Pelican's Perch #35: Those Fire-Breathing Turbos (Part 5)

In his fifth column of this series, AVweb's John Deakin continues his detailed discussion of powerplant management technique. This installment is totally devoted to the all-important cruise phase of flight, and includes both theory and hard numbers from the JPI data-logging engine monitor in John's turbonormalized IO-550-powered V-35A Bonanza. (Descents, approaches, landings, and shutdowns next month.)

John Deakin October 16, 2000

Frankly, I never dreamed this series would last for five or six columns! It has been an incredible effort, and an interesting journey for me. Now that I've gotten you up to altitude (see "Pelican's Perch #34") – and left you there for a month – it's time to set up for cruise.

Mar 12, 2007 Update

This column was written in the year 2000, when the only real turbo experience I had with these techniques was with the IO-550TN in mild weather.

We've developed additional data on very cold weather, and additional techniques to make our leaning advice more universal.

Please see Pelican's Perch #84.

Cruise

One of many benefits of these "new/old" techniques will be the ability to quit this silly talk of "percent of power." Percent used to be a useful tool, as it was a common power setting that all engines could attain, and this allowed broad comparisons between airplanes, mostly for marketing purposes. As previously explained, 65% was also getting up to the power range where engines could not be leaned properly without overheating and doing long-term damage to the hottest cylinders. With engines that can and should be operated lean of peak (LOP), a whole new way of thinking about cruise power comes into play.

Heat and Stress

Assuming you always keep your CHTs below 380°F in the climb – Rich of Peak (ROP) or (for some) LOP – then cruise is the major flight regime where you can make or break your engine's TBO, because you spend most of the engine's life there. There are two very strongly linked issues. One is temperature; the other is long-term mechanical stress. At high temperatures, metal (especially non-ferrous metal like an aluminum cylinder head) loses strength and fatigues more quickly, and with high mechanical stresses come fatigue cracks and fatigue failures. Put them together, and it's bad news for any engine.

What do I mean about "mechanical stress"? Well, think of two engines, side by side (perhaps on the same airplane), both delivering 250 HP to the crankshaft. One is running at 80°F ROP, the other at 80°F LOP at some MP and RPM setting that produces the same power.

Remember, the engine running ROP is probably running without balanced fuel injectors (e.g., GAMIjectors), and the "80°F ROP" refers to the entire engine, or an average, if you like. One or two cylinders are probably operating at the hottest possible CHT, others are running rich enough to foul up spark plugs and valve guides.

At least some of the cylinders on the ROP engine will have the timing, mixture, RPM and MP set so that the mixture lights off very quickly, builds to a very high peak pressure while the piston is still relatively near Top Dead Center (TDC) and then fizzles out early as the piston really gets moving downwards. That's a real hammer blow to the piston and cylinder head, and also to the connecting rod, bearing, and crank throw, because the mechanical leverage does not transfer that "push" to the rotating crankshaft very efficiently. It's hard on the crankcase, too, because the case is taking all the abuse from holding the parts together. At peak combustion chamber pressures of

1,000 PSI or more, that stress has to be pretty brutal, and that bodes ill for all the parts in the engine – and the airplane. Because of the high peak pressure and the small space in which it occurs, the temperatures are much higher, too, and this translates directly to higher CHTs. Heat and stress…stress and heat.

The engine running LOP has MP, RPM and mixture set so that the light-off is a bit slower, the flame front moves a bit slower, and the major part of the combustion event takes place a bit later, when the crankshaft throw is further past TDC. At this point, the mechanical leverage is better, and the piston has begun to move faster. It's a slower, steadier "push" instead of a hammer blow, and it takes place in a larger volume, with the piston moving away from TDC faster, and with a better angle with the crankshaft throw, for better leverage. The result is substantially lower peak combustion pressures and temperatures. So the engine running LOP will have CHTs about 30°F cooler. Remember, both engines are putting out the same HP, with the LOP engine having a higher MP…and lower fuel flow!

