Fuels AND Engines

FOR EXP/LSA AIRCRAFT, PART I

A status report

Story and photos by Kent Misegades, EAA 520919

FEW topics in sport aviation generate as much confusion as the subject of fuels. Unleaded avgas, 100LL, autogas, ethanol, heavy fuels, and biodiesel, all are fuels used to varying degrees in the powerplants of light aircraft. The fuels available at your airfield will depend on where you live, local and national politics, environmental mandates, subsidies to producers, and the basic economics of supply and demand.

If we pilots are confused, just imagine the predicament engine manufacturers find themselves in, trying to support a relatively small number of customers around the globe whose individual needs can be diverse and rarely under their own control. This article provides a snapshot (time frame spring 2009) of the wide variety of fuels available—and sometimes not—and how seven makers of 60- to 125-hp engines for experimental amateur-built (E-AB), experimental light-sport aircraft (E-LSA) and special light-sport aircraft (S-LSA) are dealing with this challenging issue.

PART I: AIRCRAFT FUELS

First, we'll review the variety of fuels currently available to pilots, and how this situation may change in the near future. Refer also to recent EAA articles on this subject, for instance "Fuels for the Future" (*EAA Sport Aviation*, February 2009) and "Ethanol and Rotax Engines" (*Sport Pilot*, June 2006). Note that the use of a fuel other than the one for which a particular engine/airframe combination was designed entails extensive testing and possibly recertification—so do not experiment on your own!

100LL—Despite predictions for more than a decade of its looming demise for environmental and economic reasons, 100LL remains widely available in developed nations, and prices in the past six months have dropped significantly, normally a sign of oversupply. It remains the only viable fuel for most spark-ignition engines with higher compression ratios (generally any engine developing 180 hp or more). The fuel's formulation is the same around the world, and it can be stored for relatively long periods of time. Tetraethyl lead's anti-knocking characteristics are excellent, making it difficult to find a comparable replacement.

Will 100LL disappear in the near future for environmental reasons? Unlikely, as without a suitable replacement, thousands of jobs would be lost and many airports would die—two events that should get the attention of most policymakers. Still, 100LL is definitely threatened, as the Environmental Protection Agency (EPA) must respond to a recent lawsuit by the Friends of the Earth calling for the discontinuation of 100LL.

Will refiners simply stop making it for lack of sufficient demand? If the supply of high octane racing fuel is any proof, probably not, since there will likely always be a "boutique" refiner willing to produce 100LL for a price. It is naïve, however, to assume that 100LL will always be around.

Unleaded Avgas—Also known as 91UL, this fuel is designed to replace 100LL for many but not all aircraft. As Earl Lawrence, EAA's vice president of industry and regulatory affairs, recently stated, "It's 100LL without the lead in it. We call it 91UL, but the actual motor octane is often higher, in the 92 to 94 range. Somewhere between 70 and 80 percent of the fleet could use 91UL tomorrow with no modifications, based on the STC and manufacturer approvals for unleaded fuels already in existence." So basically, if your aircraft now has an autogas supplemental type certificate (STC), you will likely be able to burn 91UL when, and if, it becomes available and 100LL disappears. Fixed

Since 1982, EAA and Petersen Aviation have issued more than 65,000 autogas STCs for 71 engines and more than 100 airframes from 17 manufacturers.

base operators (FBOs) are unlikely to install a second fuel tank for 91UL; they will probably offer one or the other. 91UL may also be suitable for newer engines that can operate today on either autogas or 100LL, as will be discussed below. That's all potentially good news for the owners of light aircraft, but 91UL is not a solution for those with higher-performance planes. The reality is that 91UL is not available today at airports; in the United States, one finds only 100LL, Jet A, and in a few places, autogas.

Autogas—Also known as "mogas," this is fuel intended for automobiles and generally purchased at the local gas station. In contrast to 100LL, there is no single international standard for autogas. It is a composition of refined petroleum and thousands of additives varying by country and even by state depending on various factors such as suppliers, climate, and mandates. The last factor has been the most dynamic in recent years.

Autogas, shipped mostly by pipelines, is also not subject to the frequent filtering and inspections required for 100LL, which is transported by tanker truck and checked at each pumping station. For older aircraft such as a 1952 Cessna 170, an STC must be purchased from either EAA (*www.AviationFuel.org*) or Petersen Aviation Inc. (*www.AutoFuelSTC.com*) before using autogas. Note that one requires an STC for a specific engine/airframe combination; available STCs are listed on both sites, and they may be purchased for a very low fee.

The reality is that, for many pilots whose engines are designed to operate best on autogas, ethanol may at times be unavoidable.

