Experimental Aircraft Association Chapter 162. Serving middle Tennessee since 1966. http://www.eaa162.org

Left Seat: Time Flies

It is hard to believe that two years of monthly meetings, special events, Young Eagles, and newsletters have now been completed and my presidency of the chapter is drawing to a close. It has been a great privilege to work with and learn from such talented and experienced pilots, aircraft builders and folks who just like airplanes and flying. It has also been heartwarming to see chapter members pitch in and do whatever was needed to get a hangar or meeting room turned into a buffet dinner and classroom. I have also realized why the gray eagles who are the foundation of most EAA chapters are the 'old guard' often thought of as the public face of the organization. The relentless pressures of 70 hour workweeks and the 24/7/365 connectedness of modern business environments makes it very tough to give collegial activities like EAA the time they really deserve. But any flying and any talking about and learning about flying is better than none, so onward we go!

This month's program will be on one of the scariest parts of being a pilot: getting and keeping your medical certificate. I've had a few adventures in this area, and will use them to illustrate the FAA Special Issuance pathway to keeping a medical certificate when one has a health condition that would otherwise be disqualifying. This program will be on October 20th at John Tune airport; if it's still warm we'll meet in Shelby's hangar (444) and if the weather doesn't cooperate we'll meet in the conference room of the terminal building. As always, light dinner at 6:30 pm and program at 7:00 pm.

The following month we will have a presentation on "Island Flying to Serve Those in Need." by Bahamas Habitat, a nonprofit organization that encourages pilots and helps with information on how to fly over-water to contribute to disaster response and sub-standard housing repair in the Bahamas and Caribbean. Twice a year they sponsor a Fly-In and Help Out event, a 4-day weekend to Eleuthera, Bahamas carrying donations to BMH and participating in building projects in progress. Come and see what it's all about!

As of this writing, Shelby Smith was still looking for a good venue for our annual holiday party. If you have any ideas, contact Shelby at rvaitor@comcast.net.

This issue of the newsletter is a few pages longer than usual to provide space for Peter Cassidy's fine article describing the proper way to lean your engine for either Lean of Peak or Rich of Peak operation. Thank you, Peter!

Fall is a fine time to fly. Hope you get the chance to see some autumn colors from the air. Stay safe and have fun!

Dan Masys

On the Horizon: Calendar of Events

EAA Chapter 162 meets on Wednesday evenings--generally the third Wednesday--of each month.

Date	Topic	Location
October 20	"How FAA Medical Certification Works"	JWN
November 17	Island Flying to Serve Those in Need	JWN
December, exact date TBD	EAA 162 holiday party	TBD

For more details see www.eaa162.org.

Safe Efficient Engine Operation

We want to operate our aircraft engine safely to ensure it gives us long, reliable service. Cylinder replacements are expensive so we'd like to avoid them as much as possible. We also want to operate efficiently. Fuel is expensive and on long cross country flights requires good fuel management. How should we operate our engines to best satisfy these goals?

We have two and often three controls to work with to manage engine operation; throttle, prop, and mixture. These controls provide us with a lot of variables. A multi-point digital engine monitor can make managing these controls much easier. Over the past 10 years or so digital engine monitors have become affordable and a "must have" instrument. They are standard equipment on most new aircraft. They do require us to spend a little time understanding what this instrument is telling us and how to use it effectively.

Picking a setting for throttle (manifold pressure) and prop (RPM) are fairly straight forward. The difficult one is setting the mixture (fuel flow). Setting the mixture wrong can cause real problems. At one extreme we can cause detonation which will destroy an engine. The other extreme is needlessly wasting fuel and settling for a short range on cross country flights. Fortunately it's not that difficult to manipulate these controls accurately and effectively.

We Generally Have Two Options

The aircraft pilot operating handbook (POH) is the first place to start looking for procedures for managing engine operation. At a minimum it will contain operating limitations and restrictions. Information for normal operation often leaves something to be desired. They usually present us with a simplified list of settings that are safe but overly conservative. They don't contain detail we need to understand what's going on in our engine and how to fine tune those settings.

