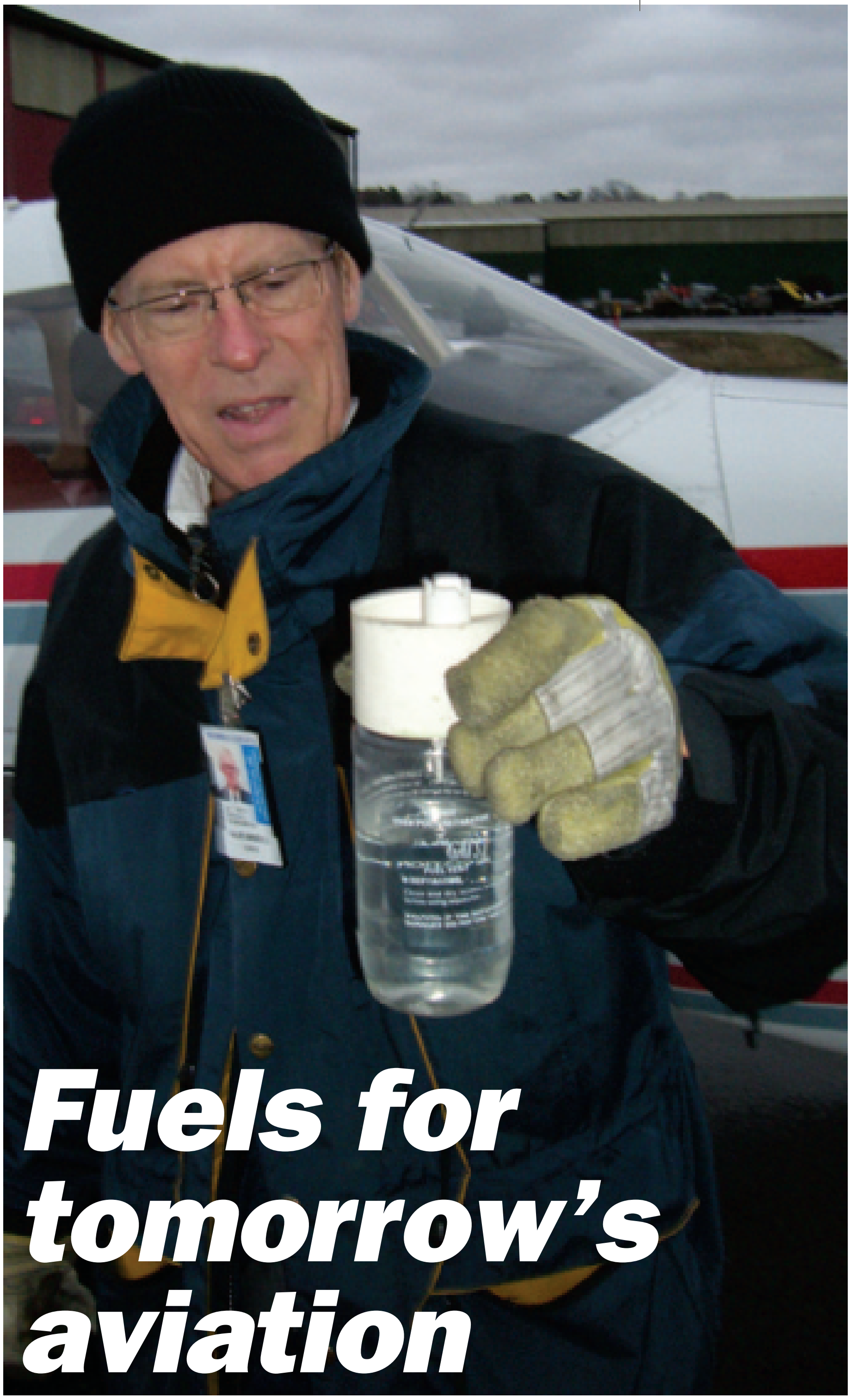

# Fuels for tomorrow's aviation

*AOPA US is working with oil companies and engine manufacturers to create an unleaded avgas substitute that can be used without engine modification. Here, **Greg Dolph** explains some of the issues*

Biofuels are in the news, but you may be wondering precisely what they are and what they might mean for aviation. Environmental concerns aside, are biofuels good alternatives for avgas and jet fuel? To answer that question we need a short primer on fuel terminology.

