High-Octane Unleaded: Where Are We?

The California legislature passed a leaded avgas ban for 2031. There's a fleet-wide, high-octane unleaded avgas that is ready to go, but distributors won't deliver.

by Rick Durden

For over three decades the FAA has been involved with various programs that have been working to get rid of tetraethyl lead (TEL) in high-octane aviation gasoline. The goal is to define a high-octane unleaded avgas that is a drop-in replacement for 100LL for every spark-ignition piston engine aircraft—fleet wide.

The desire to get lead out of avgas isn't a recent development. In October 1931, Dr. Jimmy Doolittle (Ph. D. Aeronautics, MIT, 1925), then an employee of Shell, was making one of his many record-setting flights in a Laird Super Solution. On the last leg of the flight, he carried a container of tetraethyl lead (TEL) that he would be using to increase the octane of the avgas available at his last stop up to what was needed for his aircraft.

The container leaked. The toxic fumes sickened him to the point that he was barely able to land the airplane. Doolittle, who was in the process of pushing for the development and standardization of high-octane avgas (what was to become 100/130 octane), recognized that while it was then necessary to add lead to fuel to make octane, commented that it was "not an ideal solution." He went on to say that "There had to be a better way to add octane to fuel." P. 132, *Calculated Risk*, by Jonna Hoppes, 2005, Santa Monica Press, LLC.

TEMPORARY EXPEDIENT

Nearly 100 years ago, experts in aviation fuel knew that using a toxin as serious as lead to make a high-octane fuel should only be a temporary expedient. Accordingly, we're going to take a deep, detailed dive into what has been accomplished to fix a long-recognized problem. For space, we'll limit it to this century—even with that, there's a lot of material.

PAFI

In 2014 the FAA formed PAFI (Piston Engine Fuel Initiative) to "support evaluation of candidate-unleaded fuels." For reasons unknown, even though PAFI is an FAA organization and the FAA provides two separate and equally valid routes to avgas approval, the PAFI process for identifying a fuel would be only be via issuance of an ASTM spec in conjunction with taxpayer funded FAA testing, rather than by the parallel process of FAA approval via a Supplemental Type Certificate (STC).

As background, 100LL has an ASTM spec—D910. An ASTM spec is not a recipe, it's a document designed to facilitate commerce. It achieves that goal by tabulating a series of laboratory tests that must be run on every batch of fuel produced. The values from those tests also must each fall within a defined range of results. Chevron's recipe is different than Phillips' which is different than Exxon's. But each batch of 100LL they produce will have laboratory test results that fall within the "brackets" defined by the specification.

PAFI failed. After more than $40 million in taxpayer dollars, it produced nothing.

When PAFI was brought back from the dead as EAGLE (Eliminate Aviation Gasoline Lead Emissions) in early 2022, it also, inexplicably, followed the ASTM route to a fuel approval even though EAGLE's website points out that there are two equally valid routes to FAA fuel approval, FAA STC or ASTM spec and then FAA approval. EAGLE started with three candidate fuels.

• **Phillips 66 and Afton Chemical**. The largest producer of 100LL teamed with a corporate sister, Ethyl Corporation, the importer and distributor of tetraethyl lead (TEL). Their candidate fuel used manganese (formulated in a product called MMT) as an octane enhancer. Manganese has been unacceptable in auto fuels for years due to the deposits it leaves. Not surprisingly, during testing of that fuel at the FAA tech center last fall, it destroyed the test engine from detonation or preignition. That was predictable. That fuel has been withdrawn.