There are two ways to operate your engine, Rich of Peak (ROP) and Lean of Peak (LOP). In ROP, the combustion process has an excess of fuel. In LOP, the combustion process has an excess of air. All engines can operate ROP. Many can also operate LOP. ROP produces more power but the engine runs hotter and leaves considerable deposits behind from the combustion process. Most pilots operate their engines ROP because that's the way they were taught. Yet I wonder how many are using the correct settings. LOP is a much cleaner combustion process, the cylinders run cooler, but the power produced may be a bit less. LOP is the preferred way to operate provided your engine is set up properly, you have a digital, multi-point engine monitor, and you understand the operating procedure. Not all engines can run LOP because their fuel flow is not sufficiently balanced. LOP is not new. Its principles were developed in the 1940s and the airlines used it extensively when they flew the big radial engines. LOP operation is coming back into use primarily due to the availability of affordable, multi-point, digital engine monitors. Most POHs don't mention operating LOP. Some even forbid it. That doesn't mean they can't run LOP. The POH for my Bonanza covers LOP operation and I've been operating it that way very successfully for over 10 years and 1200 hours.

Internal combustion engines are most efficient at about 25F LOP and they produce best power at about 80F ROP. The basic rule is, starting at 60% HP, the higher the power, the further away from peak EGT one needs to operate to prevent detonation and damage to the engine. This applies to operating both ROP and LOP. For example, I can operate my Bonanza at 65% HP either ROP or LOP. When running ROP, I'll be burning 15.0

GPH. Running LOP I'll be burning only 13.0 GPH, 2.0 GPH less. I'm producing the same HP so my true airspeed (TAS) will be the same. It's pretty obvious that LOP is more efficient. In case you are wondering, at 60% HP and below we can operate at any mixture setting without fear of damaging the engine.

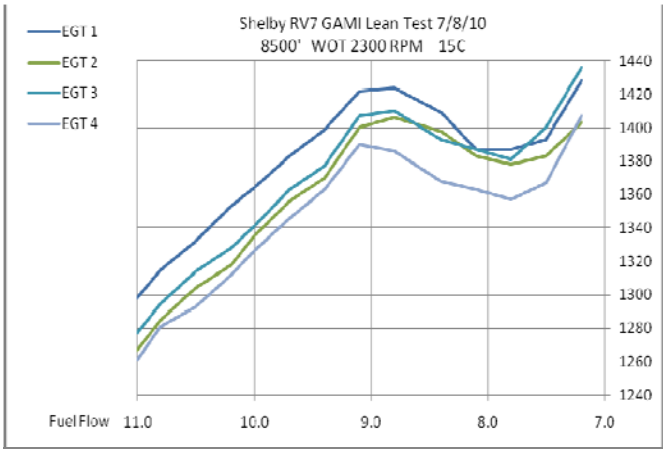
Can I operate my engine LOP? Is it an option, and, if so, what is required? This is the question Shelby Smith was asking about his experimental RV-7. Shelby's RV-7 has a 180 HP, fuel injected, Superior XP-360 engine. It's basically a Lycoming IO360 remade by Superior to their specs resulting in, presumably, improved performance. Shelby's RV-7 is well equipped including a JPI 700 engine monitor which measures and records EGT and CHT for each cylinder as well as total fuel flow. The manual for this engine gives settings for running LOP as well as ROP so operating LOP should not be a problem. Here's how we verified that LOP operation was practical for Shelby's engine and developed a procedure for Shelby to use to do so.

