of the time I can perceive no difference between the 87 octane I usually buy and 91 octane. But hold the throttle wide-open for long enough (roughly 15-20 seconds) and power drops off. This would be about the time after you applied full power for takeoff, lifted off, and were trying to clear the obstacles at the departure end of the runway.

Retarding the timing does reduce combustion chamber and cylinder head temperatures, but it also reduces power and raises exhaust gas temperatures. As a system to advance the timing and improve efficiency over a standard aircraft magneto, I am all for variable timing which has worked great in experimentals to increase efficiency when manifold pressures are lower than sea level wide-open throttle. But as a system to prevent detonation with lower octane fuels, I wouldn't want it in my plane. Yes, it can keep the engine from self destructing, but there are drawbacks.

Alcohol/Water Injection, also known as anti-detonation injection (ADI) is a tried and true method to avoid detonation for short periods of time when the engine is called upon to develop maximum power and the fuel does not have sufficient octane. It was used before WWII on military aircraft. Air racers at Reno still use it today, and effectiveness is dramatically shown when a racer exhausts its ADI fluid supply. It's also used by auto racers. Petersen Aviation, well known for their mogas STCs, developed systems for use on some normally aspirated 100 octane aircraft and engines:

"We were issued STCs for ADI (anti-detonation injection) systems in the Baron, 210, and C-188 with 285 hp IO-520s or 260 hp IO-470's in the 1980s. The systems worked as advertised but at the time there was not enough disparity between the price of 100LL and mogas for people with these airplanes to view it as worth the money. We only sold a handful of them."

"After trying for a time to sell more, I finally removed them from our PMA. It was taking an inordinate amount of time to maintain the ADI systems on our PMA given the lack of sales, so I discontinued them. I still hold the STCs but in order to sell them they need to go back onto my PMA. Depending on what octane rating the new fuel which replaces 100LL may have, ADI systems might be just the thing that is needed."

ADI. would be a great solution for those few minutes that 100 octane engines really need the full 100 octane.

Diesel. Much has been discussed about running diesel engines in aircraft. Continental has made some press this past May with an announcement that they are going to be bringing diesel engines to market soon, and they won't cost much more than their gasoline engines. Diesels in aircraft actually make a lot of sense:

- Diesel completely gets rid of pre-ignition and detonation problems, very advantageous since air-cooling will likely still reign. (I do have some concerns about the cylinder head temperatures.)
- A diesel engine's exhaust gas temperature runs about 300° to 400° cooler than gasoline engines. This would be wonderful for the exhaust components.
- I have never driven a diesel where I could detect a loss of power with high ambient temperatures, great for mitigating density altitude problems. (I have, though, felt a reduction of power with high dew-points.)
- Diesels take in so much excess air that even the normally aspirated ones I have driven had no noticeable power loss as high as I have driven them, about 11,000 feet. (Yes, they did put out more smoke, but turbocharging can take care of that.)

Finally, Sonex Reserch www.sonexresearch.com (not to be confused with Sonex Aircraft LLC) is pursuing a 40-year-old concept, a sort of a gasoline engine / diesel engine hybrid.

Over the years there have been many announcements of upcoming diesel engines for light aircraft. Most of them never materialized, a couple have successful flying examples, and there is one notable example that made their owners curse the very thought of a diesel. Teledyne Continental Motors had their TD300 at AirVenture 2010. Turned out to be the SMA Diesel that has been around fore several years. Conversion cost $80,000. They have got to do better than that.

While the expectation has been that jet fuel would be used in aircraft diesels, Exxon has gone on record stating they do not support or endorse the use of jet fuel in diesel powered aircraft. As detailed in the DieselAir newsletter of November 2008, there are some points to ExxonMobil's reasoning. I agree with others that some of ExxonMobil's position has been dictated by lawyers instead of the lab, but even with that, I feel ExxonMobil's issues can all be addressed in the design of the fuel system and diesel injection components. It just points out that putting a diesel engine in an aircraft is not as simple as we would like for to be. Like water cooling, I am just not holding my breath for Diesel to happen.

ENGINE MFG'S VIEW ON THE SUBJECT

Teledyne Continental Motors is favoring the use of 94UL. It has flown 94UL and is working with standards organizations in determining the formula. I urge all readers of this article to listen to Continental's take on this issue in an Aviation Consumer podcast, where Continental's chief engineer Bill Brogdon talks about what Continental is doing to transition to an unleaded fuel. http://tinyurl.com/CM-Podcast-1 One of the surprises they have found in their testing is that the turbocharged motors fared better with 94UL than the higher compression normally-aspirated engines:

"...in our testing with turbocharger engines--at least on the newer turbocharged engines that we have the most experience and most test time on, our cross-flow, twin turbocharged engines--those will operate very nicely on 94 unleaded. There are a few adjustments that may need to be made for some of the engines. Some of the engines will operate essentially without a change. There could well be some changes in the operating envelopes at high altitude...in cruise conditions we might have a little less detonation margin there."

