GAMI Teleconference Briefing Summary
8 March 2011

On 8 March, 2011, Mr. George Braly, of General Aviation Modifications, Inc, briefed representatives of the Clean 100 Octane Coalition regarding the progress GAMI is making in the development and certification of its candidate fully-performing replacement fuel for 100LL. The GAMI fuel is known as G100UL, or just plain G fuel.

In addition to Mr. Braly as the presenter, Clean 100 representatives on the call included:

Elliott Schiffman, Bonanzas to Oshkosh
Jonathan Sisk, Malibu/Mirage Owners and Pilots Association
Gordon Feingold, Cirrus Owners and Pilots Association
Lars Gleitsmann, Alaska Air Carriers Association
Bill Bailey, Commander Owners Group
Richard Page, Cessna Advanced Aircraft Club
Bob Thomason, The Twin Cessna Flyer
Paul Millner, Cardinal Flyers
Lee Buechler, Clean 100

Mr. Braly's comments addressed a description of the fuel and its performance; the current status for gaining approval and certification; and a few economic matters. During the course of the presentation Mr. Braly invited and answered questions. Available for download and viewing/listening are a question/answer set and the teleconference audio track.

Fuel Description and Performance

Mr. Braly discussed key performance characteristics of G fuel, in particular the distillation curve, detonation performance, lead memory and lubricity. He also reviewed the various G fuel "recipes".

Distillation Curve {See attached}

A fuel distillation curve reflects the temperatures at which portions of the fuel "boil off" to a gaseous state under normal pressures. The horizontal axis is percent of the fuel which has evaporated; the vertical axis is temperature. The higher the temperature, the less fuel remains in liquid form. Cooler temperatures at the left of the graph, higher temperatures at the far right of the graph, and temperatures between the extremes associate with engine cold starting, engine hot starting, and engine normal operating conditions, respectively.

Referencing a graph of distillation curves for 100LL, G fuel and a two-component fuel displayed during the meeting, Mr. Braly explained that G fuel very closely matches the distillation curve for 100LL. It appears as a graph just slightly higher than, and matching in shape, that for 100LL. This means that G fuel should behave similarly to 100LL for starting, normal engine operation and hot starts. The two-component fuel has a very steeply rising slope at the left of the graph, and is then flat over the typical engine normal operating range but at a much higher temperature than 100LL. It shows a similar evaporation percentage rise at the far right as do the other curves. The relatively higher temperatures to achieve a gaseous state in normal operating ranges indicates the possibility for more running difficulty during warm-up and normal operations, although cold and hot starting should not be a problem. The engine “operability” issues all end up being determined by aircraft testing during different atmospheric conditions. So far the G fuel has been tested at high altitudes (> 22000 feet) in both cold and hot weather and there is no discernable difference in the performance and “operability” when directly compared to 100LL in back to back testing with 100LL in the left tank and G fuel in the right tank of the turbo Cirrus.

Detonation Curve

Detonation occurs when excessive heat and pressure in the combustion chamber cause unburned portions of the air/fuel mixture (end gas) to auto-ignite. This produces an explosion (rather than a burning) of the remaining unburned mixture within the combustion chamber instead of a pair of normal flame fronts initiated from the two spark plugs. The explosive force produces a sudden rise in cylinder pressure. The hammer-like shock waves created by detonation subject engine components to anywhere from benign pressure increases to rather large pressure spikes. Mild or occasional detonation can occur in almost any engine and usually causes no harm. But prolonged or heavy detonation in conjunction with elevated cylinder head temperatures can be very damaging, often leading to pre-ignition and rapid engine destruction.

The FAA has specific fuel performance characteristics which protect against the onset of detonation – in the case of 100LL that protection is provided by TEL.

Using the next presentation slide, Mr. Braly demonstrated the detonation performance of a G fuel when compared with 100LL. The G fuel was close to the 100LL or slightly better in terms of detonation performance. The slide used was a scattergram of many {thousands} of combustion events for a turbocharged TCM IO 550 engine {8.5:1 compression ratio} with one set of data reflecting the use of 100LL, and the other reflecting the use of a G fuel. The scattergram plot horizontal axis is fuel flow; the vertical axis is an FAA calculated measure of detonation. The engine was operated at 35” manifold pressure and 2,400 RPM under varying fuel flows. Cylinder head temperatures were in the 440 deg F. range – that is, extremely hot. Trend lines are drawn through the scatter plots, and clearly show somewhat better detonation performance for G fuel.

When asked about detonation performance in very high powered and often supercharged engines, Mr. Braly explained that the lower compression ratios of these engines {6.5:1} present a less challenging detonation environment than engines of lesser power, but with greater {8.5:1} compression ratios. Furthermore, G fuel has a supercharge rating in the 150 range as compared with 100LL with a rating around 130. This should be of considerable comfort to those operating such engines, including warbirds. Some of the warbird aircraft may actually be able to recover some of the previously lost take-off {and full power operation} manifold pressure.

Fuel Composition

Mr. Braly then proceeded to explain there are several – perhaps many – fuel “recipes” by which one can make the G fuel and which will successfully operate high performance aircraft engines. So far, all of them are compatible with wetted engine and airframe materials in the aircraft, and potentially priced in the vicinity of 100LL.