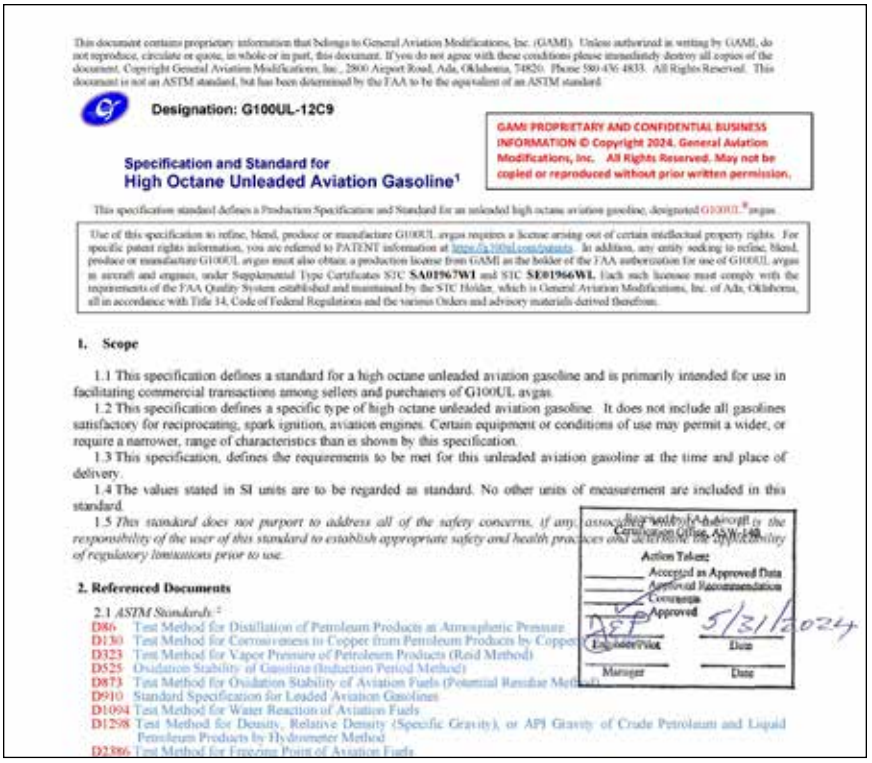
• **LyondellBasell and VP Racing**. This is another fuel that uses MMT—as an octane enhancer—along with ETBE. In June of this year the team submitted its proposed test specification to EAGLE. EAGLE members provided critiques of the spec. As a result, LyondellBassell/VP Racing withdrew its submission. We note that LyondellBassel/VP Racing says that its fuel has "similar detonation resistance to 100LL *under most conditions tested*." LyondellBasell/VP Racing now says that it is not possible to get the necessary octane required to be a true drop-in replacement for 100LL without the use of manganese or lead and that 80 percent of aircraft engines will be able to use its fuel without modification.

The problem is that the 20 percent of the engines that can't use the fuel without modification are the big-bore Lycomings and Continentals—normally aspirated and turbocharged—that need high-octane fuel and use more than half the avgas burned. According to LyondellBassell/VP Racing those engines and aircraft will require modifications reducing their horsepower output to burn the lower-octane fuel. That will cut useful load and range and may not be possible in a piston twin. LyondellBasell says it's going to continue with the process because it's the only process that can lead to a fuel that can be used in all aircraft.

That means that there may be an ASTM spec for an unleaded avgas acceptable to EAGLE that does not have the same performance capabilities as 100LL and is of lesser quality. In our opinion, that's not a high-octane avgas.

We note here that throughout the

The top portion of the first page of the Specifications and Standard STC for G100UL high-octane, unleaded gasoline, Designation G100UL-12C9, showing the FAA-approved stamp. The full spec is available on the G100UL website.



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Designation: G100UL-12C9

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Specification and Standard for
High Octane Unleaded Aviation Gasoline[1]

This specification standard defines a Production Specification and Standard for an unleaded high octane aviation gasoline, designated G100UL® avgas.

Use of this specification to refine, blend, produce or manufacture G100UL avgas requires a license arising out of certain intellectual property rights. For specific patent rights information, you are referred to PATENT information at https://g100ul.com/patents. In addition, any entity seeking to refine, blend, produce or manufacture G100UL avgas must also obtain a production license from GAMI as the holder of the FAA authorization for use of G100UL avgas in aircraft and engines, under Supplemental Type Certificates STC **SA01967WI** and STC **SE01966WI**. Each such licensee must comply with the requirements of the FAA Quality System established and maintained by the STC Holder, which is General Aviation Modifications, Inc. of Ada, Oklahoma, all in accordance with Title 14, Code of Federal Regulations and the various Orders and advisory materials derived therefrom.