Throttle, Mixture, and Prop

Much of what follows is of practical use only to those with engine monitors capable of showing EGT and CHT in each cylinder, on an engine capable of running smoothly LOP.

As I mentioned in prior columns, non-supercharged engines and engines with turbonormalizers should be operated with WIDE-OPEN THROTTLE (WOT) for all climbs, and for all cruising. Push it in for takeoff, and leave it there for climb and cruise. Simple.

However, on engines with the gear-driven superchargers and turbochargers that produce more than about 31 or 32 inches MP, full throttle may seriously overboost the engine in some phases of flight. But with any of them that will run smoothly LOP, you can set up the cruise power you want while ROP, then do "The Big Pull" (see below) to LOP. Once there, you can then ADD MP to make up the power loss. Roughly three inches extra MP is often about right, but you may need to play with it, a little. In smooth air, IAS (or climb rate) can be a pretty accurate indicator of horsepower. You will absolutely need an all-cylinder monitor to mess around with this!

While setting the throttle (MP) is easy, and mixture is too, RPM presents a lot more choices, and gets a lot more complex. If you really want "simple," just leave the RPM at redline, full-time. If you just cannot bring yourself to do this, then go ahead and reduce it a couple hundred for climb and cruise at any ROP setting. This won't hurt a thing, except PERHAPS at full sea-level power on some engines. As hard as it may be to believe, it is almost certain that full redline RPM is EASIER on these engines than "200 reduced." I still reduce by 200 right after takeoff, for I believe that noise is the number-one enemy of general aviation, and I'm willing to risk a little engine wear and tear to cut down on the "prop howl."

(Please note that I am not suggesting running max RPM in any engine where the manufacturer suggests less, or in any range of RPM where there is a red or yellow arc, or some good reason not to use that RPM. Also be aware that some feel very high RPM on a continuous, long-term basis over the life of the engine will add to wear and tear on the reciprocating parts.)

At very high power settings, you should NEVER reduce RPM more than the above ("full" or "200 reduced") when operating ROP! If you want less RPM at very high power, you MUST switch to LOP operation, FIRST. This violates the "conventional wisdom" and will seem terribly wrong, until you study the matter a little.

For example, assume you are at WOT, 2700 RPM, and ROP, and you want to get to WOT and 2100 RPM, the correct sequence is LEAN TO LOP FIRST, THEN pull the RPM back. You might confine this "advanced technique" to your own airplane, for if you do it someone else's bird and they later have a navigation light burn out, they'll blame it on your engine management. Also, if you have a "modern CFI" on board, be sure to place him in restraints before doing this, as he will be POSITIVE you're trying to kill him. I've had a lot of fun with these techniques, with some pilots! On the other hand, some of the really old pilots who flew big recips may not turn a hair, they'll say, "I've always wondered why we can't do it that way!" The famed Noel Merrill Wien hitched a ride with me one day, and I thought I'd have a little fun with him. I uttered those famous last words, "watch this," and did the Big Mixture Pull at full throttle and max RPM. He never turned a hair, just said, "We used to do something like that on the big radials, though I haven't seen it done at full power before." A lively discussion ensued, and Merrill was right up to speed. Very impressive, but he's an impressive sort of guy.

Wherever you choose to set your RPM, pick a setting where the engine runs smoothly. Vibration is a real machinery killer, and you are not going to enjoy long engine or accessory life running it at any power setting that produces vibration.

With turbochargers, there is an additional complication, for changes in RPM have a large effect on the energy passed through the exhaust (and therefore the turbo). You might want to run at 2100 RPM, but you may find the MP will drop off to some lower value. At this point, the controller is calling for “more,” the wastegate is fully closed, diverting all the exhaust it possibly can through the turbo, and it still isn’t enough to maintain that upper-deck pressure. That in turn will not maintain your sea-level MP. If mixture is not enough to bring the turbo up to speed, then you may need to increase RPM to do so, right up to the full redline RPM, limitations permitting. On the other hand, if the reduced MP is acceptable to you, that’s fine…it won’t hurt a thing.

