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Fuels for the Future

What will power your aircraft?

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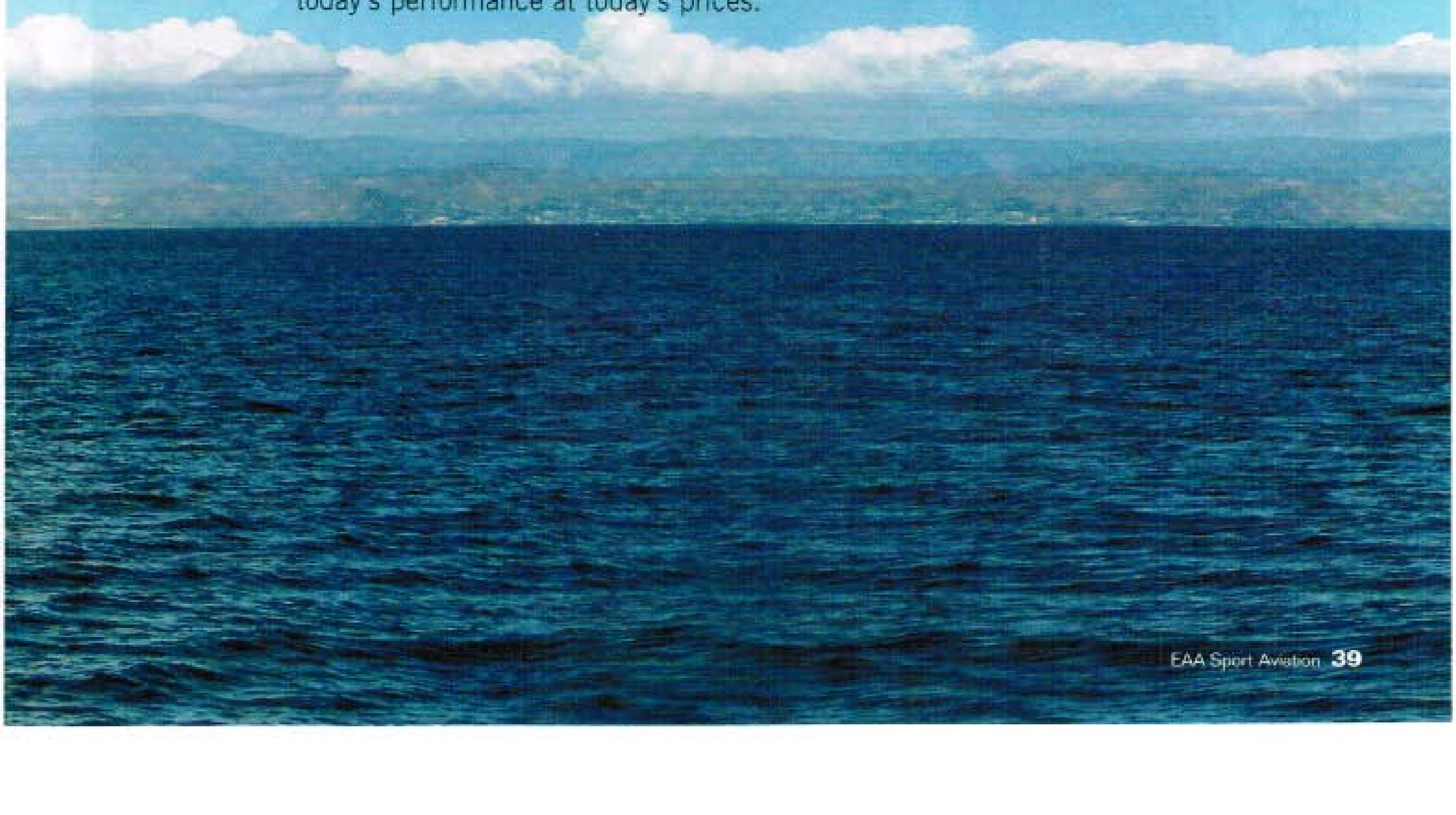
Major changes are in store for the piston aircraft fuel supply. Market forces and environmental concerns are pushing leaded avgas into the history books while ethanol is steadily blended into a growing majority of automobile gas (autogas), slowly removing that alternative. Options and a common solution are being sought, but it's unlikely the fuels of the future will equal today's performance at today's prices.



The majority of low-compression engines can be operated today without lead by using the existing autogas/unleaded avgas supplemental type certificates (STCs). It's high-performance aircraft and their high-compression engines that will be affected the most by the shift away from leaded fuels.