1. Scope

1.1 This specification defines a standard for a high octane unleaded aviation gasoline and is primarily intended for use in facilitating commercial transactions among sellers and purchasers of G100UL avgas.

1.2 This specification defines a specific type of high octane unleaded aviation gasoline. It does not include all gasolines satisfactory for reciprocating, spark ignition, aviation engines. Certain equipment or conditions of use may permit a wider, or require a narrower, range of characteristics than is shown by this specification.

1.3 This specification, defines the requirements to be met for this unleaded aviation gasoline at the time and place of delivery.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

Reviewed by FAA Aircraft Certification Office, ASW-140
Action Taken:
Accepted as Approved Data
Approval Recommended
Concurred
Approved
Engineer/Pilot — Date
Manager — Date
5/31/2024

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D86 Test Method for Distillation of Petroleum Products at Atmospheric Pressure
D130 Test Method for Corrosiveness to Copper from Petroleum Products by Copper
D323 Test Method for Vapor Pressure of Petroleum Products (Reid Method)
D525 Oxidation Stability of Gasoline (Induction Period Method)
D873 Test Method for Oxidation Stability of Aviation Fuels (Potential Residue Method)
D910 Standard Specification for Leaded Aviation Gasolines
D1094 Test Method for Water Reaction of Aviation Fuels
D1298 Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
D2386 Test Method for Freezing Point of Aviation Fuels

PAFI/EAGLE process many commentators, notably the National Air Transport Association (NATA), an organization of, among others, FBOs and fuel distributors, have asserted, without evidence, that the ASTM spec and subsequent FAA approval route to a new fuel is superior to the FAA STC process. In fact, as will be pointed out below, the opposite is true.

• **Swift Fuels UL100R**. The material we've seen on Swift's fuel is that it also uses the "oxygenate" ETBE (Ethyl-tert butyl ether) at a level of up to 25 percent. Available public information (example, Swift's patents) reflects that there will likely be 3 to 7 percent *fewer* BTUs per gallon in UL100R than in typical 100LL. That will reduce the range of our aircraft, by the same amount. At various times and places Swift, like Lyondell-Basell, also stated that UL100R will not be usable in all piston airplanes in the FAA database. That's hardly a drop-in replacement.

We note that ETBE is ethanol based, and it is chemically classified as an "ether." Remember what happened to aircraft engines when mogas with ethanol was used? Yes, the rubber compounds in the fuel systems and engines fell apart. At Oshkosh this year, data were provided that strongly suggest that the use of ETBE will create problems with diaphragms and other rubber components in our aircraft fuel systems. We are waiting to learn more on this subject.

Further, the way we read the California statutes, ETBE is illegal for use in self-propelled vehicles. We didn't see an exception for aircraft. EAGLE has not explained how ETBE can be used in California.

• **General Aviation Modifications Inc. (GAMI) G100UL**. Although this fuel appears on the EAGLE website and GAMI has been participating in a good portion of the EAGLE program, it is not an "EAGLE" fuel because EAGLE, an FAA organization, openly discriminates against the FAA STC approval route to a high-octane unleaded avgas.

So, what's up with G100UL?

Two years ago, after some 12 years of testing, the FAA issued an STC to GAMI for the use of G100UL high-octane aviation gasoline *in every spark ignition piston engine in every aircraft in the FAA database*. It has been tested and approved in every one of the piston rotorcraft engines, although formal approval for rotorcraft is pending.

G100UL is a fleet-wide, high-octane drop-in replacement for 100LL without modification to airframes or engines other than the placards to be installed as part of the STC. G100UL can be mixed with 100LL and mogas without any additional steps, so it can be mixed in holding tanks and aircraft fuel tanks.

The STC price for an aircraft owner is slightly more than two dollars per HP, a one-time fee so the capitalist that developed the fuel makes money off its hard work. We'll admit our bias, we love American private enterprise.

The spec for G100UL is on GAMI's website. After reading the FAA-approved language of the specification, it is our opinion that the spec and G100UL form the gold standard for high-octane unleaded avgas.