Go Fast or Go Far?

The only remaining decision is what mixture setting to use; whether you want to “push it,” and go fast, or slow down and extend your range. Where to run your mixture? TOUGH question, with many answers!

Repeating past advice, we CAN tell you very firmly where NOT to run your mixture, and that’s in the “danger zone” centered around roughly 80°F ROP at any power setting over about 65%. Below 65% power, do whatever you want, you’re probably not going to do any harm. The more power you set above about 65%, the WIDER that “danger zone” gets, and at very high power settings, it might be a range from as much as 150 ROP, to about peak EGT/TIT, or a bit leaner. Operating in this “danger zone” will demonstrate high CHTs, over 380°F. Avoid that area. On the rich side, run richer, on the lean side, run leaner. The “Target TIT” method described for climb (see “Pelican’s Perch #34“) works fine when ROP, but LOP needs a bit more discussion.

How much power do you want for cruise? Do you want to go as fast as you can (for that hot date with a cool blonde)? Or, do you want to stretch your range, so you don’t have to land in a state where the authorities are after you? Ahh, decisions, decisions.

In many ways, the “go-fast mode” is easier, and I use it a lot (alas, no blondes involved, though). Level at your cruise altitude (or flight level), and keep the climb power you had set until the airplane accelerates to cruise speed. No, I don’t believe in “The Step,” but I do like to get going. If I’m really eager to get there, I’ll leave 2700 RPM for cruise all the way to descent.

There’s nothing wrong with leaving the climb power setting alone for a time, until cockpit workload permits fooling around with the engine. Take someone along the first few times you do any of this, to keep an eye out for traffic, and perhaps fly the airplane while you handle these unfamiliar tasks, watch the results, make your mistakes, and learn what will happen. You can always “panic” and just push the mixture fully rich, while you gather your wits again.

As the speed increases after your level-off, you’ll see the CHTs start to drop from the additional cooling airflow, so go ahead and close the cowl flaps at this point (you may need to crack them open, or even open them fully later, but try it with them closed, first). On my airplane, at cruise speeds, the cowl flaps will make about 3 knots difference in the IAS, and about 6 or 7 degrees F in the CHTs. Set your engine monitor to show the CHT on the hottest cylinder, and I hope you have something like the JPI EDM-700, which will display CHT in one-degree increments. Do I care about one-degree accuracy? No, of course not, but I DO want to see the TREND as soon as possible. If that instrument is showing 334°F and I do something that changes it, the first few twitches up to 335, 336, or down to 333, 332, etc., will start telling me what I need to know very quickly. If you have to wait for a 10-degree, or worse, a 25-degree change to see it, you’re going to spend a good deal more time figuring out what’s going on.

The Big Pull

Now, ignore your sweaty palms and your throbbing heart, thinking of the unnatural act you are about to commit. It is an act that 90% (99%?) of all pilots out there believe will instantly destroy your engine, and many will loudly tell you so (with no data). It won’t. Just reach down and grab the red knob (mixture), and smoothly pull it back to about 15 GPH fuel flow on an IO-550, or a tiny bit less than that on the IO-520 (14?), a bit less still on the IO-470 (13?). The idea here is simply to get THROUGH the danger zone to something under peak EGT on the lean side, without lingering in the high-temperature danger zone any longer than necessary. Don’t jerk the red knob out, but “The Big Pull” should take no more than three or four seconds. It’s a very smooth, but very positive and aggressive action. Don’t delay; the only potential for harm here is if you spend too much time in “The Danger Zone,” centered around 80°F ROP. You should feel a slight power loss from this “pull,” and if you go a bit too far, the engine may get a little rough. Just enrich until it gets smooth again. This INITIAL mixture setting is NOT critical; it is only critical to get through the “danger zone” to your starting point. You will have plenty of time to refine this setting without rushing.