Earlier this year the United States Environmental Protection Agency (EPA) accepted the final comments on a lawsuit from the Friends of the Earth (FOE) that contends that 30 years of exceptions allowing the continued use of 100 low lead (100LL) avgas is long enough. FOE points to the tetraethyl lead additive's adverse impact on humans and the rest of nature as the reason to eliminate it. (Lead impairs brain functions of those who touch or breathe enough of it.) Aircraft in the United States are about the only vehicles in the world still using leaded fuel. Standards set by the Clean Air Act were first implemented in 1973 to shift automobiles to unleaded fuel by the early 1980s before the outright ban on using leaded fuel in road vehicles took effect in 1996.

"Friends of the Earth was thorough in the development of its 2006 lawsuit," says Earl Lawrence, EAA vice president of industry and regulatory affairs. "EPA has to answer that suit," he concedes. "I don't think we have six months [before changes are required]." The EPA already has implemented new emissions limits that could restrict flights at the largest general aviation (GA) airports, but further action will likely be in the form of an advance notice of proposed rulemaking to regulate GA lead emissions. In its lawsuit, FOE pointed out that GA aircraft account for 65 percent of the total lead emissions in the United States. That's 125.5 tons annually.

While the EPA is looking to industry to provide a road map, Lawrence reports the agency so far is seeking the lowest impact solution. "There has been discussion about prohibiting the construction of new engines and aircraft that require leaded fuels starting two years after a formal EPA response [to the FOE lawsuit]," he says. Besides slamming that door, the EPA could also require all piston aircraft that can fly on unleaded fuels to use only unleaded fuels such as a 91UL (unleaded) avgas that can be produced today.

"It's 100LL without the lead in it," says Lawrence. "We call it 91, 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. That would create the economic incentives for the distribution. In other words, it would force the oil companies to start shipping it and force engine and airframe companies to produce new aircraft that are compatible with the new lower octane unleaded fuels." (The 1,600,000 tons of 100LL produced annually worldwide is only 0.5 percent of the auto fuel produced. Only one factory in the United Kingdom makes the tetraethyl lead additive.)

What the Numbers at the Pump Mean

A comparison of typical automobile gasoline anti-knock indicators (AKI), the number on the pump, with motor octane numbers (MON):

Regular	**87 AKI**	car gas	=	**82.5 MON**
Premium	**91 AKI**	car gas	=	**87.5 MON**

Note: Typical 100LL is 104-106 MON.

If EPA went that route, Lawrence adds, it wouldn't actually outlaw 100LL, so warbirds and other high-performance aircraft could still use it. But, leaded fuel would likely become more expensive and harder to find, which is the dilemma being balanced: "Do you pay more for a specialty fuel so some of the fleet can use it, or do you make modifications to the aircraft?"

Jeff Decker

Avgas and avgas tanks are destined to disappear if the EPA prohibits the use of any leaded fuels.

Bob Warner, left, confers with Harry Zeisloft, center, who led EAA's autofuel testing program, and the now late Jim Barton, who logged hundreds of hours in a Cessna 150 in the early 1980s to demonstrate the viability of autofuel in general aviation aircraft.

A mountain of research over the past 25 years guides these decisions. The EPA has shown a willingness to accommodate and understand research before forcing a change for aircraft.

"We've got to remember that we've won, in a way, by delaying this change for all these decades," asserts Lawrence. But that doesn't mean the transition will be easy. "There's no silver bullet. If there was, it would have been found by now. A wide range of chemicals and compounds have been studied by experts in both industry and academia, and the government verified the testing."

The bulk of the latest research is coordinated through the Coordinated Research Council (CRC) Unleaded Avgas Development Panel. More than 60 members from 40 organizations serve on that committee, which released its latest report on 30 unleaded blends in April. The conclusion states, "Although full-scale engine tests indicated some blends were capable of providing knock-free operation in the test engine, those blends represented the use of specialty chemicals which require further evaluation with respect to environmental impact. Economic viability of the blends tested...will also need to be evaluated separately by industry." The report continues, "Although experimental blends of specialist components may achieve or exceed the 100LL specification of 99.6 MON minimum, such formulations...potentially compromise other important specifications."

As industry tries to match that motor octane number (MON), Lawrence sees three sets of options. The first simply leaves out the lead and satisfies the needs of 70 to 80 percent of the fleet. The second option, for the remaining high-performance pistons that use the majority of the avgas produced, "is using some of the unfriendly additives we've identified." Those are expensive, but a tolerable cost might be found that allows an unleaded fuel to be produced with high enough octane performance to satisfy the needs of most of the remaining aircraft.