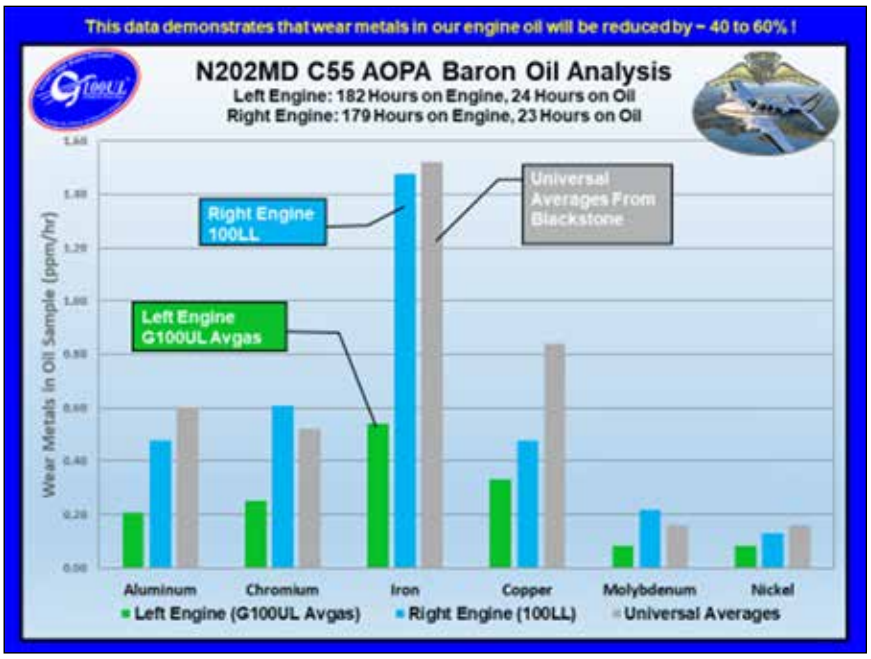
G100UL OCTANE

Avgas has historically been identified with two numbers, such as 80/87, 100/130 or 115/145. The lower number is the Motor Octane Number (MON). 100LL, under its ASTM D910 spec, has a minimum MON of 99.6 (which is rounded to 100).

The higher number on the octane description is the "Performance Number" (PN), also called the "supercharge" or "rich" rating—the detonation resistance of the engine at full power with a full rich mixture. This is basic to every aviation fuel; it's been a part of the definition of avgas for over 80 years.

However, from the material we have seen, there is no supercharge rating included in the proposed specifications for either Swift or LyondellBasell/VP. The supercharge rating values are critical as they strongly indluence the real-world performance of the aircraft engine across the entire range from lean to rich fuel-air ratios. That appears to explain why those fuels can't be run in any of the big-bore engines that require the 130 supercharge rating at full rich and full power—Cirrus, Bonanzas, Cessna 200-, 300- and 400-series airplanes, and others—the ones that do most of the day-to-day flying in the general aviation world.

By contrast, when tested, G100UL's



Graph of wear metals in the AOPA-sponsored Baron running 100LL in one engine and G100UL in the other after approximately 180 hours in service showing wear metals of the G100UL engine reduced by 40-60 percent versus the 100LL engine.

supercharge rating has been typically more than 161. The laboratory test engine is unable to measure at any higher value. That's equal to or better than the old purple 115/145 avgas run in WWII fighters, bombers and transports. It means that the big iron still being flown at reduced power on 100LL will again have full power available.

In our opinion, anything that comes out of EAGLE—at taxpayer's expense—better top the capabilities of G100UL.

STC RIGOR

The STC process for the approval of G100UL was more rigorous and more onerous than the ASTM approval process. ASTM does not do or even "witness" testing. At the most basic level, to get a "fleet-wide" engine STC, GAMI had to show that G100UL was as good as or better than 100LL. *That's not the case with an ASTM approval*, especially where it now appears that the remaining EAGLE fuels will not have the 100/130 octane ratings of 100LL and will not be suitable for use on most of the high-performance general aviation engines.