Once well over on the lean side (as opposed to “The Dark Side”) it is almost impossible to hurt the engine. Consider this important point. In fact let me repeat it. **Even at very high MP and/or RPM, if you are well over on the lean side of peak EGT/TIT, it is virtually impossible to hurt the engine.**

The rules have changed!

So now, on the lean side, watch that hottest CHT for a few seconds. If it starts up or down quickly, then adjust the mixture, remembering that since you’re now on the lean side, LEANER IS COOLER. If you’ve been taught the “correct” CHT responses only on the rich side all your flying life, this is going to short-circuit your mind the first few times, and you’re SURE to get it backwards. (Ask me how I know.) If you get hopelessly confused, just shove the mixture full rich, think about it, get your pounding heart under control, and try again.

The idea here is to first, get over on the lean side and THEN adjust it a bit. Get that CHT headed in the general direction you want it to go, but in a slow, “stately” manner, watching it tick, tick, tick up or down, one degree every few seconds. Those without one-degree resolution will have to be a bit more patient, watching for 10 or 25-degree changes, as necessary. Don’t stare at it, keep watching for traffic, but check it every few seconds with a glance.

Yes, I know. It sounds like a lot of work, and difficult. You must be patient, and realize you are working against all the “training” you’ve had, all your ingrained habits. They may have been good habits when you were limited to ROP operations, but now you have the ability to run in a different mode. Be patient. Once you have done this a few times, you will suddenly realize this method is EASIER, and there is actually a good deal less fiddling needed, compared to operating ROP.

How much power do you want? Well, for the absolute maximum performance, regardless of fuel burn, keep enriching from the lean side (raising the CHT) and set that hottest CHT at 380°F. I suggest that only those with “alarmed” instrumentation push this “limit” so hard, as several things can cause the CHT to rise quickly. You may well not catch it without something to really get your attention. The JPI flashes the entire display, which I find to be just about the minimum warning I want, (I wish it could be tied into the audio system.) For a more relaxed flight, run CHTs a bit leaner (cooler), around 350°F to 370°F, and let it go at that. That is a more stable setting, still with excellent performance. When making adjustments, use the EGT (NOT CHT!), and move the mixture just enough to change the EGT by about 5 or 10 degrees F, then wait for the response on the CHT. EGT reacts instantly (on the JPI), while CHT takes a bit longer. Set the EGT, look around outside for a minute, then check back to see what the CHT did in response.

On most airplanes, you will find that there is a considerable “slop” in the engine controls. If your previous adjustment was “leaner,” and you want “richer,” it is very likely that the initial movement of the mixture control will have no effect on EGT at all. Patience, that’s just cable slop. When you actually see the EGT move, you’ll know you finally took up the slack.

If you want the very highest power settings, you’ll also need to check the TIT, to make sure you’re not exceeding the limits (if any) on the turbo system. I’d suggest 25 to 50°F cooler than the absolute limit from the manufacturer of the turbo, which allows for any possible errors in the placement of the TIT probe, or the system. The Garrett turbochargers come in two flavors. Some have limits at 1650°F TIT, some 1750°F. But these are “stress-creep” limits, determined at the absolute maximum turbine speed. At least in the TATurbo, the turbines do not run anywhere near that speed, so the limits are actually quite conservative. Not to be exceeded, of course, but not to be feared, either.

That’s all you need to do for cruise!

Best-Range Operation

Well, I lied. There ARE a few more considerations.

Suppose you don’t want maximum speed, but maximum economy, or the best miles per gallon (MPG) of fuel?

Your first step to accomplish this is NOT to think about mixture settings (or "percent of power"), but AIRSPEED! You need to determine what the best indicated airspeed is for YOUR airplane, for the most MPG. Next time you're on a cross country, in very smooth air, on autopilot, play test pilot, and gather a bit of data. Here's one way to do it.

