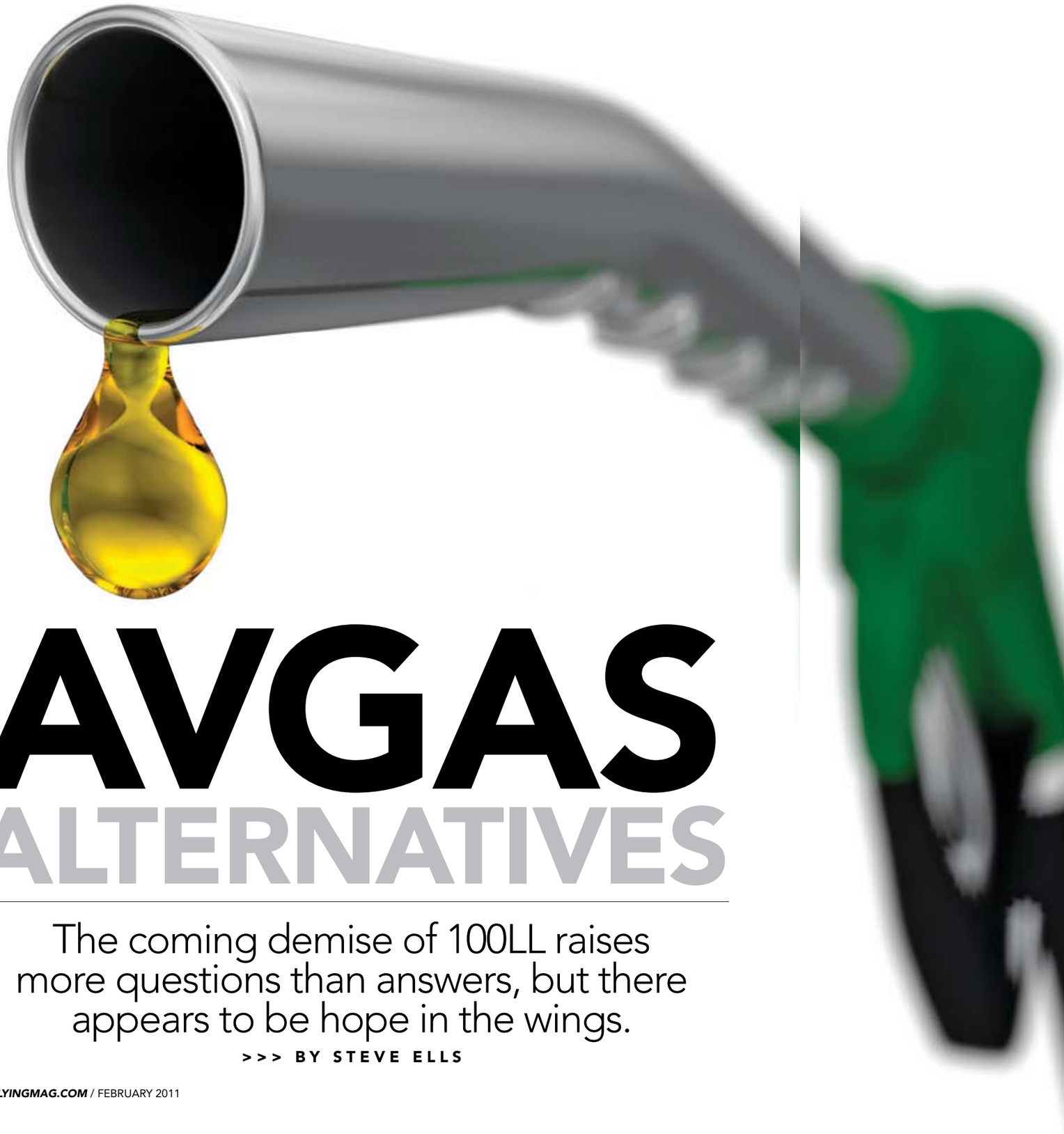


AVGAS ALTERNATIVES

The coming demise of 100LL raises more questions than answers, but there appears to be hope in the wings.

>>> BY STEVE ELLS

IN APRIL 2010, THE ENVIRONMENTAL Protection Agency released an announcement that it was proposing to gather data to determine if leaded avgas is an environmental health hazard.