"The naturally-aspirated 8.5:1 100 octane engines are more of an issue, because those engines do detonate at maximum power on 94 octane unleaded fuels. There are a number of technical approaches we can take to that problem."

One route Continental is pursuing is replacing an engine with the next size larger engine having a reduced compression ratio. Reducing the compression ratio would decrease the power about 4%, but the increased displacement will gain back all of the power lost in the compression ratio reduction. I say keep the compression ratio up, but limit the manifold pressure on the larger engine so that it produces no more power than the smaller engine. The pilot would have to limit the throttle at low altitudes, but could open up the throttle at altitude and enjoy the increased power.

Continental says they are concerned about the economy of retrofitting the legacy fleet. I think it would be good business to have affordable upgrades. However, going to a larger engine pretty well rules out field overhauls, which would be a boon for business at Continental.

Lycoming has taken the opposite view, that we must have a 100 octane fuel. I do not agree with Lycoming's position, but I also urge all readers to listen to the complete *Aviation Consumer Podcast* with Lycoming's view on the subject. Lycoming's Michael Kraft talks about how many billions of dollars would be lost if we had a lower octane fuel. But he does admit they don't know what a 100 octane unleaded fuel would cost. Some of Lycoming's reluctance may be due to FAA research that has determined the Lycoming TIO-540-J2BD (used in Piper Navajos) and Lycoming IO-540-K model engines to have the highest octane requirement engines in the active fleet.

WHAT DOES IT ALL MEAN TO CHAPTER 1138?

- No one with an engine certified for grade 80/87 aviation fuel would be hurt one little bit by 94UL or the Hjelmco AVGAS 91/96, or 82UL.
- Operators with engines certified for 91/96 aviation fuel may be affected a little bit by 94UL, and significantly by 82UL.
- Those of us who fly engines certified for 100/130 could:
  get by with some operating limits imposed, or,
  add equipment to let the engine run the fuel, or,
  do some modifications/changes at overhaul time.

Those flying normally aspirated engines requiring 100/130 could probably get by with "flat-rating" the engine to a certain manifold pressure. I am taking a wild guess that 24" or 25" of manifold pressure might be your engine's absolute limit. While your performance down low would be decreased somewhat, up high your performance would be unaffected. It is not quite that simple, though, as on many engines the mixture was enriched when the throttle was wide open, and with the throttle pulled back some to limit manifold pressure, some engines may not have their "rich mixture" for takeoff and climb. But that can be dealt with.

Most planes I have flown, particularly the ones that burn 100 octane, had enough performance at low altitudes that limiting manifold pressure would be a very workable solution for most of the pilots, most of the time. Pilots who use very short airstrips at low altitudes would have a problem.

David Howe's Harmon Rocket with a "bone stock" engine. Limiting his maximum manifold pressure should suffice. He might not be able to open up the throttle fully until he gets up to, say, 5000' and he might be limited to *only* 2000 fpm climb! If that was not enough, he could add an ADI system.

Richard Vandersteen's turbo-normalized Velocity would probably be the most affected of all of us in Chapter 1138. A turbo-normalized engine is one that was optimized for normally-aspirated operation, but to which a turbocharger has been added. Compression ratios are the higher ratios used in a normally-aspirated engine. Richard could use an ADI system for takeoff, but ADI systems don't carry enough of their mixture to allow continuous use. More intercooler would help a little at altitude. GAMI's PRISM system may be available to him. He may have to live with operating limitations. His entire fuel system is compatible with ethanol, so he has that option. Richard is one who can figure out a solution if anybody (I know) can, and since he is experimental, he is free to try.

Brad Baird's Lancair IV's operation I thought would be a problem. Brad told me his manifold pressure for takeoff is 39". At first I assumed that would result in certain detonation with 94UL fuel. However, after listening to Aviation Consumer's Engine Report on Future Fuels: TCM's Chief Engineer Bill Brogdon—
http://tinyurl.com/CM-Podcast-2

I am not so sure 39" MP at sea level would be the issue. Brad said he has made takeoffs with 31" MP, so he has that option. While it was fine for a takeoff from a low altitude airport, he has concerns about trying it at a higher altitude airport such as Bishop CA. Brad uses 31.5" to climb, and 28" cruise, neither should be a problem on 94UL below the flight levels. If Bill Brogdon is correct, 94UL should not be too much of a detriment to his operations. There would be limits on manifold pressure that Brad could otherwise use up high.