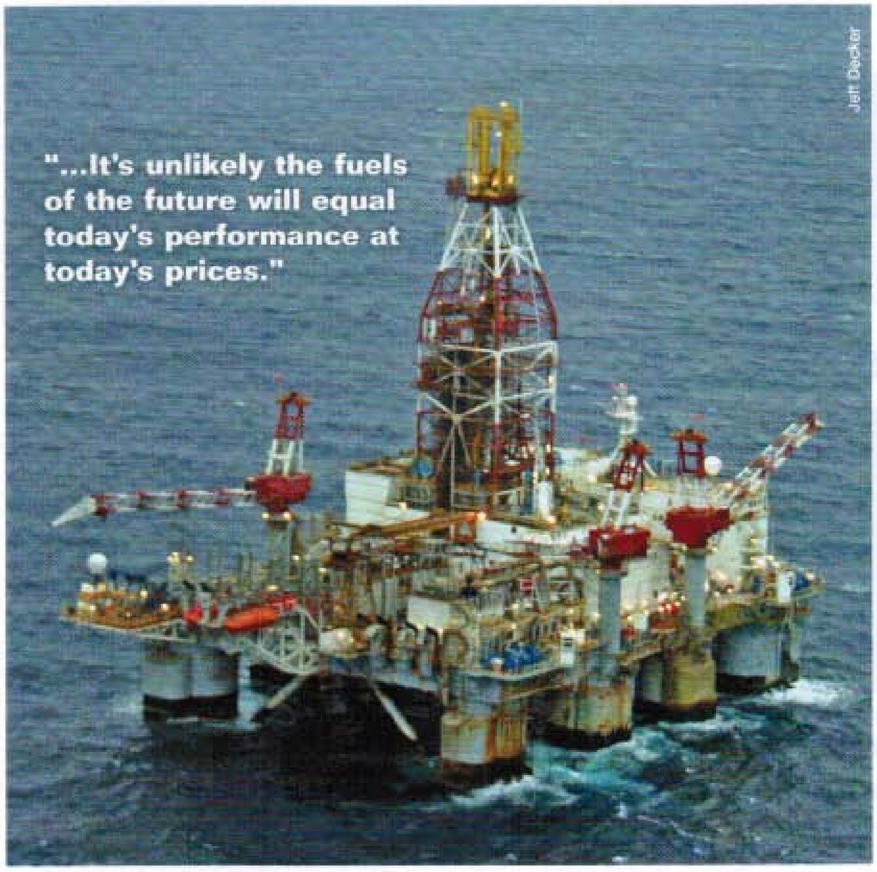
The third possibility is a totally new fuel among the array of bioengineered alternatives being developed. Most of the biofuels are formulated for jet and diesel engines, but a SwiftFuel process has emerged from a group at Purdue University, and its inventors say it actually brings a 15 percent range boost and 50 percent drop in manufacturing costs. They say the fuel has no sulfur emissions, has a 30-degree lower freezing point than 100LL, requires no stabilizers, and could be available in 2009. Developers hope to open a 2,000 gallon per day "pilot" plant at Delphi Municipal Airport in Indiana (I19).

The exact SwiftFuel chemical process is protected information, says Swift Enterprises Research Director John Rusek, but one key is the fuel does not have added oxygenates like ethanol. As with other biofuels, the raw material can be anything that can be converted into sugar. "It's the components of biomass that are the most important, and that's where a lot of people miss the point," he says. "It's not about any specific crop."

The innovations the SwiftFuel inventors have developed, and the process they hope to sell, are in the second half of the conversion process and could easily be adapted to existing ethanol facilities, he says. "America has already invested in that infrastructure. Why not use it?" asks Rusek.

When the inventors presented SwiftFuel to the FAA, it met 42 of the 44 specifications in ASTM International Standard D910, which is the current specification governing 100LL aviation gasoline.

Performance could be the least troublesome aspect for SwiftFuel, says Doug Macnair, EAA vice president of government relations. "The big unknowns with that fuel are...is the production process scalable in a financial way and are the materials available?"



Any new fuel will likely be cleaner, easing the pressure the EPA put on four major GA airports on October 15, 2008. That action appeased a federal court order to reduce the acceptable lead levels by 90 percent. Van Nuys Airport in Los Angeles, Centennial Airport near Denver, Phoenix's Deer Valley Airport, and Orlando Sanford International Airport were among the 135 sites estimated to have annual lead emissions above 1 ton, joining battery manufacturers and industrial boilers in having to implement new mandated monitoring. If lead emissions exceed acceptable standards, these facilities will need to develop a corrective plan by 2013 and put it into action by 2017.

"I think when each of these airports gathers their own numbers based on real data, some of them will fall off [the list]," predicts Walter Desrosier, vice president of engineering and maintenance for the General Aviation Manufacturers Association (GAMA). The EPA added up all GA operations, he points out. "The data for landings and takeoffs doesn't differentiate between pistons and turbine jets." (Jet fuel doesn't contain lead.)

FOE suggested aviation grade ethanol (AGE85) fuel as a substitute. Development of this fuel has been ongoing for some time, but efforts to establish an industry specification have been slow. Not all aspects of the fuel have been explored and shown to be satisfactorily compatible with the existing aircraft fleet.