The announcement in the form of an advanced notice of proposed rule making (ANPRM) has created reactions that range from a willingness to move forward in the search for the new lead-free avgas to alarm at the idea of government mandated changes and outrage due to what some see as a misguided plan to replace one boutique fuel with another. Regardless, the ANPRM served as a wake-up call to GA that 100LL is on the way out and the aviation community needs to figure out what to do next.

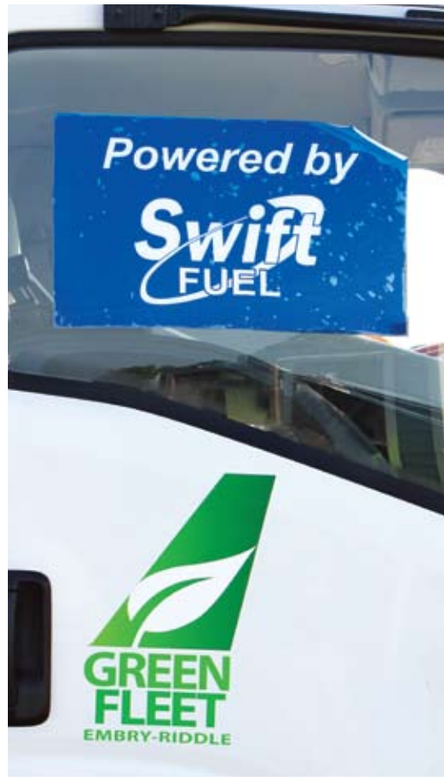
Responders to the ANPRM questioned whether the tiny amount of lead in the GA fuel supply, which accounts for one-10th of 1 percent of the transportation fuel used in the country each year, presents a credible threat to health. Some bemoaned that scant attention was being paid to the fact that supplies of ethanol-free premium auto gas — a viable and FAA-approved fuel for more than 150 piston-powered airplane types and approximately 70 percent of the airplanes plying the skies — are rapidly shrinking due to congressional mandates to increase ethanol usage, a state of affairs that actually required more pilots to use 100LL instead of a viable unleaded auto-gas alternative.

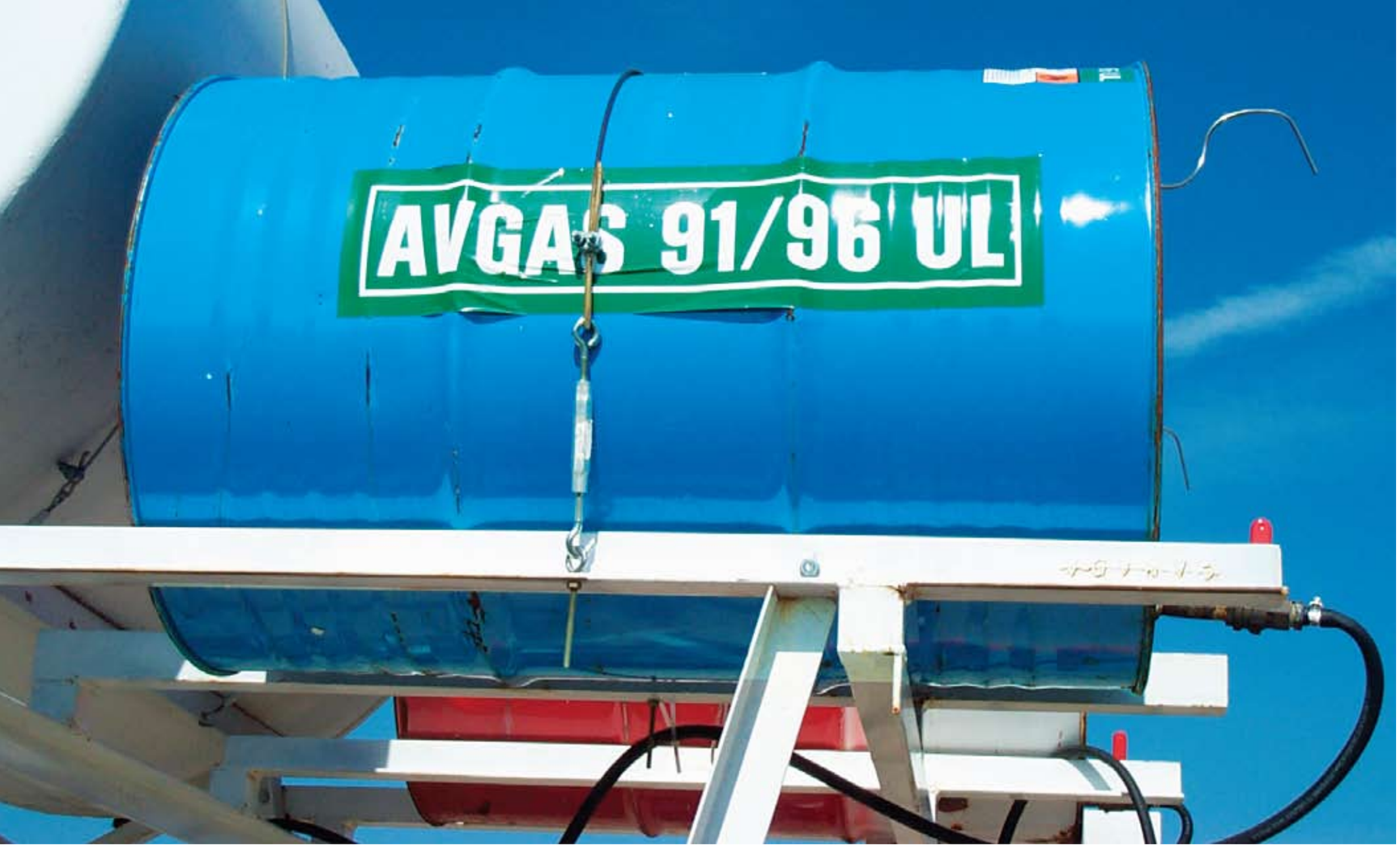
"This industry is dealing with a massive changeover situation, and people don't seem to realize how big this issue is," said Lycoming senior vice president and CEO Mike Kraft at AirVenture 2010. "When you change the fuel, you change a primary element of this industry."