This is an important concept because it means the industry should be creating a way to define a fuel or a range of fuels that “work” and then writing a specification around the “fuel that works”. Unfortunately, ASTM has been attempting to create a fuel that would fit within the existing specification (but without the lead) for many years without apparent success.

Mr. Braly’s supporting slide was a bar chart representing the composition of 8 different fuels – 3 versions of 100LL {very different recipes} currently being delivered by refiners to FBOs, 4 G100UL versions, and Swift Fuel. All of these fuels have been shown to successfully operate in high performance aircraft engines. Although there are no known issues revealed by testing conducted to this date, including aircraft “wetted” component compatibility testing and fuel component toxicity reviews, G fuel continues to undergo testing with respect to wetted components in the fleet. So far, in no case has there been any evidence of any harm to any of the wetted components.

When asked about the use of exotic, expensive components in the current G fuel, Mr. Braly answered there are none. All G fuel components are produced in sufficient volume {for other uses} to establish the reliability of likely pricing at reasonable levels. Mr. Braly emphasized that mesitylene {tri-methylbenzene, or TMB} is not a necessary component of G fuel, although it could be used in some part if it were ever produced in volume and competitive prices to other available and workable components.

When asked about the presence of toluene in G fuel as a toxicity concern, Mr. Braly answered that toluene is not part of the formulation and while it might be present in small portions, it would be incidental.

Lead Memory

Lead memory is the tendency of lead bromide deposits to remain fixed to cylinder components as a by-product of combustion using leaded fuels. There has been a belief within the FAA and small portions of the industry that these deposits remain, and will contaminate the performance of an unleaded fuel in engines which have operated using leaded fuels {100LL}. There are published studies by Cessna and British Petroleum that did not find any persistent lead memory effect. The FAA Tech Center did not find evidence of persistent lead memory effect. However, some in the FAA have continued to claim that lead memory effects are “real”.

Mr. Braly offered a slide naming six organizations/studies which claim there is no evidence for such an effect. Mr. Braly specifically discussed GAMI's experiment with cylinder walls in which cylinders operated with lead fuel were subsequently operated with unleaded fuel; and cylinders operated with lead fuel, and then scrubbed clean, were subsequently operated with unleaded fuel. There was no difference in performance for any of these cylinders – cleaned of lead bromide deposits, or otherwise.

Lubricity

"Lubricity" is the term used to describe any beneficial lubrication effects – in this case, of tetra ethyl lead in 100LL. It is suspected that non-hardened valve, valve stems, and valve seats on engines produced prior to 1930 require lead for lubrication. This is a particular concern for radial engines and extremely high performance engines, like those from Merlin. Mr. Braly offered a slide naming three studies demonstrating there is no requirement for such lubrication for engines which use hardened components. He made reference to a recent telephone conversation with Mr. Ray Anderson of Anderson Aeromotive, an overhaul facility for Pratt & Whitney and Curtis-Wright radial engines, who said that all of the engines for which Anderson provides services are outfitted with hardened parts, and been so ever since he can recall.

Approval and Certification Matters

Mr. Braly commented that GAMI plans to earn STCs for engine/airframe combinations for G fuels and to extend these awards to other engine/airframe combinations on the basis of similarity. He thinks the progress being made within FAA for STC approval has slowed considerably compared to where he expected it would be following last summer's meetings with FAA personnel. In particular, Mr. Braly commented that FAA's behavior seems to indicate it does not yet know what parameters need to be specified, and what values those parameters should take. Mr. Braly cited several examples, including "how good is 'good enough'" with respect to minimum octane. {At one point the FAA asserted the minimum octane should be changed to reflect the average delivered octane of recent 100LL fuels which would be as much as 102 to 103 MON, vs. 99.6 MON in the 100LL D910 specification. This remains unresolved and is a critical pacing item.} *Others have criticized GAMI for failing to settle upon a final formulation, yet it is FAA's uncertainty that is causing GAMI to continually reformulate as it chases the shifting requirements.*

Discussing the D910 specification for 100LL, Mr. Braly noted that the specification is a purchasing document intended to define "what to buy", based upon performance characteristics. It is not a specification that defines a single recipe for achieving the desired performance characteristics. As a result, and noted earlier, 100LL batches will vary significantly one to another, chiefly based upon the economics of available components – but all batches will produce the required performance.

A listener commented that the D910 specification was written as experience was gained with the 100LL fuel in service.

GAMI hopes to gain ASTM approval for G fuel at some point, but does not believe the speed at which ASTM moves will enable timely approval for a replacement for 100LL.

In his view, the ARC committee is trying to find a solution for a problem for which at least one workable solution is already available. The ARC process runs a serious risk of perpetuating the problem that Michael Kraft warned against last summer. Kraft said at Oshkosh in August 2010 that "… we need to quit loving the problem and just fix it."

