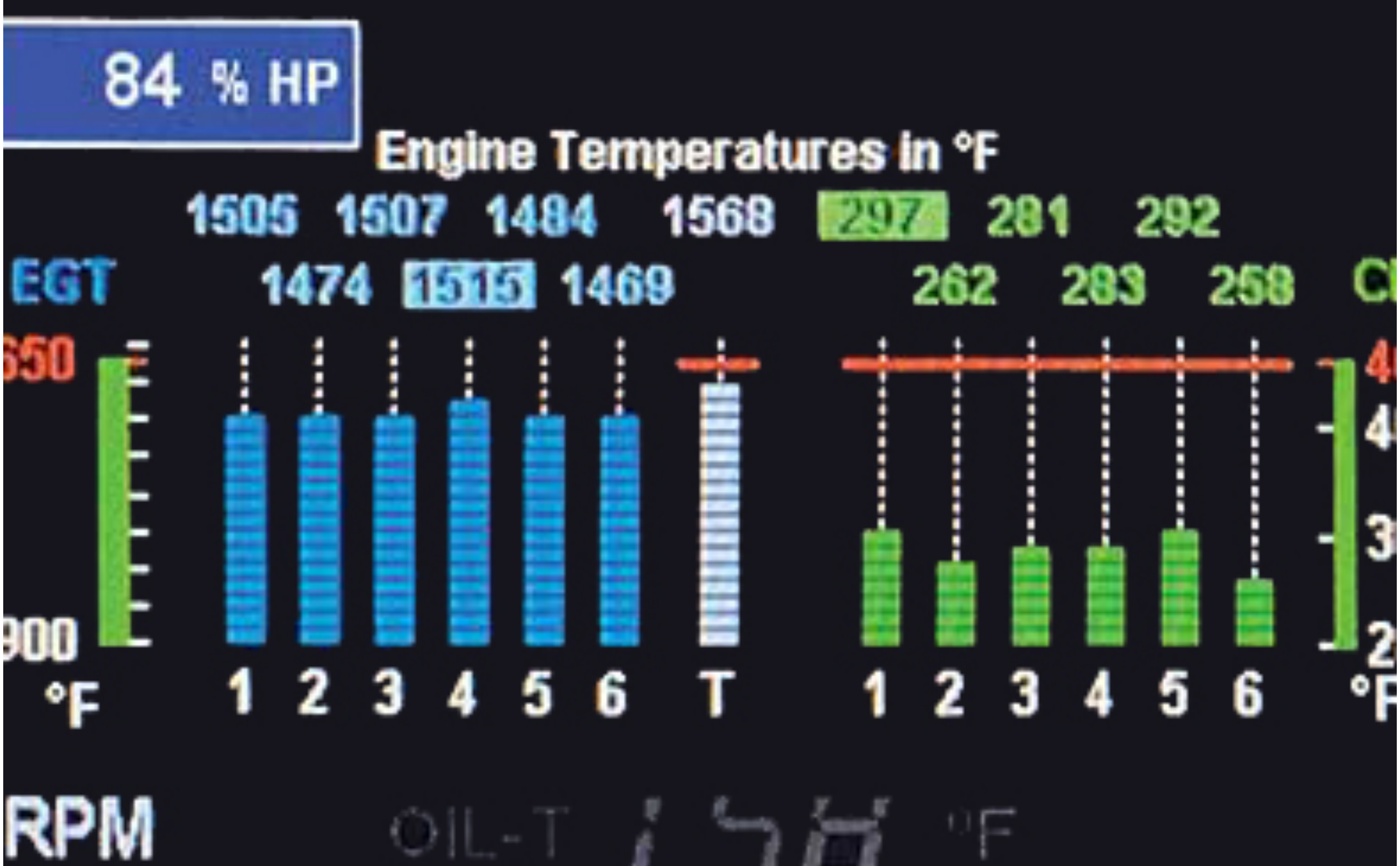
Flying the Red Knob:

Finding My Way Through the Lean-of-Peak Wilderness



Flying the Red Knob: Finding My Way Through the "Lean of Peak" Wilderness

By Mike Jones

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This article has taken two years to ripen. Even elephants and whales don't have a gestation like this missive.