FAA STC POLICY

FAA long-standing policy regarding fuel approvals is set out in Advisory Circular 20-24D. When it comes to seeking approval for a fuel via STC, the FAA states in section 8 e (1), "The FAA has determined that independent fuel specifications may be acceptable for definition of aviation fuel operating limitations if they provide an equivalent level of property, performance, and quality control as governmental, military, or industry voluntary consensus based standards."

Therefore, per FAA policy, a fuel approved under STC cannot be approved ***unless it is every bit as good as a consensus-based standard***—which is what ASTM is.

APPROVAL LANGUAGE

Showing the rigor of the G100UL STC approval, the following FAA-approved language appears in the FAA-approved spec for the STC for G100UL: (Paragraph) "X1.1.4 This specification incorporates and requires use of additional or alternative laboratory test methods which are *more modern and more precise as compared to several of the laboratory test methods traditionally used over the past 75 years for industry standard fuel specifications such as ASTM International D910 (Grade 100LL) and D7547 (Grades UL91 and UL94).* (Emphasis added.)

The FAA itself, an independent agency, through its own rigorous certification process, determined that G100UL and its specification exceeded ASTM standards. That is a huge finding, in our opinion.

There's more.

In the next paragraph in the FAA-approved specification defining G100UL avgas, it states: "X1.1.5 This specification and standard was approved by the FAA based, in part, on FAA Advisory Circular AC 20-24B, and FAA Policy Memorandum 'Policy for Aviation Fuel and Oil Operating Limitations, 14 CFR Part 33.7' [ANE-2010-33.7-5A]. That same policy is also referenced in the most recent revision of AC 20-24D, paragraph 5 a (2), and as further therein referenced in paragraph 8 e (1). Those FAA policy statements, together with multiple standard ASTM tests required in the matrix of the TABLE 1 properties of this specification, establish that, as a necessary part of the approval and issuance of FAA STC SE01966WI, that *the FAA has, in fact, made a determination that this Specification and Standard for a High Octane Unleaded Aviation Gasoline provides, not only an equivalent, but, in fact, an enhanced level of quality control of the properties and performance of the aviation gasoline produced under this specification and distributed throughout the supply chain, as compared to the traditional governmental, military, or industry voluntary consensus based standards which have previously defined and controlled the production of aviation gasolines used for spark ignition piston engines.*" (Emphasis added.)

"Throughout the supply chain"—that's important language, because it means from the refinery into the airplane wing.

G100UL IN SERVICE

We note that about one year ago, the head of AOPA, the organization that represents general aviation pilots, with no financial interest in the continued use of 100LL, Mark Baker, appeared to have recognized that EAGLE is deeply flawed. One of the chairs of the board of EAGLE, Mr. Baker took an early and graceful exit from EAGLE. He then promptly put himself in the Beech Baron

sponsored by AOPA that is operating one engine on 100LL and one on G100UL, because he trusted it. We previously flew and reported on the Baron project.

How is that Baron project going, you ask?

After about 180 hours of operation on newly overhauled engines, Blackstone Labs, a recognized aviation oil analysis facility, noted that the wear metals in the engine using G100UL were 40 to 60 percent *below* universal averages and well below those of the engine using 100LL. That's the graph of the results on the previous page.

Borescope measurements and photographs document that there has been no valve seat recession, an issue that has been raised by the detractors of unleaded avgas. Wear metals are dramatically less than with 100LL.

When lead was removed from automobile fuel, engine life increased dramatically. That's been predicted for aircraft engines as well. This is evidence that the prediction is accurate and is exhibit one for applying for approval to increase TBOs for engines being run on G100UL.

One Commemorative Air Force group that restored a WWII Douglas A-26 has recently flown the airplane with G100UL in the left engine. It has 2000-HP R-2800 engines operating at 44-48" of manifold pressure.

WHERE IS THE FUEL?

Right now, there are pilots and FBOs trying to have G100UL on their airports, but distributors won't deliver it. Vitol Aviation, who is making G100UL, has more than a million gallons ready to go but no distributor as yet will deliver it.