Strict adherence to the limitations prescribed in the STC is a must, the most important being the minimum octane rating and the prohibition against using fuels containing ethanol. There are many operational issues involved with the use of autogas, for instance the necessity for self-fueling since few airports supply it (see the sidebar "Where's the Autogas"). The importance of practicing safe grounding procedures to prevent fires when self-fueling cannot be stressed enough!

For further details on the use of autogas under an STC, be sure to read all the information from EAA and Petersen Aviation and consult with your mechanic and experts in your aircraft's type club. Most of the newer engines aimed at the E-AB, E-LSA, and S-LSA market have been designed to operate best on premium ethanol-free autogas.

Ethanol Blends—Also known as ethyl alcohol, pure alcohol, grain alcohol, or drinking alcohol, ethanol is a volatile, flammable, colorless liquid. It is essentially what is found in alcoholic beverages. Most ethanol is produced through fermentation of cane or corn sugars and has been used for combustion engines for many decades, including as the fuel for the German V-2 rocket of World War II. In recent years, anhydrous (waterless) ethanol has become a favored additive for autogas as a replacement for MTBE (methyl tert-butyl ether), an early substitute for lead, which has been largely banned for environmental reasons. Both MTBE and ethanol are used to raise gasoline's octane number and as an oxygenate to reduce carbon monoxide produced during combustion.

Common blends are denoted as E5, E10, E22, E25, E85, or E100, depending on the volumetric percentage of ethanol content. E10 blends are common across the United States and Australia today. E25 is the minimum mandated by law in Brazil as of July 1, 2007. In the United States, E85 is the federal government's targeted blend for "flex-fuel" vehicles, and it is gradually becoming available at gas stations in the Midwestern states and in parts of Europe, especially Sweden. E100, also known as "straight ethanol" or "hydrous ethanol," contains no gasoline, only alcohol and about 5 percent water by volume, a residue of the distillation process. Flex-fuel vehicles in Brazil are common today and capable of running on anything from 100 percent gasoline up to E100 straight alcohol, a result of that country's policies aimed toward energy independence and a unique climate and agricultural infrastructure that favors the growing of sugar cane, the best feedstock for ethanol production.

There are many arguments pro and con surrounding the use of ethanol in vehicle fuels, and it is not the purpose of this article to delve into them. The reality is that, for many pilots whose engines are designed to operate best on autogas, ethanol may at times be unavoidable. As will be described in Part II of this article (to appear in the June issue), aircraft engine manufacturers have reacted to the increasing use of ethanol blends in gasoline around the world by making adjustments to their products. This does not mean, however, that aircraft that may operate with E5 or E10 will gain any advantage from the presence of ethanol. Indeed, the use of ethanol blends in aircraft can cause a number of serious effects, for instance:

- Water absorption leading to corrosion, phase separation, and engine failure.
- Higher exhaust gas temperature, as ethanol burns leaner.
- Decomposition of composite fuel tanks and some tank sealants, leading to clogged fuel systems and possible engine failure.
- Competition with engine lubricants and damage to rubber gaskets.

Opinions differ regarding the acceptable level of ethanol that may be used without significantly impacting an engine's performance. Dean Vogel of the Aero Technical Institute, a Rotax aircraft engine maintenance training school associated with Lockwood Aviation Supply in Sebring, Florida, had this to say about ethanol blends in Rotax engines, "Anything up to about 22 percent won't have any effect—or might even have a slightly positive effect. It's after you go past 22 percent that performance starts to decay unless modifications are done to the engine. If the systems in the automobile/airplane will handle E10, chances are E22 won't be any different." (Note that Rotax currently approves ethanol blends only

Where's the Autogas?

SINCE THE FEDERAL AVIATION ADMINISTRATION policy changed in 1982 to permit the use of automobile gasoline in aircraft, more than 65,000 autogas STCs have been issued by EAA and Petersen Aviation for 71 engines and more than 100 airframes from 17 manufacturers. In late 2004, ASTM International released the first edition of consensus standards for light-sport aircraft. Today there are nearly 100 special light-sport aircraft, or S-LSA, factory-built light aircraft models on the market for fun flying, instruction, or rental. In addition, numerous experimental LSA (E-LSA) designs and standard category aircraft that meet the definition of LSA exist.

A large percentage of LSA have powerplants that were designed to operate on premium ethanol-free autogas. With the success of the autogas STC and the rapid growth of LSA's popularity, one would expect to find autogas available at many airports. Quite the opposite is true: At the 3,691 airports tracked by AirNav.com, only 134 reported autogas for sale in February 2009; that's fewer than 4 percent of all airports in the United States. Ironically, these 134 airports do not include Oshkosh,Wisconsin, Lakeland, Florida, or Sebring, Florida, airports where one can find hundreds, if not thousands of aircraft burning autogas at major events held there annually. This implies difficulty for cross-country flights and the necessity for self-fueling, with its inherent fire and ethanol risks as well as airport restrictions.