It started at AirVenture 2024, when an eighty-minute taxi over rough grass on a steamy Thursday morning fritzed the perfectly good Continental TSIO-520 in my Cessna Centurion. Early in 2025 a brand-new engine was glued to the nose of my plane along with a new panel, featuring a state-of-the-art JPI digital engine monitor.

A modern engine monitor is the technology that enables lean-of-peak operations, a procedure with which I have long wanted to experiment. But researching the proper procedure is only slightly less difficult than climbing Mount Everest in tennis shoes. Not because data is rare, but because it is so abundant. And contradictory. And incomplete. And out of date.

I am not exaggerating. There are hundreds of articles, substacks, videos, posts, and diatribes about lean-of-peak operations, including many discussions of the danger of the "Red Box" where temperatures and pressures can quickly turn a snappy new engine into an asthmatic hunk of steel. Who is right?

I'm a big fan of my Pilots Operating Handbook, so I turned to it for the definitive answer. On page 4-24 it mildly suggests, "Operation on the lean side of peak is not approved." Wow. That argument is settled.

Until I spoke with Paul New, the airplane whisperer at Tennessee Aircraft Services and occasional contributor to this newspaper.

SECTION 4
NORMAL PROCEDURES

CESSNA
MODEL T210N

lean to establish the peak EGT as a reference point and then enrichen by an increment based on data in figure 4-4.

Continuous operation at peak EGT is authorized only at 70% power or less. This best economy mixture setting results in approximately 5% greater range than shown in this handbook accompanied by approximately 4 knots decrease in speed.

NOTE

Operation on the lean side of peak EGT is not approved

When leaning the mixture, if a distinct peak is not obtained, use the corresponding maximum EGT as a reference point for enrichening the mixture to the desired cruise setting. Any change in altitude or power will require a recheck of the EGT indication.

Detailed information on use of the engine combustion analyzer is presented in Section 9, Supplements.

New calmly reported lean-of-peak flying is simple to do, highly cost-effective, prevents plug-fouling, and is easier on the engine. Grouchy Mike Busch not only adamantly recommends lean-of-peak operations; he literally scoffs at pilots who run rich-of-peak. Other experts voiced similar opinions, including Paul Ferraris who flies a Mooney, Jason Schappert of MzeroA online flight school, Martin Pauly in his Bonanza, and the lean-and-hungry Craig Peyton in another Mooney, all of whom run lean-of-peak without hesitation. Perhaps the one person with the most concrete "how-to" advice was John-Paul Townsend, Tech Support manager at General Aviation Modifications, Inc.

(GAMI). There's a lot on information (and mis-information!) to digest when exploring lean-of-peak operations.

New Tricks for an Old Dog

I related to New the procedures I used: take off at full power. Above 500 feet AGL I pull the power back to the top of the green arc and climb at about a thousand feet per minute. In cruise I lean to 125˚F rich-of-peak. Pretty snappy flying? New was unimpressed.

"Forget all that 'top of the green', 'bottom of the green' crap," he said. "All that stuff goes out the window. Those are only normal, rich-of-peak cruise recommendations from Continental. They're not limitations. That's a myth. That's just a bunch of hooey. So just toss all that garbage out where it belongs."

Paul New, of Tennessee Aviation Services

New explained that the danger zone for detonation is rich-of-peak, which is exactly where I've been flying my airplane for the last twenty years.

"You know where the POH tells you to lean to 50˚-75˚F rich-of-peak?" he asked. "That is exactly the place where you should be most worried about detonation. In fact, your engine probably was running with very light detonation all the time."

Let's be clear here: leaning is useful, even essential. A cool engine is a happy engine. Optimal combustion produces a "longer, slower, and more gentle push on the piston" according to

Paul Ferraris, which reduces stresses on the hundreds of components in the engine. Yes, we need full throttle and full rich to generate take-off power, but the engine isn't working very efficiently. Unburned fuel keeps the engine cool and prevents detonation, but that wasted fuel is expensive. An engine is most efficient just slightly rich of peak EGT (where I have been flying for twenty years). But that's far from optimal because of the wear inflicted on the engine by the harsh conditions.