First We Need To Do A Flight Test

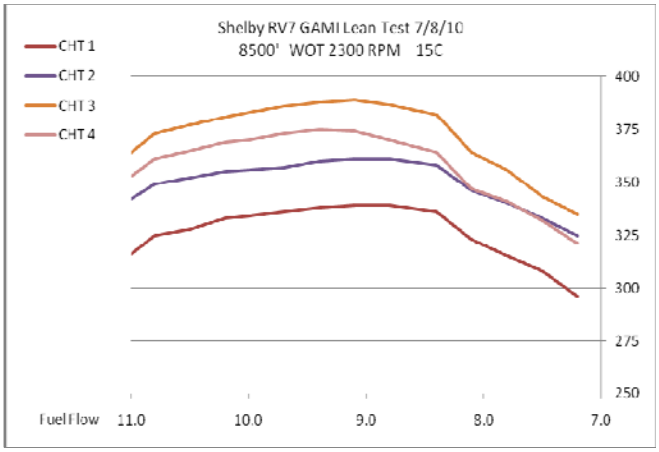
The first step is to do a GAMI Lean Test. The purpose of this test is to determine how balanced the fuel flow is between cylinders. GAMI www.gami.com is the company that has done extensive research over the past 20 years to better understand what it takes to operate engines efficiently. They also developed special fuel injectors to improve fuel flow balance enabling LPO operation for many engines that could not do so otherwise. GAMI also runs a program called Advanced Pilot Seminars (APS) www.advancedpilot.com designed to educate owners in engine operating techniques, especially LOP operation. By taking the APS course you can learn a tremendous amount about engine operation including the theory behind this discussion. It's available either live or online and a worthwhile investment for any pilot.

All engines can operate ROP, but not all engines can operate LOP. Fuel injected engines have the best prospect of operating LOP because the fuel and air intake is better controlled. It's possible to operate some carbureted engines LOP by adding a bit of carburetor heat. The GAMI Lean Test gives us a plot of EGT vs. fuel flow so we can see where each cylinder peaks and, more importantly, how they peak relative to each other. To operate LOP, we need all cylinders to peak within 0.5 GPH of each other otherwise the engine will run unacceptably rough LOP.

The test is easy to do. You take the airplane up to about 8500', set the throttle wide open, set the RPM to where you normally cruise, and vary the mixture from rich to lean in small (0.2-0.3 GPH) increments recording the resulting EGTs and CHT. Cowl flaps, if equipped, should be open to keep the CHTs from exceeding 400F. This is a two person job and an autopilot helps to keep the plane flying steady. Allow a minute or so at each setting for temperatures to stabilize. Back home, we plot the data using a spreadsheet program like Microsoft Excel. Below is the graph we got for Shelby's RV-7. We flew at 8500', 2300 RPM. We picked 2300 RPM because that's the setting Shelby generally uses in cruise. We kept leaning until the engine ran rough which was at 7.2 GPH.



As expected, this is a good engine to operate LOP. From the EGT graphs we see that cylinder 4 peaks first at 9.0 GPH, cylinders 1 and 3 peak next at 8.9 GPH, and finally cylinder 4 peaks at 8.8 GPH. As a result we say the GAMI lean spread is 9.0-8.8 = 0.2 GPH. This is very good. The spread of the TCM IO550 in my Bonanza is 0.5 GPH and it runs fine LOP.



In addition, Shelby's CHTs are all comfortably below 400F.

There is, however, something unusual with the EGT plots in the way they increase again after falling at the peak. The experts on LOP operation at Advanced Pilot Seminars tell us the increase is normal and is due to the exhaust valve beginning to open before combustion ceases. It does not usually appear until 100 to 150F LOP. They wonder if this engine has a custom cam. This is not a problem but might limit our range of LOP operation.

Operating LOP

Knowing we can operate LOP is good, but we still need to know how to set the engine controls: throttle, prop, and mixture. The settings we use depend on the horse power (HP) the engine is producing. When running LOP the formula for power output is different than ROP. For this engine, which has a compression ratio of 8.5:1, the formula is:

HP = 14.9 x fuel flow in GPH
%HP = (HP/180) X 100

The formula is the same for the TCM IO550 in my Bonanza which has the same compression ratio except that for %HP we use 300 instead of 180. Note that HP when running LOP is not a function of manifold pressure or RPM, only fuel flow. This is not the case when running ROP.

Here are the recommended settings for Shelby's RV. LOP numbers are relative to #2 cylinder which is the last one to peak in this case. The degrees LOP are recommendations from GAMI/APS.