My Cessna T210 probably would likely fare okay with 94UL. If Bill Brogdon was correct, then the limitations imposed by 94UL will be in areas I never operate in anyway. My airplane has maximum allowable manifold pressures at altitude that are not due to the capacity of the turbo system. Looking at the chart below, notice that 35" M.P. is allowed up to 17,000'. At that altitude, the turbocharger has raised the manifold pressure more than 20 inches over ambient, and the air coming out of the turbocharger has risen approximately 300° due to heat of compression. More boost would raise the induction air temperatures even higher. The engine is running hotter, since the air at 18,000' is only half as dense as sea level atmosphere and cannot remove the heat from the cylinder cooling fins as effectively. Put both of those heat issues together, and detonation margins dictate the requirement to limit manifold pressure above 17,000.' The table to the right shows my limits using 100 octane.

Environment	Maximum Allowable
5-minute takeoff	36.5"
S.L. to 17,000'	35"
18,000'	34"
20,000'	32"
22,000'	30"
24,000'	28"
26,000'	26"
28,000'	24"
30,000'	22"

My best guess is that with a 5" reduction of manifold pressure I could safely operate on 94UL at altitude. However, let's say I had to reduce my manifold pressures by 5" for all operations:

- I normally don't use full power on takeoff. Only one airport, Oceano, gets "balls to the wall."
- I normally use 30" M.P. "cruise climb" per the P.O.H. Wouldn't affect me below 17,000'.
- In the 25 years I have been flying my plane I have not had it in the flight levels...the reduced performance in the flight levels would be no concern of mine.

If I could use 32" for a minute at takeoff, and 30" up to 17,000', my operations would be no different than they currently are, except for the tiny, sea level strip at Oceano CA. If I wanted all the power the engine is certified for, installing a good intercooler and reducing the manifold pressure so that the engine only produced stock power should enable me to use 94UL probably as high as I can currently use 100 octane without an intercooler. Manifold pressure limitations I can certainly live with, it may entail rewriting the performance charts in the POH. I just hope they don't take the easy way out and simply reduce the maximum allowable gross weight.

MY SUGGESTED COURSE OF ACTION

We have this fuel argument all backwards. The last thing we need is an expen$ive, boutique fuel. If a cost competitive 100 octane fuel really can be made, great. But cost seems to be the big "gotcha." A premium of $1 or $2 per gallon initially does not sound too bad, but think about it. Most GA engines will consume at least 10,000 gallons of fuel over a TBO run. Most engines that specify 100 octane will consume 20,000 to 40,000 gallons during their TBO run. A $1 saving will pay off in the long run.

Given the absolute requirement that any proposed avgas should do no harm to existing systems, the petroleum industry needs to tell the aviation industry what octane unleaded fuel they can provide at a "good" price, for many years to come. Avgas that is expensive in relation to other fuels will likely result in the further decline of its usage. Much of the fleet can run just fine on 91 octane. Many of them today use 100LL for the convenience of not having to cart it to the airport, or assurance they will not get alcohol or methanol. 79,000 mogas STCs have been issued and an estimated 60,000 of those are active in the US. If the price of avgas climbs out of sight, more operators will purchase the mogas STC and those that have it will be more likely to use it. The engines that do specify 100 octane don't need it 100% of the time.

I have read posts from several people with aircraft that cannot legally use mogas stating that if avgas gets more expensive, they have a tank of avgas for takeoff, climb, and landing, but use mogas in the other tank for cruising. Illegal. Not smart. But some may do it anyway and still less avgas will be used.

The aircraft that need 100 octane, need to make the modifications to use a lower octane fuel, and move on. I am saying that as a member of that group which will have to adjust my operations, do modifications, or both.

Course of action:

- Keep 100LL until a permanent solution can be found.
- Determine a specification for the future--the long-term future.
  - Fuel suppliers absolutely need to be at this meeting.
  - The fuel needs to be a fuel that is close to the mainstream, and can be tapped from the pipe lines that criss-cross this nation.
  - The composition of the fuel must do no harm to any airframe or powerplant. The octane can be dealt with through engine design.
  - Think globally--it needs to be a fuel that can be easily produced around the globe.
- Consider 82UL. If a higher octane can be derived from a widely available existing product, great!
- Don't yield to special interests. The fuel needs to be good for everybody. If some small group wants unlimited octane, they can go get it and pay for it.
- Make the fuel the eventual international standard.
- If needed, choose an interim fuel such as 94UL or Hjelmco AVGAS 91/96 UL. Almost all 100 octane engines can get by with some operating limitations. If the proposed phase-out of 100LL really is 2017, or even 2015, everybody will have plenty of time to figure out how to operate safely with 94UL or AVGAS 91/96 UL.
- Once the final specification is hammered out, give everybody a full TBO cycle to get prepared for the fuel
  - Continental recommends 12 years maximum for all of their engines.
  - Lycoming states, *"all engines that do not accumulate the hourly period of time between over hauls specified in this publication are recommended to be overhauled in the twelfth year."*

