



Avgas Technical Briefing and Fuel Comparisons for Aviators

For the majority of us who are not organic chemists or fuels engineers, understanding the properties of aviation gasoline that are relevant for operational safety and utility is a bit foreign. With the help of a leading expert in aviation fuel, refining, and distribution, we offer the following information to provide laymen with a basic understanding of the issues.

Background & Concepts

1. Gasoline Blending

- a. Typical refinery has a dozen or more gasoline components, each component of different hydrocarbon composition:
 - i. Paraffins (hydrogen-saturated hydrocarbon)
 - ii. Olefins (hydrogen-unsaturated hydrocarbon)
 - iii. Aromatics (six carbon rings)
- b. Gasoline components octane-blend non-linearly. Example:
 - i. Component A = 95 motor octane
 - ii. Component B = 95 motor octane
 - iii. Component C = 95 motor octane
 - iv. Blend A+B = 97 motor octane (positive blending bonus)
 - v. Blend B+C = 93 motor octane (negative blending bonus)



F1/F2 Octane Test Engine

2. Different Kinds of Octane Ratings

- a. Several different kinds of octane standards exist;
 - i. Each type measured in a laboratory engine (a purpose built engine only for testing fuels, not an aircraft engine)
 - ii. Laboratory engines tailored for each octane standard
- b. Octane standards were developed to tailor lab measurement of non-linear blending to actual engine operating conditions.
- c. Automotive Octane Ratings
 - i. Research Octane Number, or RON (F1)
 - ii. Motor Octane Number, or MON (F2)
 - iii. In the US, pump octane is reported as $(RON + MON)/2$

iv. Problem somewhat simplified by modern automotive engines' ability to accommodate various octanes by knock detection and electronic engine control, not typical of aircraft engines at this time.

d. Aviation Octane Ratings

i. Lean Octane rating (F3)

1. Very similar to Motor Octane (F2)
2. The 80 in 80/87 and 100 in 100/130

ii. Rich Octane rating (F4)

1. Operating conditions based on very high supercharger boost of WWII fighters and 1950's piston engine airliners: 60 - 80" MAP
2. The 87 in 80/87 and 130 in 100/130

3. Aviation Octane Lab Engines & Unleaded Avgas

- a. For years it's been observed that F2 and F3 laboratory octane engines do not demonstrate the expected high octane from various unleaded fuel blends proposed for aviation engines.
- b. GAMI has done extensive aviation engine test stand work to correlate actual aviation performance with unleaded avgas properties, not just octane test engine ratings. Laboratory test engines appear to underreport the benefit of "heavy" aromatic fuel components, which include xylenes and trimethylbenzenes.

Avgas Specification Comparison

SPECIFICATION	100LL (ASTM D910)	GAMI G100UL	SWIFT 100SF	NOTES
F2/F2 Motor Octane (MON)	99.5	98.5	102.2	GAMI has demonstrated that G100UL measuring 98 test engine octane has greater knock resistance in actual aviation engines than minimum specification 100LL, even though it measures 99.5 on the lab engine. Discrepancy between test conditions and actual usage.
F4 Aviation Rich Octane	130	130	130	Measurement of detonation resistance at best power on the mixture response curve (about 0.11 fuel/air ratio).
Lead (maximum)	2 grams/gallon	0	0	Tetraethyllead (TEL) is a relatively low cost additive to boost detonation resistance. Resulting atmospheric lead emissions while relatively low, are politically unacceptable. General consensus is that TEL will be prohibited in avgas by 2017.