Operating LOP			
60% HP	7.2 GPH	Peak to 10F LOP	At this power level you can set the mixture anywhere from peak on down and not hurt the engine due to detonation.
65% HP	7.5 GPH	at least 10F LOP	You can actually operate up to peak at this power level. 10F LOP ensures you are in the LOP side.
75% HP	9.1 GPH	at least 25F LOP	
80+% HP	10.3 GPH	at least 50F LOP	

To set up LOP operation, once we get to cruise, we set the throttle wide open (WOT), set the RPM to where we like to cruise, then lean the mixture until we are sufficiently LOP.

Picking an RPM is a matter of deciding if we want to go far (most efficient) or go fast (highest airspeed). In my Bonanza it's a choice between 2500 RPM and 2300 RPM, though if I want to go really far, I'll reduce the RPM as low as 2100. I almost always use 2300. It gives me good range and the noise and vibration are reasonable. At the altitudes I generally fly, 2300 RPM results in 60-65% HP depending on the altitude.

We're actually setting fuel flow and degrees LOP at the same time. It sounds like a juggling act, but it's actually easy to do. As we lean, we note the EGT and HP (fuel flow) at the peak, then continue to where we are sufficiently LOP for the resulting HP (fuel flow). The way we do it in practice is to lean to 50F LOP (a safe number for any HP), note the HP we're getting and increase the fuel flow if appropriate. There is no benefit for being overly LOP. For example, if at 50F LOP we have 7.8 GPH or 65% HP, we are overly lean and should increase the fuel flow a few degrees to be more efficient. If we want a different HP as a final power setting, we simply increase or decrease the RPM a bit and re-lean.

A good initial setting is to set the mixture at a target fuel flow where I know I'm on the lean side of peak and close to my final setting. For me in my Bonanza, that's 12.8 GPM. Note that changes in the environment, like summer to winter, will cause the numbers to change. Also, going for a target fuel flow is only the initial step. The final setting must always be relative to peak EGT.

The LOP settings above from GAMI/APS are not out of line with what Superior recommends. The Superior manual for Shelby's engine says "Best Economy Cruise (approximately 75% power and below) – Do not lean below peak EGT on carbureted engines. Lean to peak EGT to 50°F lean of peak on fuel injected engines." The Superior recommendation is conservative and if we follow it we do just fine. The GAMI/APS data lets us do a little better; operate a bit more efficiently because the most efficient operating point is around 25F LOP.

How did it work out for Shelby? On his next trip Shelby did some checks for LOP operations and, as predicted, he can run LOP except his CHTs are too high. #3, the hot one (top curve above) was in the 400-415 range which is too high. This is with fuel flow in the 7.8 GPH range. To cool things down he had to switch to ROP with fuel flows in the 11-12 GHP range. Shelby can run LOP, but he needs to work on his engine cooling. The problem is not detonation. The LOP setting he's using has him comfortably outside the detonation range. It's just that CHTs are too high for continual operation. Note Superior considers 200-400F as optimal (See "A Word About CHTs" below). Until he improves cylinder cooling, Shelby should operate well ROP.

Operating On the Rich Side of Peak (ROP)
If we want to go really fast (best power) or are having problems running LOP, we can switch to ROP operation. While best power is found at about 80F ROP, you can't always operate at this point. It may be too close to the peak for the power level we want so we'll have to settle for something less than optimum.

Since LOP operation is more demanding of the ignition system, It is not unusual for ignition problems to show up LOP first. The higher the altitude and the more lean the mixture the more demanding is the load on the mags. An in-flight mag check will help pinpoint problems and should be done periodically. There is a proper way to do an in-flight mag check. Don't do it unless you know the correct procedure.

Like LOP operation, there is a correct way to set it up. In Shelby's case he should lean ROP relative to #4 cylinder since that is the first one to peak. The Superior engine manual says "Maximum Power Cruise (above 75% power) – Never lean below 75ºF on rich side of peak EGT. Monitor cylinder head temperatures." GAMI/APS says this is much too close to peak and runs the risk of engine damage from detonation. Here are the GAM/APS recommendations for operating ROP.