The EPA

Tetraethyl lead (TEL) is added in small amounts to aviation gasoline (avgas) to boost the octane number. Avgas must have an octane number of 100 to protect today's high-powered engines from detonation.

TEL was removed from auto gas in 1996, and although there were a few glitches during the transition period,





lead-free auto fuel has worked well.

Despite its octane-boosting properties, TEL is not without its share of negative side effects. In addition to toxicity issues, some piston engines are prone to spark plug fouling, valve sticking caused by lead adhering to valve stems and valve guides, piston-ring land contamination and preignition due to lead deposits on piston crowns. Both Teledyne Continental Motors (TCM) and Lycoming have published more than one service directive related to the negative effects of TEL.

The momentum against 100LL has been building for years. In 2006 a petition was filed with the EPA that requested that the agency determine if TEL in avgas constitutes a threat to public health or welfare. And to make matters worse for 100LL, in 2008 the EPA found that adverse health effects occur at much lower blood-lead levels than was formerly understood. As a consequence the National Ambient Air Quality Standard (NAAQS) for lead was reduced by an order of magnitude from 1.5 to 0.15 micrograms per cubic meter.

At a public forum during AOPA Summit late in 2010, the EPA suggested that around 50 percent of the airborne lead in the United States can be linked to 100LL avgas. The EPA is conducting air sampling studies at five busy GA airports around the country to quantify the amount of lead being emitted during flight operations.

Take the lead out of today's avgas and the octane number drops to 94 — still high enough to protect the majority of today's engines but not all engines. Adoption of a new avgas that does not provide the same detonation protection as today's 100LL avgas would instantly render most twin-engine and high-performance airplanes unairworthy.

Toward a New Avgas

Ideally the new lead-free avgas replacement will be affordable, will fit easily into the present production and transportation infrastructure and will be in high enough demand to attract investors and producers.

American Society of Testing and Materials (ASTM) standard D-910 establishes 44 parameters for today's leaded avgas. One of the challenges in creating a lead-free avgas is determining how closely the new avgas formulations comply with these parameters and, if they don't, whether or not the deviations are acceptable. Alignment with the parameters makes it much easier for the airframe and engine manufacturers and the FAA to approve the new avgas for use in both today's legacy airplanes and tomorrow's airplanes.

A new ASTM specification will be written for an unleaded fuel formulation. Both of the two companies working on formulations for lead-free avgas have submitted applications for ASTM standards for their fuel.