A much leaner fuel/air mixture burns more efficiently, allowing the engine to produce more power on less fuel. More efficient combustion produces that "more gentle push" which minimizes vibration and engine wear. Sounds good to me.

Most pilots use EGTs to manage their leaning processes because EGTs change quickly (5-15 seconds) while cylinder head temps take minutes to settle down.

"As you lean the mixture, EGTs, CHTs, internal cylinder pressures (ICPs), and TIT all rise. Unchecked, they could get dangerously high and shorten the life of the engine," Townsend, the GAMI expert, explained patiently. "Many engines run rough [lean-of-peak]. So pilots richen the mixture, which puts the temperatures where you don't want them to be, back in the Red Box. [Pilots] come away thinking LOP is bad for engines," when in truth, pilots should expect a smoother, cooler, healthier engine when running a properly configured engine lean-of-peak.

The key phrase, dear reader, is "properly configured."

The GAMI Innovation

It's important to listen to the experts at GAMI. In 1994 two farsighted chaps named George Braly and Tim Roehl founded GAMI to produce custom fuel injectors. They developed a piston engine test facility that is "equipped with the most precise pressure and flow measurement equipment found anywhere in the aviation industry." Then they accumulated a rich dataset about the induction systems for the innumerable makes and models of aircraft engines we all fly today. GAMI is uniquely qualified to devise new products and processes to help pilots operate more safely and efficiently.

GAMI also has great customer service. I dialed their number and was promptly routed to Townsend, their expert on fuel injectors. Townsend was hired while still in high school to create the schematics for GAMI's initial fuel injector STC filings with the FAA. After a stint in the Marines and graduating from college with a degree in physics, he returned to GAMI and has worked for almost 30 years in engineering, R&D, manufacturing, and sales support roles.

Soft-spoken John-Paul Townsend is one of the few true gurus of lean-of-peak operations, having helped pilots balance their fuel-flow with GAMI fuel injectors for the better part of thirty years.

In contrast, I spoke with the experts from Continental at Oshkosh. They advised that my brand-new, fuel-injected, turbocharged, $70,000 engine would run lean-of-peak just fine with the standard fuel injectors they deliver. Everyone in the room gasped.

Townsend politely but strongly disagreed with Continental's guidance. "Most of Continental's fuel injectors are not 'tuned' such that the cylinders reach peak EGT at the same fuel flow," he explained. GAMI injectors "tune" the induction system by using orifices of different sizes on each injector; one size does NOT fit all. Each GAMI injector is tailored specifically for the specific cylinder on each specific engine. They are shipped with heat-proof labels to ensure they are installed in the proper home.

“The goal is to get the total fuel spread down,” Townsend coached me. “It doesn’t matter whether we make the leanest ones richer or the richer ones leaner. The goal is to get all their EGTs to peak at close to the same fuel flow.”