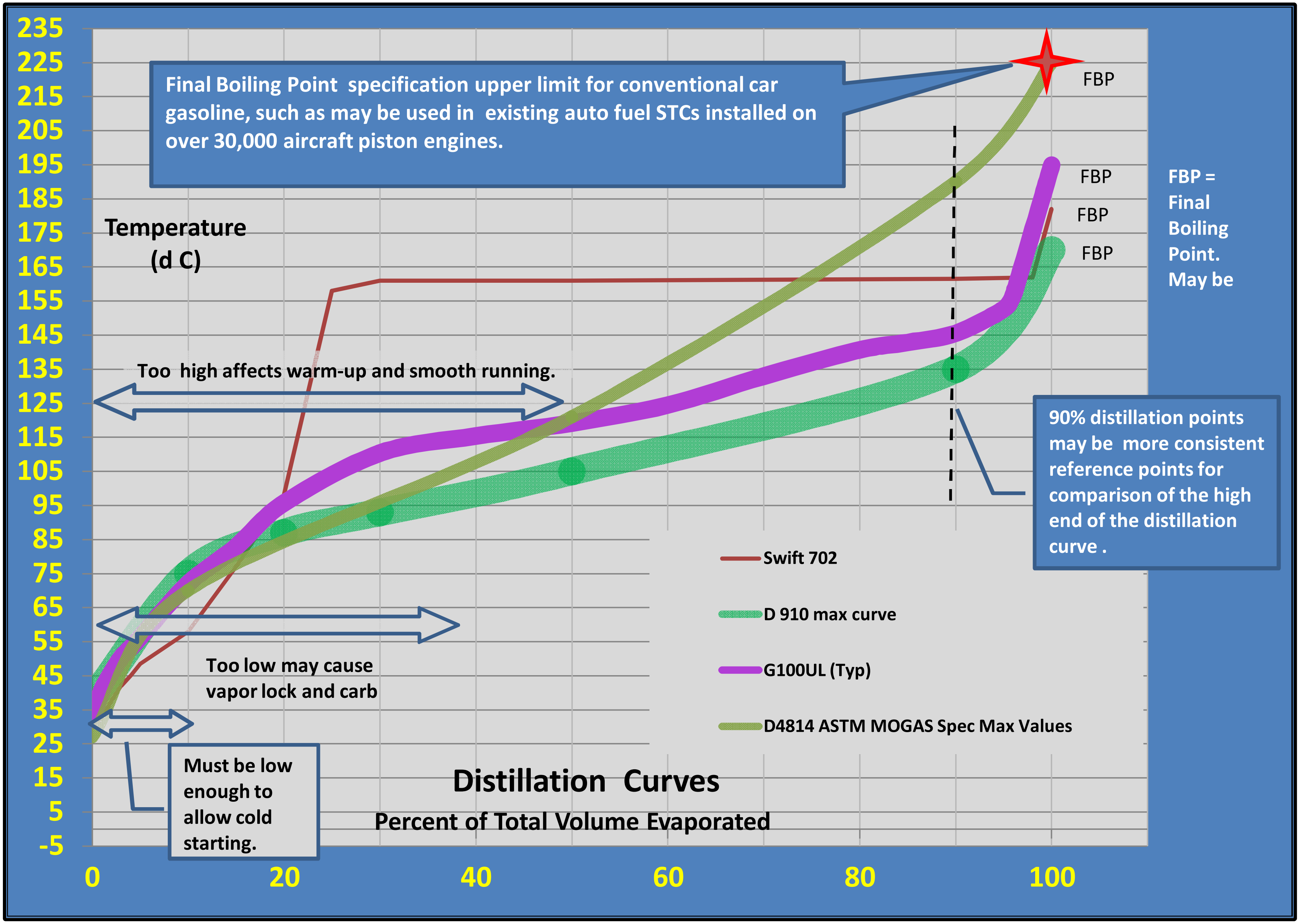
Economic Considerations

Given that the components for G fuel are all "within the confines of any refinery", Mr. Braly believes that G fuel pricing at the pump will be approximately 50 cents greater than whatever the current price for 100LL would be {or would have been} at the time. That is, it is largely governed by the prices obtained for other petroleum-based fuels.

GAMI does not intend to manufacture, or distribute, anything. Theirs' is a licensing business model where they plan to license others to manufacture and to distribute G fuel. There was no discussion of companies which might do either for G fuel.

How Can The Clean 100 Coalition Assist?

Mr. Braly commented that, whenever the opportunity arises, continuing to ask "Why not G Fuel" to FAA and others central to the approval and certification process would be most helpful.


Final Boiling Point specification upper limit for conventional car gasoline, such as may be used in existing auto fuel STCs installed on over 30,000 aircraft piston engines.
FBP
FBP
FBP
FBP
FBP = Final Boiling Point. May be
Temperature (d C)
Too high affects warm-up and smooth running.
90% distillation points may be more consistent reference points for comparison of the high end of the distillation curve .
Swift 702
D 910 max curve
G100UL (Typ)
D4814 ASTM MOGAS Spec Max Values
Too low may cause vapor lock and carb
Must be low enough to allow cold starting.
Distillation Curves
Percent of Total Volume Evaporated
235
225
215
205
195
185
175
165
155
145
135
125
115
105
95
85
75
65
55
45
35
25
15
5
-5
0
20
40
60
80
100