Even though Glenn Passavant, EPA's project manager for this issue, told the industry at AOPA Summit 2010 that "over the next several years we will start getting more monitoring data," suggesting a leisurely approach to the transition, key industry players don't think we have that kind of time. Engine manufacturers Lycoming and TCM are urging adoption of the new avgas standard within the next year.

Octane Boosters

There are a multitude of challenges in creating an unleaded alternative to 100LL, but chief among them is finding a replacement for the lead.

D-910 restricts the maximum amount of TEL in 100LL fuel to 2.0 milliliters per gallon. Real-world 100LL airport pump supplies almost always contain less lead, so our engines can clearly get by without that maximum amount.

The good thing is that TEL is not the only octane enhancer we know of. The bad news? Some are more hazardous than TEL. Beginning in 1992, methyl butyl tertiary ether (MBTE) was added to automobile gasoline to raise the octane number but was phased out beginning in 1999 due to its groundwater-polluting characteristics.

Mesitylene — also known as 1,3,5-trimethylbenzene — is an aromatic hydrocarbon that's been proved to provide adequate detonation protection for today's high-performance aircraft engines. Most of the mesitylene now available is manufactured in China. One estimate puts the quantity in the United States at less than six railroad tank cars. It's expensive on the bulk market. Yet it's a critical component of new avgas formulations being developed by both of the two companies vying to produce tomorrow's lead-free avgas.

New Fuels on the Horizon

One of the companies is forging ahead with a traditional petroleum-based approach. Its formulation uses mesitylene or a related aromatic, such as one of the forms of dimethylbenzene, in place of TEL to jack up the octane of high-grade aviation alkylate base stock. The other company will grow its supply of mesitylene by converting biomass via a proprietary catalytic process to produce sufficient quantities of this aromatic hydrocarbon.

General Aviation Modifications Inc. (GAMI) of Ada, Oklahoma, has developed a petroleum-centered plan for producing the new avgas: Add aromatic compounds such as mesitylene and/or one of the xylene offshoots to the high-quality alkylate base stock (94 octane) that's already in production as the base stock for today's TEL-laced 100LL. Xylene is a plastic precursor and is plentiful. Ta-da! An avgas that can be put into production using existing production facilities and matching up very well with almost all D-910 performance mandates.

Modifications must be implemented at the production plants, but George Braly, chief engineer at GAMI, said the fuel can be made with components "that are found inside the fence of any refinery." Braly predicted a price of $5 to $6 a gallon for G100UL, the company's replacement fuel. Braly added, "G100UL can be made at any of the seven or eight refineries around the country that produce 100LL avgas."

Swift Technologies of West Lafayette, Indiana, has a different plan. The Swift formulation is a binary (two-part) fuel consisting mostly of mesitylene mixed with a small amount of isopentane (2-methylbutane). The difference is that the Swift supply of mesitylene will be extracted from biomass through a catalytic process developed by John Rusek, who has a doctoral degree in chemical engineering and atomic physics, and Jon Ziulkowski, vice president of renewable fuels at Swift. The production process has been proved on a small scale.

Mary Rusek, spouse and partner, said that one of the advantages of Swift fuel is that it can be made from local

TETRAETHYL LEAD: $(CH_3CH_2)4Pb$

ETHANOL: C_2H_5OH

biomass such as "wood chips in the Northwest, sorghum in the South or sugar beets from Maine." Rusek also said that Swift already has signed letters of intent from five out of the six oil companies to distribute 100SF.

"We have plans on paper where we would take an ex-ethanol plant, make a few changes and produce our fuel," Rusek said.

"We believe we can scale up for full-scale production in one year," said Swift CEO Dave Perme, who also said, "Research shows that we can get to a competitive price compared to 100LL."

A recent survey lists 216 ethanol production facilities in the United States. Projected ethanol demands have not approached the production mandates passed by Congress. As a consequence, plant construction has slowed, some plants are mothballed, and a few are being sold at auction.

It appears that GAMI and Swift are the only two players in the new avgas game. But underneath all the formulations, standards, testing and approvals required to get to the new avgas is a plan to introduce another leaded avgas: an ultralow-lead 100 octane fuel.

94UL and Auto Gas

In 2009 TCM flight-tested 94UL — which approximates today's 100LL without the lead — in a Hawker Beechcraft G36 with a 300 horsepower, fuel-injected IO-55B engine and in a Cirrus SR22T 315 horsepower, turbocharged, fuel-injected TSIO-550 engine. *Flying*'s Robert Goyer flew the SR22 with 94UL and was impressed by the power and performance of the low-compression engine on the unleaded version of our current avgas.