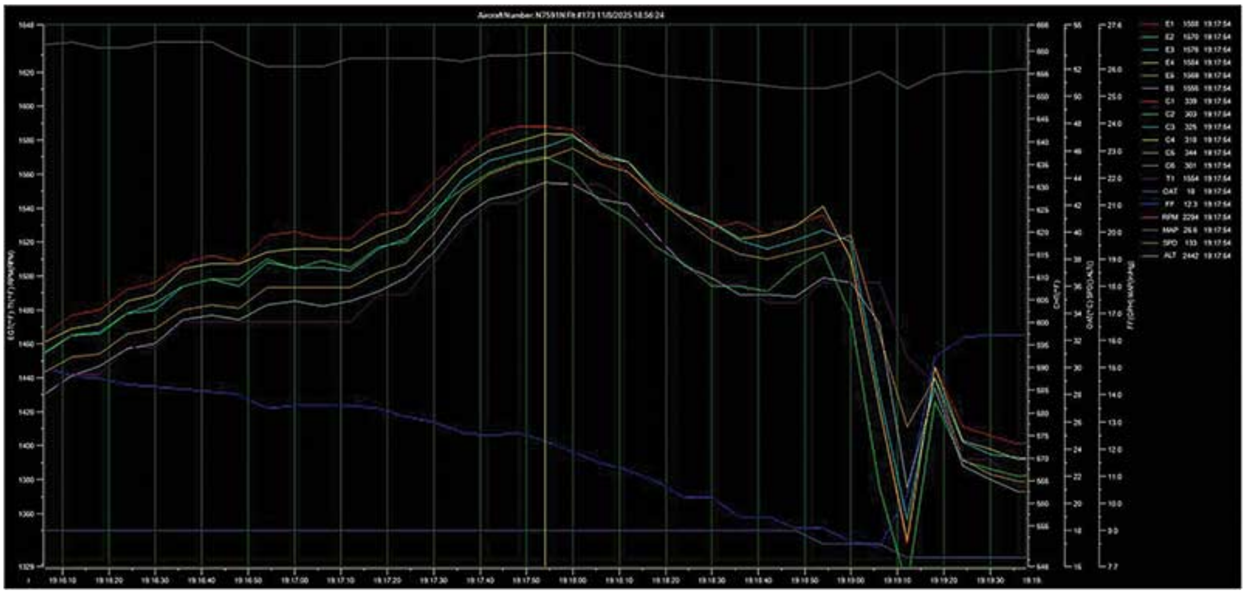
“You can’t see the difference in the nozzles,” Townsend told me when I asked about the physical hardware. “The difference is measured in tens of thousandths of an inch. Maybe 2/10,000 will be the difference between two nozzles. It’ll be so small you’d have difficulty even measuring it mechanically.”

While we’re on the subject, Townsend feels that lean-of-peak operations for non-turbo aircraft are quite feasible. Normally-aspirated engines “run just fine lean-of-peak, assuming they have balanced GAMI injectors,” he said with a smile. There are exceptions — some low-compression IO-470 engines struggle to run smoothly lean-of-peak — but he states even carbureted engines can play this game. On the other hand, New is a bit more cautions. He feels the lean-of-peak operations are much trickier with non-turbocharged airplanes. To prevent a reader from an expensive mistake, let me be explicit: the procedures I tested are for turbocharged airplanes. Your mileage may vary.

New Injectors

The first step was to benchmark my engine’s performance with a rite-of-passage called a GAMI-lean test. The object is to set a benchmark for the fuel-flow in each cylinder as the engine is leaned. Ideally, each should peak at about the same fuel flow. My JPI EDM-930 collects new data every second. After uploading it to the Savvy Aviation web site, I clearly could see the action under the cowling.

It turns out, a precise GAMI-lean test takes a bit of practice. Also, the temperature sensors have a bit of latency, especially for cylinder head temperatures, so my first attempts were a little vague because of my worries about transiting the "Red Box." But despite my fumbles I was able to determine the fuel flow spread was about 1.5 gallons per hour.



A typical GAMI lean test, as displayed on the GAMI software. This is the actual data from the second GAMI test. The chart was produced using JPI's "Easy Trends" software. Townsend likes the software because he can match the peak EGTs to the manifold pressure, RPM, fuel flow, airspeed, and altitude all on the one graph. "It can be overwhelming unless you're used to it," he said. "You have to know what you're looking for with the different colors."

This is a fairly large spread. It means some cylinders are substantially hotter (or cooler) than the others because the injectors are providing the wrong quantity of fuel. As proof, when the engine was leaned way, way out — to under nine gallons an hour — the engine ran rough, just as both Townsend and New had predicted. I enrichened the mixture and she slid back to the normal rumble. Whew.

My maintenance team installed the new GAMI injectors, which had a price of just over $1,000. About the size of your pinky finger, all shiny and brass, they don't look like much value for the money. But GAMI had calibrated these injectors specifically for my engine.

I flew the GAMI test again. I started outside the Red Box at 65% power, manifold pressure at 26 inches, a fuel flow of 14.9 gallons/hour, and 2300 RPM.