**Energy density**: how much energy a fuel produces per unit of measure. Most of the figures you see in the media are based on volume not weight as nobody really cares how much your car weighs or whether you get less range on a tank, but in aviation weight is paramount so we will use the figure Mega-Joules per Kilogram, shortened to MJ/Kg. It's not important how much energy one mega-joule is, it's only for comparison. The higher the figure the better, as the more energy it packs per unit of weight the longer range you get off of a tank.

**Water Separation:** avgas and JetA1 are not hygroscopic, ie they don't mix with water (which is good), but some fuels are. Water in your fuel can lead to power loss or engine failure. Worse, with hygroscopic fuels you can't detect water in your fuel without special equipment, and then how do you separate it? Likely you'd have to discard the whole tank!

**Freezing or gelling point:** We don't want our fuel turning to sludge while we're cruising at FL 140 above the Alps, do we? The lower the freezing, gelling, or waxing temperatures the better.

**Volatility:** How readily does a fuel evaporate? High volatility can cause vapour lock at high density altitudes, which causes engine failure.

**Octane:** A measure of a fuel's resistance to detonation, where a fuel/air mixture explodes before the spark. Detonation can literally tear your engine apart, which is why avgas has such a high octane rating. Higher octane fuels can be compressed much more without detonating. Octane level isn't applicable for Jet A1 or jet fuel substitutes.

**Cetane Level:** Diesel engines work by injecting fuel into a cylinder under compression and having it spontaneously combust; in other words they rely on detonation in order to work. Cetane level is a measure of how well a fuel performs under compression, higher numbers meaning a better, quicker burn.

**Solvent Characteristics:** fuels that are solvents can dissolve older seals, hoses and fuel bladders. This is a big concern for older aircraft and some new ones.

Fuel substitutes are a problem for certified aircraft from a safety perspective. If you can create a fuel that mimics the characteristics of an existing fuel exactly, then you can do a like-for-like transition or maybe even mix fuels, but if there are significant differences you will have to do an STC on every single aircraft which is not trivial. Also, some substitutes give you less capability; mogas can be used with an STC in many aircraft, but it limits operating density altitude due to mogas' higher propensity for detonation and vapour lock.

## Avgas substitutes

Avgas is petroleum-based with a low freezing point, low volatility, and high octane number, which it achieves by being blended with the toxic chemicals Tetra-Ethyl Lead and Ethyl-Di-Bromide. It is expensive because it can't be produced without taking the refinery off-line afterwards for a cleaning, and the fuel must be moved in different trucks from unleaded fuels. It's a fuel with a limited future and we will be well rid of it.

The challenge of finding an avgas substitute is that it must be a one-size-fits-all solution. Avgas is used in aircraft and engines spanning a century of technology and must perform at very high density altitudes and a wide

***Left: Lars Hjelmberg, President of AOPA Sweden, produces unleaded avgas for the home market***

**Table 1: Avgas and Substitutes**

| Fuel | Energy Density MJ/Kg | Hygroscopic? Y/N | Freezing/ Gelling point C | Volatility | Octane Number | Solvent? Y/N |
|---|---|---|---|---|---|---|
| Avgas | 43.2 | No | -58 | Low | 100 | No |
| Ethanol | 29.7 | Yes | -114 | High | 116 | Yes |
| ETBE | 36.4 | No | -90 | Low | 110 | No |
| Butanol | 36.6 | No | -110 | Low | 94 | No |

temperature range. Substitutes for avgas are mostly alcohol or alcohol derivatives that can either be fermented and distilled from sugars produced from sugar cane, sugar beet, corn, and possibly even cellulose (if the R&D works out you may be able to brew your own fuel from your grass trimmings). Alcohols can also be synthesized chemically from petroleum distillates or by-products. They are less toxic and burn cleaner than avgas but have less energy density so you won't get as far on a tank.