Johnny Doo, TCM's vice president of engineering, agrees that the higher-horsepower turbocharged engine — with 7.5:1 compression — ran fine on 94UL fuel. Unfortunately, the 300 horsepower normally aspirated engine, with 8.5:1 compression cylinders, "was not happy," Doo said.

The telling difference between the two engines is the compression ratio.

Doo said TCM tested the fuel to determine how well the company's high-powered engines performed on 94UL.

"94UL has an existing ASTM spec, so we wanted to see where we stood if it was the final fuel," Doo said. He said that installing lower-compression pistons or "smart" ignition systems, or limiting takeoff power, would be required to provide the required detonation protection for TCM's 8.5:1 compression ratio engines if 94UL is adopted as the new avgas.

According to TCM, the piston change to lower the compression ratio from 8.5:1 to 7.5:1 would reduce the engine's maximum power by 3 or 4 percent. This swap would reduce a 300 horsepower engine's maximum power output to between 288 and 291 horsepower.

"Smart" ignition systems are programmed to automatically change (retard) ignition spark timing at the onset of detectable detonation. This would automatically reduce engine power. Imagine seeing a panel-mounted "power reduced" light start blinking as the runway end looms in the windshield. In addition to the operational snafus, this would present a formidable certification headache.

All of today's existing engines can be made to run on 94UL, but the changes required for a fleetwide conversion would cost millions and would stir up a hornet's nest of airplane and engine recertification issues. Not to mention awakening the third rail of capitalism — product liability issues.

Questions have also been raised about the possibility of getting Congress to back off on ethanol mandates to guarantee a nationwide supply of ethanol-free premium grade auto gas for aircraft. Auto gas supplemental type certificates (STCs) by the Experimental Aircraft Association (EAA) and Petersen Aviation are invalidated if an airplane is fueled with auto fuel that contains ethanol.

Doug McNair, vice president of government relations at the EAA, said there's no political will in Washington to oppose ethanol mandates; in fact, Congress recently passed legislation mandating higher levels of ethanol in auto gas.

There is a growing consensus that a 100-octane replacement fuel of some kind is needed to replace 100LL.

"100 Octane," Says Lycoming and Cessna

Jack Pelton, Cessna's chairman, president and CEO, boiled down the issues swirling around the search for an unleaded avgas in a November 2010 statement when he said, in part, "The key is to not leave anyone behind; the solution must be global and it must be technically and financially viable."

Pelton's "global" solution comment is important. U.S. airplane and engine manufacturers have been slowed in their attempts to expand into new markets by the leaded-fuel requirements of high-performance engines. 100LL is expensive outside the United States and is close to nonexistent in most developing regions of the world. The development of a new lead-free 100 octane avgas would be a boon for U.S. companies seeking expansion in today's emerging and largely untapped aviation markets.

The call for a 100 octane fuel was voiced by Kraft at Lycoming and echoed by John Bouma, manager of propulsion systems at Cessna. Kraft said that "we're going to get one chance in one grade" and urged all concerned parties to work together when he said, "We need to mobilize our resources and get on with it," during a speech at AirVenture 2010.

Kraft stressed how important it is to the industry to make a decision before AirVenture 2011 due to the long lead times needed to bring the new fuel to market.

Is Less Lead OK?

During a presentation at AOPA Summit in November 2010, Passavant discussed the EPA position in a 10-page PowerPoint presentation. Passavant also told the audience that "the law doesn't say there has to be zero lead — just that there has to be action."