"Ethanol drastically changes the water separation of the fuel and its vapor pressure," warns EAA's Macnair. There's also a corrosion potential from regular use; fuels with ethanol left sitting unused in vented tanks tend to phase separate causing corrosion throughout the fuel system. Ethanol requires more fuel flow, which leads up to a 40 percent reduction in the aircraft's range. Outside of the warm climate and abundant ethanol infrastructure of Brazil, Macnair says, AGE85 just won't be viable for aircraft.

Not only is ethanol harmful, but the autogas STCs held by EAA and Petersen Aviation forbid the use of ethanol blends. EAA holds STCs for 71 engines and more than 100 airframes from 17 manufacturers. As of May 2008, 65,000 STCs have been issued. (EAA first tested lead alternatives in 1964 and in 1982 opened the door to STCs for automotive fuel, or autogas/mogas.)

That experience will help EAA gain new STCs for new fuels or modifications to the high-performance aircraft fleet. "What we're looking for is a way to expedite the process to certify groups of aircraft, or families of engines, to use new and existing fuels. We are working with the FAA to find new and creative ways," explains Macnair.

There's a mountain of problems to address besides the performance loss that engines exhibit when using unleaded fuel. Changes in fuel flow or horsepower output will affect performance, and aircraft handbooks will have to be rewritten. A fuel that weighs more or less would throw off an aircraft's weight and balance, as would a new and heavier engine.

EAA estimates at least 80 percent of the piston aircraft fleet will function without problems on unleaded avgas, specifically the low- and mid-compression engines designed for octanes up to 80 and 91 MON, respectively.

Octane Needs Vs Compression Ratio

Octane needs for various compression ratios can be estimated for air-cooled aircraft engines as follows:

Low compression (7:1 to 7.2:1) type certified to **80 MON**

Mid compression (8:1 to 8.5:1) type certified to **91 MON** and STC'd to **87 MON** premium autogas

High compression (8.7:1+) & turbocharged engines type certified to **100+ MON**

Ethanol plant in West Burlington, Iowa. The SwiftFuel developers believe these facilities could be converted to make biofuels as well.

Others estimate 70 percent of the fleet will be unaffected. Some models may be able to operate on a new unleaded fuel with simple changes. A manufacturer could reduce the maximum cylinder head temperature via an airworthiness directive or a type certificate revision. Other engines depend on the detonation protection of 100LL and can't easily compensate for a lower octane. If the fuel-to-air mixture inside a piston engine combusts at the wrong time, it would create holes in the pistons and cause the engine to tear itself apart. Technology does offer hope. Full authority digital engine controls (FADEC) and other electronic timing controls are capable of pinpoint monitoring and adjustments not normally possible. Lycoming's iE2 (integrated electronic engine) was designed to power the leading high-performance pistons of today with multiple fuels. "By moving to an adaptive, closed loop, cylinder-by-cylinder control system, you can compensate for some loss of octane," states Michael J. Kraft, Lycoming vice president of research, development, and engineering. "Going further up the 'trick' line, you could include the go-fast gizmos that we've placed on Jon Sharp's Nemesis NXT engine."

Kraft believes a 100-octane unleaded fuel, or 100UL, may come to market. "What would happen if we were faced with very low octane ratings...say 91UL or lower? Possibly a change in engine technology would be needed. Remember, today's high-performance aviation engines were designed around the then-available fuel. If the fuel changes, the engine will need to change either in control methods or mechanical configuration," he says. "There are limits as to how far down you can go without impacting the power rating."

Rhett Ross, the president of Teledyne Continental, said last spring that the company was developing an engine for either diesel or jet fuel to be certified by 2010. Spokesperson Mac Little won't comment on existing prototypes. "You'll probably have to follow up with us every six to eight months," he says. "We have 1,800 types of specifications, and we have to test each and every one of them."

What about modification kits that could adapt today's engines for tomorrow's fuel? "It's an active program," Little hints, adding, "We won't get

Comparison of Fuel Possibilities

FUEL	AIRCRAFT	AVAILABILITY
Petroleum-based unleaded similar to 100LL without the lead	Significant modifications for high-compression and turbocharged engines. No effect on 70 to 80 percent of the fleet.	Transparent for producers, distributors, FBOs. Same cost as today's 100LL.
SwiftFuel biomass hydrocarbon fuel or other possible specialty fuel	Could possibly satisfy the needs of the current high-performance fleet. Initial engine testing by FAA Tech Center has had positive results.	Still in the uncertain research and development phase. Proprietary and patented biochemistry process. No demonstrated production. Unknown cost.
Dual-fuel interim transition approach (unleaded for most existing fleet & all new aircraft; leave 100LL in market for remaining high-performance aircraft)	Transparent for existing fleet. Significant modifications for new production high-performance engines/aircraft.	Infrastructure costs and handling issues for two fuels. Cost of leaded fuel likely to rise faster than unleaded. FBOs may choose to only offer one fuel.