SPECIFICATION	100LL (ASTM D910)	GAMI G100UL	SWIFT 100SF	NOTES
Density (lbs/gallon)	5.85	6.25	6.67	Proposed unleaded fuels may require adjustment to current specifications: <ul style="list-style-type: none"> • Heavy aromatics are, not surprisingly, heavier. • Increase in density requires pilot attention to weight and balance. Higher fuel weights will slightly decrease full fuel payload, or slightly decrease range for same T/O weight.
Distillation – Boiling Points (BP)	Sets standard	Midway between 100LL and Swift 100SF	Heavier (higher BP)	Unleaded fuel candidates require distillation and end boiling point variances from existing specification. <ul style="list-style-type: none"> • Heavy aromatics that make unleaded avgas feasible are higher boiling point. • Significance: distillation specifications ensure full and homogenous vaporization of fuel. • Testing to date indicates broadened distillation spec is compatible with the existing fleet, but some operational modifications may be required, e.g. carb heat at idle on cold days.
Vapor Pressure min/max	5.5 / 7.0 psi	5.08 / 7.0 psi	5.5 / 7.0 psi	Tendency of more volatile fuel components to evaporate.
Freeze Point	< - 58°C	< - 58°C	< - 58°C	Nature of heavy aromatics may make a cold filtration test useful as microcrystals of aromatics can plug filters at very low temperatures. Preliminary work indicates some 100LL blends may have this issue as well.
Net heat of Combustion BTU / pound	18,702	Slightly Higher than 100LL	Slightly Higher than 100LL	Energy density. Amount of energy obtainable from a given fuel for power.
Copper Strip Corrosion	Sets Standard	Same	Same	Avgas must pass the copper strip test to assure metal parts in fuel systems will not be corroded.
Sulfur	Sets Standard	Same	Same	Significant because by products of sulfur combustion can cause corrosive wear of engine parts.
Oxidation Stability	Sets Standard	Same	Same	Historically, oxidation stability compliance has required avoidance of olefins and less stable aromatics.
Water Reaction Volume Change	Sets Standard	Same	Same	Need to avoid water-loving materials that can cause high altitude, low temperature water drop out.

SPECIFICATION	100LL (ASTM D910)	GAMI G100UL	SWIFT 100SF	NOTES
Electrical Conductivity	Sets Standard	Same	Same	Generation of static electricity can create hazards in handling avgas.
Refinery Compatibility	Sets Standard	Similar	Not yet known	Some avgas blenders already dedicate toluene (light aromatic) for avgas blending: <ul style="list-style-type: none"> • Could potentially proceed similarly with similar volumes of heavier aromatics for G100UL. • Swift 100SF logistics could be different: five times greater import volume, trace acetone issues, requires more logistics.
Distribution Infrastructure Compatibility	Sets Standard	Similar	Similar	Possible exception with Swift, depending on point of supply
Cost	\$4-6 / gallon	Est. < 10% higher than 100LL	Comparable to 100LL	Swift estimated at 2010 SNF that 100SF would be substantially higher than 100LL. As of July they believe it will be comparable.

The Clean 100-Octane Coalition is an informal alliance of General Aviation owner/pilot associations (type clubs) representing a majority of the piston-engine aircraft that will be affected by a transition from 100LL avgas to a yet undetermined unleaded aviation gasoline. The Coalition exists to educate aircraft owners & pilots, and to advocate for their interests with government agencies, aviation vendors and trade associations, who control or influence the avgas fuel approval process. Our goal is to encourage a regulatory climate that fosters innovation that will lead to a single aviation unleaded gasoline appropriate for all general aviation piston aircraft without operational limitations or hardware modification requirements, transparent and compatible with existing 100LL.

The Clean 100 Octane Coalition is growing, but presently consists of:		
Cirrus Owners and Pilots Assn	Malibu Mirage Owners & Pilots Assn	Beechcraft Pilot Proficiency Program
Cessna Pilots Assn	The American Navion Society	Mooney Aircraft Pilots Association
Cessna Advanced Aircraft Club	American Bonanza Society	The Twin Commanders Flight Group
Commander Owners Group	Piper Magazine	Bonanzas to Oshkosh
Twin Cessna Flyer	Cardinal Flyers	Twin Commanders Flight Group
Register your support at our website: http://100octaneformyplane.com or www.100octane.info .		