As I leaned further, to 13.1 gallons/hour, the EGTs seemed very hot. Worried about the Red Box I enrichened the mixture and sent the file to GAMI.

Townsend reviewed my temperatures using a JPI software tool called "Easy Trends" which can be downloaded to any Windows-based PC. A gentle soul, Townsend chuckled at my tentative efforts.

"OK, so you didn't quite get to peak but you were real close," Townsend agreed. "As delivered, you probably had a 1.3 gallon-per-hour spread. Now [after the first set of injectors] it's 0.6 gph, so it's been cut in half. But we really want to be 0.5 gph or less. So cylinder #2 needs to be richer and maybe cylinder #5 needs to be a little leaner."

Townsend instructed his tech support team to send me two new injectors. I thanked Townsend profusely for the goodies — I thought he was doing something special for a celebrity — but I was humbled to learn this is the normal procedure for GAMI. They will keep sending new injectors until all the EGTs peak simultaneously, which is defined as a fuel-flow spread under 0.5 gallons/hour.

The GAMI fuel injectors are vitally important to the health of the engine in lean-of-peak operations, but they are very small and unpretentious in their appearance. Each injector is tailor-made for each specific cylinder and engine, and allows flyers to get the variation in fuel flow to be under 0.5 gallons/hour across all the cylinders in the engine.

The new injectors took about two weeks to arrive and about two hours for my mechanics to install. They did the trick, and Townsend was pleased to report my spread was now about 0.4 gallons/hour. Suitably armored, I was ready to try lean-of-peak operations. The next question was, How?

Finding "Lean-Find"

My JPI manual had explicit instructions on lean-of-peak operations. This is an eight-step process which involves a lot of button-pushing, knob-twisting, and studying the digital display as the magic unfolds. State of the art, truly.

Brandon Smith of Pinehurst Aviation Services installed the fuel injectors on the Centurion.

I was very skeptical. First, while all those buttons are being pushed the engine is deep inside the Red Box, which is abusive to my $70,000 baby. After all, detonation can destroy an engine in minutes. But here's JPI telling me to s-l-o-w-l-y crank that old red knob while producing the very hottest temperatures that engine can produce? This seemed like a bad idea.

I asked New about the "lean-find" procedure. "That lean-find stuff, it's a waste of time," New said bluntly. "If you're twisting the mixture, through the dead center of the Red Box, you're going too slow." He suggested that when transitioning from rich to lean spend as little time as possible in the Red Box. "Just grab that red knob and pull it back to a fuel flow of say twelve gallons an hour," he coached me "That's going to be very lean but you won't hurt anything. That's all there is to it."

Wow. New is a very good teacher, and once the paramedics got my heart started again he explained what I would see.

"Say you're going to start at 30 inches and 2300 RPM. You're going to quickly pull the mixture back to twelve gallons an hour. Every time. You'll feel the airplane slow. Check your TIT and EGTs to be sure you don't have any anomalies [a bad spark plug or a plugged fuel injector]. Then enrichen to get the TIT to the temp you want."

In short, and in contradiction to almost all the videos and substacks out there, pilots should manage lean-of-peak operations using the turbine inlet temperature, not EGTs. Both New and Townsend agreed that EGTs are not helpful when flying lean-of-peak. "The turbo inlet temperature (TIT) are real numbers to watch," New explained. "The turbo spins at tens of thousands of RPM. The higher the TIT, the faster it is spinning, so TIT is the temperature to use to make sure that we don't over-temp."

The punch line to all this is that if you're flying the red knob you're going to run your engine in a very different way. New told me about a customer with a Centurion who always flies his airplane at near wide-open throttle, 35 inches of manifold pressure, 2300-2400 RPM, always lean-of-peak.

"He doesn't cook the valves and burn things up," New explained. "When you're on the lean side of peak, that red mixture knob becomes your power lever. As long as the engine is running smoothly, you can pull that power lever [the mixture] back as far as you want." He added that on his personal (non-turbocharged) airplane he sometimes leans the engine so far it simply stops.

But I wasn't out of the woods, because at new lean-of-peak I had lost about twelve knots of airspeed. While I want to be efficient, I bought a Centurion to go fast. What could I do?