I have heard for years pilots and aircraft owners complaining about the cost of flying and an expensive fuel is not going to improve the situation. There are many parts of the world where avgas is not available; we need to expand ourselves. Quoted in AvWeb August 4, 2010, GAMA CEO Pete Bunce stated, "As the global economic recovery picks up steam, markets outside of North America continue to hold promise for renewed growth in our industry." Our planes are capable of flying all over this planet, so make the fuel available all over the planet.

When I first started this article I was concerned that the people having something to lose without 100 octane are going to make the most noise and get the most attention. I underestimated their resolve--the *Clean 100 Octane Coalition* is making a lot of noise. Remember, your engine will use 20,000 gallons of fuel, plus or minus, over the course of a TBO. The voices who don't need 100 octane, but can use it, as well as the voices that need 100 octane but are willing to move on to a more readily available fuel, are going to get drowned out asking for a reasonably priced, widely available fuel. The aviation industry needs to quit screaming "Octane!" and listen to owners and operators saying "Availability" and "Affordability." If we want our own, elite special fuel just remember the numbers and get ready to pay dearly for it.

Fly safe!

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RELATED READING AND LISTENING

- MBA Thesis: Sustainable Aviation Gasoline Alternatives. March 12, 2010, 143 pages. This goes far and above anything I have written here. It has almost everything I have talked about, and a lot more. If I had discovered it before I was finished with my article, I could have just sent you all the link and saved myself a lot of work!
- A very comprehensive article about avgas:
  http://en.wikipedia.org/wiki/Avgas
- GA Fuels Blog, run by Dean Billing, Kent Misegades, and Todd Petersen. Frequent updates of short news clips about what is happening in movement to unleaded avgas.
  http://www.generalaviationnews.com/?cat=525
  One which runs counter to some accepted think ing is; Misconceptions about the 100LL replace ment conundrum:

http://www.generalaviationnews.com/?p=26130#more-26130

- FlyUnleaded.com's excellent, "Two Misconceptions about the 100 Octane Replacement Conundrum."
- Petersen Aviation list of airframes approved for autogas and list of engines approved for autogas.
  http://www.autofuelstc.com
- Aviation Consumer's Engine Report on Future Fuels: TCM's Chief Engineer Bill Brogdon--podcast and downloadable MP3. (Previously referenced.)
- Aviation Consumer's Engine Report on Future Fuels: Lycoming's Michael Kraft--podcast and downloadable MP3. (Previously referenced.)
- A Visit to Teledyne Continental Motors
- Aviation Consumer's Gas Engine, Jet Fuel: Sonex's Dr. Andrew Pouring--podcast and downloadable MP3.
- Kitplane's Avgas 2020, June 2006. A dated but excellent look at history of avgas and where it might be headed.
- AvWeb's Paul Bertorelli, "For Lycoming, 100 is the Magic Number."
- Alcohol Injection System's promotional "116 Octane with Water Injection."
- E.A.A news, "Embry-Riddle to test Swift Fuel in their Fleet."
- Medill Reports' August 26, 2008 "Swift Enterprises hopes to take off with renewable aviation gas."
- AOPA's Avgas, "Beyond the 'silver bullet'.
- AOPA Online's article about 82UL is Industry approved, and, 82UL is F.A.A. approved.
- Shell Oil Company's Aviation Products homepage.
- "Full-Scale Engine Detonation and Power Performance Evaluation of Swift Enterprises 702 Fuel," a 181 page document, is available in a PDF from the F.A.A. and from Swift.
- Pure-Gas.org--list of ethanol-free gas stations.

Table of fuel consumed during a TBO Run of a few selected engines:

	T.B.O.	Average Cruise G.P.H.	Gallons per TBO
Continental A65	1800	4.4	**7,920**
Continental O200	1800	6.3	**11,340**
Continental O470A-U	1500	11.1	**16,650**
Continental O470U	2000	11.1	**22,200**
Continental TSIO520	1600	16.0	**25,600**
Continental TSIO550C	2000	17.8	**35,600**
Continental GTSIO520	1600	22.0	**35,200**
Lycoming O235	2400	6.5	**15,600**
Lycoming O320	2000	8.5	**17,000**
Lycoming IO360	2000	10.5	**21,000**
Lycoming IO540	2000	16.0	**32,000**
Lycoming TIO540	2000	19.0	**38,000**