The lack of autogas at our airfields begs for grassroots efforts with the support of the alphabet groups (AOPA, EAA, GAMA, LAMA, and NATA). It's not an issue limited to aviation: boaters, snowmobilers, operators of emergency generators and tools powered by two-stroke engines, and classic car and motorcycle owners all require a supply of ethanol-free gasoline. Autogas should not come at the elimination of 100LL (or its unleaded replacement), though, implying the need for an additional fuel tank/pump with all the expense and environmental issues that make this a difficult option for FBOs without justification from potential customers, that is, aircraft owners and operators.

There is evidence that markets are reacting to the increasing demand for autogas. In Europe, ethanol-free premium autogas has become readily available at airports in recent years as engines such as the Rotax 912 have become the standard for new light aircraft. Crucial in any effort to obtain autogas at our airfields are two things: (a) assurance of a continued supply of ethanol-free premium octane gasoline, and (b) the continued supply of 100LL for all those aircraft that cannot burn autogas.

Some EAA chapters have been vocal in their efforts, for instance Chapter 1345 of Bend, Oregon (*www.EAA1345.org*). When Oregon's state legislature deliberated passage of mandates requiring E10 autogas without any exemptions whatsoever, the chapter's founding president, Dennis Douglas, became very active in the political process, giving an excellent presentation at a public hearing that helped educate legislators. One chapter member, Jeff Witwer, Piper Malibu owner and president of Carbon Neutral Plane (*www.CarbonNeutralPlane.com*), summed it up this way, "It is naïve of the aviation community to think that it can call the shots on the composition of auto fuel because we'd like to use a small fraction of it without ethanol."

Dean Billing, also of Chapter 1345, has taken the issue a step further by combining forces with other groups, establishing the Ethanol Free Premium Unleaded Gasoline Coalition. Background information and state-by-state contacts can be found on the group's website, *http://e0pc.com*.

As a result of this grassroots effort in Oregon, the state's final bill included an exemption for premium octane unleaded gasoline. Yet another Oregon pilot, Arty Trost, will publicize the need for a secure supply of ethanol-free premium during her flight from Oregon to Sun 'n Fun 2009, flying all the way in her autogas-fueled, 1984 Maxair Drifter ultralight. For details on Arty's latest adventure, see *www.LessonsFromTheEdge.com*.

up to E5.) When designed for greater amounts of ethanol, for instance in the new generation of flex-fuel vehicles, engine performance and efficiency burning E85 can be superior to running with gasoline, according to Vogel.

Readers are urged to read "Fuels for the Future" by Jeffrey Decker (*EAA Sport Aviation*, February 2009) and Phil Lockwood's article "Ethanol and Rotax Engines" (*Sport Pilot*, June 2006) for good summaries of the advantages and disadvantages of ethanol as well as its effects on engines and aircraft components. Other excellent reviews of the problems that ethanol can cause are found in Rotax Service Instruction SI-912-016 R1 as well as on the EAA Auto Fuel STC website (*www.EAA.org/Autofuel)* and the Petersen Aviation website (*www.AutoFuelSTC.com*). Just because a fuel pump at your local gas station is not labeled as containing ethanol, don't take it for granted. Make sure you test each and every batch of autogas you purchase for your airplane. The two websites cited above both provide directions on making and using a simple tester.

A historical footnote on the use of ethanol in aircraft engines is the research work performed in the 1980s and '90s at Baylor Institute for Air Science, Baylor University, Waco, Texas. STCs were obtained for the Lycoming O-235 and IO-540 engines running on 100 percent alcohol. Tests were also performed on the Lycoming IO-320 powerplant. For details on the modifications required, the engines' performance, and potential advantages for using 100 percent ethanol in engines modified for their use, see the institute's website (*www.Baylor.edu/bias/index.php?id=5302)*.

In October 2004, the Brazilian aircraft manufacturer Aero Neiva (a division of Embraer) introduced the agricultural aircraft EMB-202A, powered by an IO-540 burning 100 percent alcohol. It is considered the first commercially available aircraft to operate on the fuel. Also in Brazil, the company AeroÁlcool Tecnologia Ltda has obtained significant experience modifying conventional aircraft engines to operate on 100 percent ethanol (*www.Aeroalcool.com.br*).

Heavy Fuels—Compared to the fuels mentioned above, kerosene, diesel, and Jet A are all readily available "heavy" fuels. A number of promising diesel (compression-ignition) engines for aircraft have emerged in recent years. While these are still not common in the lower horsepower range, this situation is likely to change in the coming years. Some of these new diesels were described in the September 2008 issue of *EAA Sport Aviation* in an article by George Wilhelmsen ("A Flock of New Engines," page 33) and another by Budd Davisson ("Thorpedo Diesel Coming Into Its Own," page 48).