DISINFORMATION

For over a year there has been an active disinformation campaign led by NATA and, to a lesser extent, GAMA (General Aviation Manufacturers Association—not to be confused with GAMI), although we were told that at a meeting at AirVenture only one GAMA member, Lycoming, now opposes G100UL.

We'll go through the claims of G100UL shortcomings and the response to each, based on our research and in conversations with George Braly, co-proprietor of GAMI.

• **Insurance companies won't insure G100UL**. Untrue. Per George Braly: "Each of the major distributors has directly advised GAMI that they have obtained the same product liability insurance for their sale of G100UL avgas as they have for 100LL. Furthermore, Vitol Aviation was able to add G100UL avgas to its policy with no increase in premium."

• **An STC doesn't provide the legal liability protection of an ASTM spec**. Also, untrue. There's no difference. As we prepared this editorial, we worked with two attorneys. One, a retired aviation attorney, pointed out that a consensus spec such as ASTM does not provide any sort of defense to an aircraft accident lawsuit. As with compliance with an FAA regulation or approval, it is evidence that the jury can consider, but it doesn't give a defendant a special defense.

The other attorney did a standard computer search for any lawsuit, anywhere in the U.S. court system, involving aviation fuel in which an ASTM spec provided a defense. There was none. There was no case in which the D910 ASTM spec for 100LL was even mentioned.

That attorney did find a case in which ASTM was sued for failing to provide a spec. It alleged that direct competitors of the plaintiff fuel maker denied an ASTM spec to keep the plaintiff from being able to bring its product to market. The case was dismissed for procedural reasons so there was never a finding on the allegations.

• **G100UL isn't approved by aircraft and engine manufacturers**. That's true. What's more important is that only the FAA can approve a fuel for use on an engine or with an aircraft per federal law. Whether it is approved by Lycoming or Cirrus is irrelevant—if it's approved by STC, that's the end of the story. Manufacturers may not like STCs (we saw it with VGs), but they do not have the authority to second-guess the FAA when it tests, approves and issues one.

In addition, per George Braly, "Lycoming and Continental have each sent engineers to GAMI and have flown G100UL avgas and compared it back-to-back with 100LL and have each stated to GAMI that they cannot tell the difference in operation when compared to the use of 100LL."

In addition, Braly said, "each of the distributors have reviewed the G100UL avgas FAA-approved specification and told GAMI that they had no objection to that specification—and none of them have stated to GAMI that they have any reason to 'disapprove' of G100UL avgas."

• **NATA claims that the ASTM process is more rigorous than the FAA STC process because the STC process doesn't look at the supply chain**. Untrue; as pointed out above, the FAA-approved STC spec said that the G100UL spec provides the same or better protection for the integrity of the supply chain, than does the ASTM spec for 100LL.

Curt Castagna is the chair of NATA. When AOPA's Mark Baker left EAGLE, Castagna took Baker's co-chair seat. Castagna is the most vocal of the groups attacking the FAA's entire STC program, claiming that it is no good and that FBOs won't sell fuel without an ASTM spec and distributors won't deliver it.

When a private company has members of its management that are publicly maligning the company's basic policies and procedures and also working to thwart the accomplishment of its goals, those managers get fired. We can only wonder why Curt Castagna and NATA are still on the EAGLE board?

Currently, pilots and FBOs are demanding G100UL. NATA's actions appear to be stopping delivery to those willing buyers.

CONCLUSION

There is currently litigation in California requiring FBOs to sell no-lead avgas when it is commercially available. We can't help but think that the actions of NATA and GAMA to stop G100UL delivery to users that want it aren't going to play well in the lawsuit. We're going to be watching closely.

As we go to press, the California legislature has passed a bill to ban leaded avgas by 2031. It is expected to be signed by the governor.

G100UL has demonstrated its viability. As an aircraft owner, we're ready for the benefits of a high-octane, unleaded avgas—we want more BTUs per gallon, longer oil change intervals and TBOs and no longer having to deal with fouled plugs.

In our opinion, there's no excuse for any more delivery delay.