Both New and Townsend agreed: either start at a higher manifold pressure or push it up once you've leaned the engine.

"At 30 inches of manifold pressure and 12 gallons/hour, you're at 50-something percent power," New estimated. "You started at a very low power setting, at the top of the green arc. Remember what I said about the green arc? Just push the throttle in and increase the power. As long as you're lean-of-peak you're not going to hurt anything. You're approaching peak EGT from the lean side, which is the safe side." He alternatively suggested that I could push the throttle up to 32 inches of MP, then lean, then 34 inches and lean, and even 36 inches and lean, finding those fuel flows from the lean side of peak. "That will get you those six or seven knots."

Townsend disagreed, slightly. "It's a bunch of unnecessary steps," he wrote in an email. "If you know you are going to end up at 16 gph, just set those MAP and RPM settings initially, and lean quickly to 16 gph."

The Big Pull

On Sunday, Nov. 30th, I took their collective advice. I rolled old N7591N out of the hangar, thoroughly preflighted, and launched into a cold, grey, Thanksgiving sky. At 2,500 feet I was flying with my normal settings: 75% power at 30 inches of manifold pressure and 2,300 RPM. As usual, the CHTs were around 360˚F and the turbo was at 1450˚F, producing 140 knots indicated. Everything exactly as it has been for the past two decades.

Then I made my move. Following the guidance from New and Townsend, I boosted my manifold pressure to 34 inches — way over that green arc! — and gave that big red knob one heck of a pull. Instantly the plane slowed. I adjusted the fuel-flow to 13 gallons/hour. When things calmed down, I was at 85% power, 34 inches MP, 2300 rpm. My CHTs were all in the high 200s, far cooler than I had ever seen before. The EGTs were lined up like little soldiers at exactly 1500˚F. Most importantly, the turbo was quite happy at 1570˚F, nowhere near red-line. The engine ran very smoothly and strong.

A tale of two engines. Above, flying rich-of-peak. Notice the fuel flow is 18.7 gallons/hour, and the hottest cylinder (#1) is at 359˚F. Below, flying lean-of-peak. The fuel flow is now 13.0 gallons/hour (saving $35 a hour, easy) and the hottest cylinder is still Number 1, but its now at 297˚F. A cool engine is a happy engine.

And the outcome? 140 knots. Exactly my previous airspeed, but burning only thirteen gallons/hour. I was getting exactly the same speed while saving five gallons of fuel every hour. That 28% greater efficiency. Or, to put it in more actionable terms: my range went from 840 nautical miles to 1,200 miles, far more than my bladder will permit.

Here's the discouraging part. I've owned this plane for 25 years. I put 400 hours on the old engine (when I bought the plane), 1,800 hours on the second engine, and now have 120 hours on this new engine. For each of those 2,320 hours I was burning five gallons more than I needed. That's $73,000 of wasted gasoline and money. Now I just feel stupid.

Who's The Expert?

I asked New how it could be that JPI, Continental, and others could be giving the world such "bad" advice, but he was sanguine about the situation.

"Well, those folks at the engine monitor places, most of those people are not pilots," he said. "They can tell you all about their monitors and their software but they don't know this stuff. They know a lot about monitoring an engine, but they don't know anything about running an engine."

He went on to report that JPI and Electronics International both produced owner handbooks that described using their instruments to achieve lean-of-peak operations. "It was, it is, so horribly wrong," he said. "It's just unbelievable."

But I was unconvinced. Who could know more about an engine than the company that made the device to monitor the engine? Surely they knew every nook and cranny of those sturdy machines. I called JPI, serial number in hand, and quickly got a very cordial tech support tech on the phone. I told them I wanted to fly lean-of-peak. Their answer?

Call John-Paul Townsend at GAMI.

"He knows it all."

About the Author

Dr. Mike Jones is based in Pinehurst, NC and consults with small airports to improve their performance and sustainability. He's got 4,000 hours in his logbook and usually flies his 1979 Cessna Centurion. You always can reach him at PilotMike2012@gmail.com.