Diesel aircraft engines are not new, however. The German Junkers Jumo 205 diesel engine first entered service

Fueling Safety

THERE IS A DANGER of static electricity buildup anytime you're using plastic fuel cans. If conditions are just right, and the right sequence of events takes place, there can be a fire. Since we can't predict or verify when the "right" conditions exist, it's best to protect against the static buildup. This can be done by grounding the plastic can as follows:

In order to do the best job of grounding a plastic fuel can when using it to transfer fuel into your aircraft, you have to modify the can somewhat. You need to provide a proper path for the static electricity to flow from the can to the aircraft, and then to the ground.

To properly ground the fuel can, you'll need to add a conductor of some sort. Get a length of "grounding strap" (a flat, woven metal strap) from the local auto parts store (or from an aviation supply house). This length of grounding strap must be long enough to run down the inside of the can from the filler neck to the bottom, and then all the way along the length of the bottom of the can (inside the can). You'll also need a brass screw, a couple of large diameter washers and an appropriate nut. The screw should be long enough to pass through the can, the grounding strap, the two washers, and the nut and still have enough length left to clip a ground wire to it.

Drill a hole in the can, just below the filler neck opening. This hole should be *just* big enough to get the brass screw through, and should be in a location where you can touch it by reaching down through the filler neck with your fingers. Also drill a hole in the grounding strap for the screw to pass through. Feed the grounding strap down through the filler neck so that it runs down from the filler neck and across the bottom of the can. Then put a large diameter washer on the screw, pass the screw through the grounding strap and then through the hole you made in the can.

You'll need some kind of fuel-proof sealer to put around the screw where it passes through the plastic can. Again, your auto parts store will be the best source for this. Put some sealer on the screw where it comes out of the can, then put another large diameter washer on and secure with the nut. Now you've provided a path for the static to get from the can to the aircraft, through the screw and a short "jumper" wire that you'll clip to the screw and to the filler neck of the aircraft.

Of course, this will only work properly if you then ground the aircraft itself to a good ground source. A well pipe or a copper rod driven into the ground will work well for this, so you'll have to make a ground wire to go from the chosen grounding source to the aircraft itself.

At this year's U.S. Sport Aviation Expo at Sebring, Florida, Jet Fleet Management (Fort Lauderdale, Florida, *http://JetFleetMgmt.com*) displayed 150-, 280-, and 500-gallon capacity fuel trailers aimed at those who burn autogas.

in 1932 and successfully powered a number of airplanes and Zeppelins. An interesting related development is NATO's "one fuel" policy, aimed at eliminating 100LL and autogas from the battlefield. This policy is putting pressure on the suppliers of spark-ignition unmanned aerial vehicle engines to operate on diesel or JP-5/8 only. Some of this technology is finding its way into the LSA community as will be described in Part II of this article. In many parts of the world, for instance on the African continent, Jet A is the only aviation-grade fuel found at airports, as related to the author by missionary pilots recently returning from central Africa. Clearly, there are multiple reasons for engine manufacturers to consider the use of heavy fuels today.

Biodiesel—Whereas Brazil, the United States, and other major agricultural lands such as Australia have pursued the use of ethanol in autogas, European countries have focused more on the production of the heavy fuel biodiesel, a reflection of the relative popularity of diesel-powered passenger cars there. Rapeseed oil is the most common feedstock used to produce biodiesel, which, like ethanol, is blended with petroleum diesel to produce fuels denoted as B10, B20, B50, and B100, that is, from 10 percent to 100 percent pure biodiesel. With the certification of diesel engines for aircraft becoming more common, the subject of biodiesel-powered aircraft is likely to follow along the lines of those powered by ethanol blends. Successful demonstrations of biofuel-powered *jet* aircraft have been made recently, for instance Green Flight's L-29 and Virgin Atlantic's B-747, pointing to the potential future supply of the fuel at airfields.

SUMMARIZING AVIATION FUELS

Supplies of 100LL appear to remain adequate for now, and prices have stabilized in recent months. While there is no universal replacement for 100LL yet, progress is being made, as described in Jeffrey Decker's article in February's *EAA Sport Aviation*. The annual worldwide production of 100LL fuel accounts for less than 1 percent of unleaded gasoline. The amount of autogas used in aviation, while rising, is even smaller.

While it appears that the widespread mandated use of ethanol blends in automotive fuels is inevitable, states that have invoked such mandates appear sympathetic to the needs of various groups, including aviation, and have exempted premium octane fuel. How the engine manufacturers are coping with the changing landscape for fuels will be highlighted in another feature article next month.

A pilot since age 15, **Kent Misegades** is president of EAA Chapter 1114 (Apex, North Carolina) and is a member of EAA 506, IAC 19, and VAA 3 chapters. He flies a 1952 Cessna 170 based at Cox Airport (NC81) in Apex.