Operating ROP		
60% HP	Peak to 25F ROP	At this power level you can set the mixture anywhere from peak on down and not hurt the engine due to detonation
65% HP	at least 75F ROP	
75% HP	at least 125F ROP	
80+% HP	at least 175F ROP	

Like LOP, don't go overboard in setting the mixture ROP. ROP is by definition based on excess fuel for combustion and we don't want any more than we have to. We pay for too rich a mixture with carbon build up that fouls plugs, sticks rings, and sticks valves. ROP is a dirty combustion process. We don't want it to be any dirtier than necessary.

A Word About CHTs
When setting engine controls, we need to be monitoring the CHTs. Superior as well as Lycoming and TCM are too generous in the upper limits. The Superior manual for the XP-360 engine says the following about CHT limits:

- *Never exceed (red line) CHT is 500F*
- *Maximum operating CHT for performance cruise is 430F*
- *Maximum operating CHT for economy cruise is 400F*
- *Optimal CHT operating range is 300-400F*

GAMI/APS say CHTs should never get above 400F. The 430F limit allowed by Superior is too high and will lead, over time, to unnecessary cylinder failures. CHTs can be lowered by increasing fuel flow and/or increasing air speed. Worst case, engine cooling and baffling will need to be improved. We generally get these high CHTs on takeoff and initial climb and if they are over 400F, action needs to be taken. In Shelby's case he's getting it in cruise. The plane won't fall out of the sky, but you'll pay for it in time. On the TCM IO550 (300 HP), a good solution is to set maximum fuel flow about 2 GPH higher than the TCM recommended max (28.4 instead of 26.4 GPH).

Summary

Whether we operate LOP or ROP there is a correct and safe way to do it. LOP operation is preferable for the health of the engine but not always possible or appropriate. It's not a good idea to land with a LOP mixture setting. As you descend the mixture will get increasingly lean and this really complicates a go-around. Smart pilots understand and utilize both conditions depending on the situation.

Peter Cassidy

EAA SportAir E-LSA Repairman-Inspection Course

The FAA's Experimental Light Sport Airplane (E-LSA) rules have a few quirks. For example, if you build a light sport airplane from a kit, such as a Van's RV-12 or Zodiac, and license it as an Experimental Amateur Built (EAB), you can get the FAA repairman certificate for that one aircraft and do essentially any maintenance you want on it, as well as conduct and sign off the annual condition inspection. If you license that same aircraft as an E-LSA, you are only allowed to do an annual condition inspection on it after you have attended an FAA-approved 16 hour course and passed a test on the subjects covered in the course. And it gets even quirkier than that. After you have your certificate to do and sign off the inspection, you may identify airworthiness deficiencies that need to be corrected. By the E-LSA rules, *anyone* can do those needed repairs, without certification or training. (Whether they should is quite a different matter.)

Knowing that an annual condition inspection was inevitable for the RV-12 my wife and I are building, we took the initiative to put a couple of folding bikes in the back of the RV-10 and fly to St. Louis for the EAA SportAir "Repairman Light Sport Aircraft Inspection Rating Course", which begins on a Friday evening, goes all day Saturday, and ends Sunday afternoon with an FAA written test. The class was held in the EAA chapter meeting room at St. Louis Downtown airport (formerly the Parks College airport), with attendees offered low cost accommodations at several nearby motels.

The class was full, with 15 students mostly representing owners of 'fat ultralights' (Challengers seemed to be the most popular breed). One other person besides us was an RV-12 builder, and nobody was an owner of one of the new factory built S-LSA aircraft.

The objective of the course was clear and simple: to provide (just) enough training to enable an owner of an E-LSA to determine whether their personal aircraft is in condition for safe operation. In the best traditions of the FAA, the first part of the course was memorizing definitions, rules and regulations, and the legal documents needed to keep an E-LSA aloft. Substantial time was spent on the Operating Limitations (OL) as a key airworthiness document, including what changes to an aircraft would be considered major changes and thus need to be reflected in the OL. Also addressed were the various types of Airworthiness Directives and their nonbinding cousins, manufacturer Service Letters and Bulletins.

Most pilots are familiar with the FAA's human factors educational materials focused on the question of "Am I Safe to Fly?" Of interest, they have a similar approach to mechanic's work, with an analogous "Am I Safe to Perform Maintenance?" set of checklists and issues to consider. Also addressed was a 'theory of flight' section, with emphasis on how primary control surfaces affect each of the axes of movement of an aircraft.