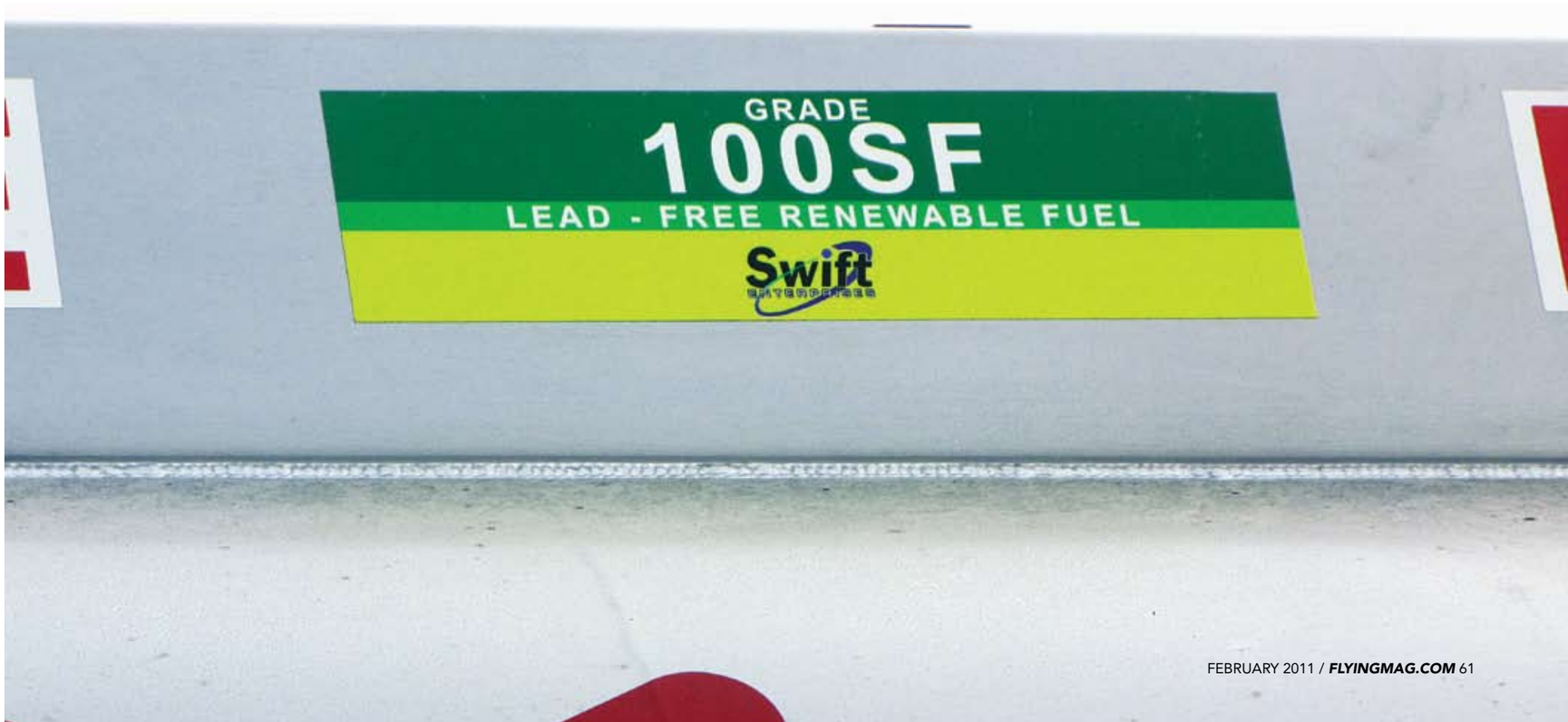
One action that's endorsed by today's avgas providers is bringing very low-lead 100 octane avgas (100VLL) to the market. Since 100VLL can be produced today under D-910, the existing ASTM standard, this step would not require a large investment in infrastructure or time. Industry insiders all cited 100VLL as a viable interim step forward that would not only reduce lead emissions but would answer the EPA's call for action on the part of the industry.

The introduction of 100VLL would reduce lead levels. Would it prove to be an acceptable long-term solution to both greenhouse gas and lead concerns? Would politics play a role in easing mandates or making ethanol-free unleaded auto gas available? These questions are among those voiced every day on Internet chat rooms and aviation websites.

The more pressing concern for the future of the new avgas is demand. If the cost numbers provided by GAMI and Swift are realistic, flying would still be affordable for most of today's owners. And if the new avgas could be manufactured and transported using existing infrastructure, the odds of a smooth transition improve dramatically.

But if there isn't enough demand to provide a reasonable long-term return on the capital investment required to bring the new avgas formulations to market, the only viable solution may be 100VLL or engine modifications or a combination of the two.

Passavant left all options open when he said, "We want to move in an orderly, fact-based manner so that, when we make a determination of the data, there's a good fact-based process and a way forward to resolve it." Passavant added that the EPA "is thinking about the cost and the safety."



ISOPENTANE: C_5H_{12}

METHYL TERTIARY BUTYL ETHER: $C_5H_{12}O$