As you can see from *table 1* above, none of the substitutes really stack up in terms of energy density. Butanol and ETBE have only 85% of the energy density of avgas although because they burn cleaner and have less additives they get closer to 90% of the range. Your average Cessna 172 would suffer a 30 minute reduction in endurance. Ethanol is a poor choice of fuel for aircraft at only 68% of the energy density of avgas, but also being very hygroscopic, having high volatility, and being a powerful solvent. It's a poor choice for cars as well, truth be told. ETBE is derived from ethanol and some natural gas products and is much better than ethanol. It's widely used as an octane booster and has been used in a Swedish 91/96 unleaded avgas blend for 25 years. Hjelmco 91/96 UL conforms to the international ASTM D910 fuel standard and if the ETBE is produced from bio-ethanol then it can be considered part bio-fuel. Butanol is an interesting new bio-fuel being considered because of the recognized problems with ethanol. It's fermented exactly like ethanol but has much better characteristics and unlike ETBE it doesn't require a secondary process to produce.

## Jet A1 and substitutes

Jet A1 is a kerosene (aka paraffin oil) based fuel with additives to prevent gelling and gumming. Although turbines can run on just about anything that burns, kerosene based fuels are preferred as they don't burn as readily if spilled. Far from being a solvent Jet-A1 is actually a lubricant. Kerosene is prone to waxing and gelling at low temperatures which is why most aircraft either have fuel tank heaters or have an anti-freezing/gelling agent mixed in at the pump.

See *table 2*, below

The good news for Jet A1 substitutes is that they are much closer to, or in the case of NExBTL, higher energy density then the fuel they replace. Both bio-diesel and NExBTL are derived from natural oils pressed from land or aquatic plants but produce different products in different ways. Standard Bio-Diesel is produced using an old technique called transesterification which produces large amounts of glycerine as a by-product, and the fuel itself can spoil, while NExBTL uses a more modern process to produce synthetic fuel that is chemically identical to Jet A1 but has less impurities. Both types of fuel can be blended with regular Jet A1 in any percentage.

Bio-Diesel is less cut and dried than alcohol fuels because the quality of the fuel that is produced entirely depends on the type and growing conditions of the nuts and seeds from which they are pressed. Bio-Diesel can be derived from edibles like rapeseed (canola), sunflower and soybean, or inedibles like palm oil, hemp, or flax. Palm oil is considered the best for aviation. The trouble is getting enough of whatever type of seed without starving people or cutting down enormous swathes of rainforest. Help looks to be coming from the ocean as algae is being developed that is excellent feedstock for both diesel and alcohol. However, that's some way off.

The EU has finally come to its senses and has put the brakes on mandating bio-fuel percentages in all fuels until we can produce them sustainably from inedible plants that can be grown while mitigating environmental impact. However, that's no reason not to push for acceptance of unleaded avgas alternatives or blends of jet fuel with some biofuels. In the case of avgas the amount of ETBE that will be used is paltry and can easily be produced sustainably. Many biofuel alternatives are cheaper than avgas at its current ridiculous price, and if they help us reduce our carbon footprint and raise our profile then they are a win-win-win proposition. We should be embracing sustainable fuels for sustainable light aviation. ■

**Table 2: Jet A1 and substitutes**

| Fuel | Energy Density MJ/Kg | Hygroscopic? Y/N | Freezing/ Gelling point C | Volatility | Octane Number | Solvent? Y/N |
|---|---|---|---|---|---|---|
| Jet-A1 | 42.8 | No | -40 | Very Low | 60 | No |
| Bio-diesel | 42.2 | No | -10 to -38 | Very Low | 50-60 | Moderate |
| NExBTL | 43.0 | No | -30 | Very Low | 85 | No |