The bulk of the course material was directed at the steps needed to perform an annual condition inspection. Embedded in this part of the curriculum

was the really fun part of the course, the practical inspection exercises. For its part in the course, EAA builds a set of inspection samples which are small pieces of airplanes or airplane parts mounted to wooden boards. These include examples of safetying methods (including safety wire and safety clips on turnbuckles), wooden components (including ten different pieces of wing spars from wooden aircraft, nine of which were not airworthy), varieties of welds on tubular structures, and flight control systems including bellcranks, pulleys, cables, and their associated hardware. EAA built a model of a stick and rudder control system and attached it to a large flat board, in a kind of "What's wrong with this picture?" exercise that includes just about every mistake that can be made with rod end bearings, nuts, bolts, washers, and cotter pins. Also included was a hands on demonstration of how to perform a compression check on a four cycle aviation engine.

Our instructor was a very experienced A&P/IA who added lots of his personal experience of things he had observed doing hundreds (or was it thousands?) of annual inspections on aircraft. He owned a Cessna 182, and it was clear that a large part of his business was caring for other people's Cessnas. This created an interesting dynamic in the class, since nearly all of the machines that people in the class owned were powered by Rotax engines, and the instructor had essentially no experience with Rotaxes. The collected experience of the class became the teacher on the nuances of 2 stroke and 4 stroke Rotax engines, and for newcomers to that type of engine, the pervasive feeling was that these critters really are different, but we didn't feel that we knew much about why or how. (This thirst for knowledge was later quenched for my wife and me by purchasing a DVD from Aircraft Spruce on Rotax 912 engine operation and maintenance).

Sunday afternoon was crunch time: a 50 question FAA standardized test, for which the minimum passing grade was getting 40 correct. Everybody dropped a few points because of some excruciating trick questions on the exam, but everybody passed.

Two new E-LSA inspectors show off their diplomas.

And everybody learned at least a few new things, though we all had a bit of a sense at times of being in traffic school, just putting in our 16 hours for the FAA on a curriculum that easily could have been covered in half that time.

As with all EAA activities, one of the great parts of the experience was that it resulted in new friends and acquaintances, and time for standing around during the breaks and telling tall tales about our piloting and aircraft owning experiences. Our decision to take our folding bikes led to even more friends, since the St. Louis weather forecast was off the mark and our sunny weekend turned into showers and thunderstorms. A couple of fellow students and the course instructor, all of whom had extra seats in their pickup trucks, gave us rides to and from the hotel and the EAA meeting site. Aviation folks helping other folks out, and having a good time doing it. It's what EAA is all about.

If there's an E-LSA in your future, we don't really have to recommend this course since the FAA gives you no option other than taking an approved course to get your inspection repairman rating. And going the route of an EAA SportAir workshop to accomplish that is guaranteed to add some fun and fellowship to the curriculum.

Dan Masys

Experimental Aircraft Association Chapter 162

MEMBERSHIP APPLICATION

Type (circle one): Reg Member $30 Senior (65+) $10.00 Youth $10.00 Info Correction Only

Date: Name you would like on Badge:

Name:

Last First Initial Spouse

Address:

Number Street City State Zip

Phone numbers:

Home Cell Work

E-mail:

Date of birth:

EAA National:

Membership Number Expiration Date

Occupation: ☐ Retired

FAA Ratings:

Aircraft Project Underway: Percent complete:

Aircraft Now Owned: Based at:

Special Skills that might help others:

Interest in chapter 162 activities:

[ ] President [ ] Secretary [ ] Newsletter
[ ] Vice President [ ] Treasurer [ ] Flyout event leader
[ ] Board of Directors [ ] Tech Counselor [ ] Other:

I prefer to Receive my Newsletter:

[ ] Electronically as PDF by e-mail
[ ] By regular mail

Payment enclosed:

Please mail this form with payment to:

EAA Chapter 162
PO Box 22298
Nashville, TN 37202-2298

OR
Join/Renew online at http://www.eaa162.org.
Click on the **Join EAA 162** link