The following table was logged by climbing to 10,500′, and setting up a high cruise power setting, one of my favorite "go-fast" modes, full throttle, 2500 RPM and LOP. I tweaked the mixture up until my hottest cylinder (#4) was about 390°F. Gross weight was very close to maximum, 3,400 pounds, C.G. somewhat forward.

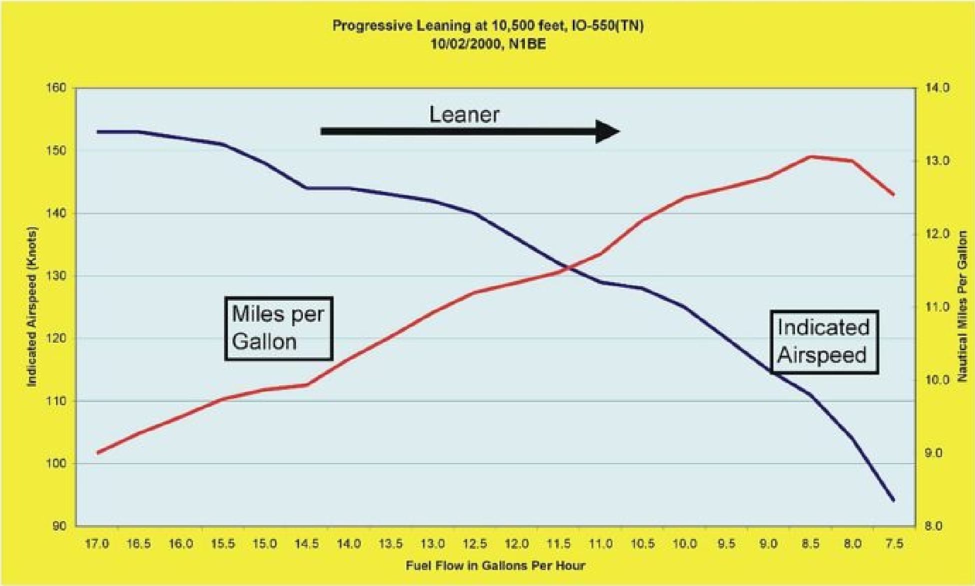
At about two-minute intervals, I reduced the fuel flow in 0.5 GPH increments, as shown in the leftmost column. After the airspeed stabilized at each setting, I noted it as shown in the second column. After landing, I plotted it all out on an Excel spreadsheet. Initially, all I wanted was the no-wind MPG (as shown in the column just right of center), but I figured someone would want to see the data for differing winds, so I cluttered it up a bit with those calculations, too.

Please note very carefully that in using IAS for these calculations, we are NOT seeing true miles per gallon! In order to do that, we would need to convert everything to TRUE airspeed. But that adds a level of complexity that is not necessary if we are simply trying to determine the optimal IAS to use for best-economy operation.

Gallons per Hour	Indicated Airspeed	Miles Per Gallon (MPG) at wind speed								
		-40	-30	-20	-10	0	+10	+20	+30	+40
17.0	**153**	6.6	7.2	7.8	8.4	9.0	9.6	10.2	10.8	11.4
16.5	**153**	6.8	7.5	8.1	8.7	9.3	9.9	10.5	11.1	11.7
16.0	**152**	7.0	7.6	8.3	8.9	9.5	10.1	10.8	11.4	12.0
15.5	**151**	7.2	7.8	8.5	9.1	9.7	10.4	11.0	11.7	12.3
15.0	**148**	7.2	7.9	8.5	9.2	9.9	10.5	11.2	11.9	12.5
14.5	**144**	7.2	7.9	8.6	9.2	9.9	10.6	11.3	12.0	12.7
14.0	**144**	7.4	8.1	8.9	9.6	10.3	11.0	11.7	12.4	13.1
13.5	**143**	7.6	8.4	9.1	9.9	10.6	11.3	12.1	12.8	13.6
13.0	**142**	7.8	8.6	9.4	10.2	10.9	11.7	12.5	13.2	14.0
12.5	**140**	8.0	8.8	9.6	10.4	11.2	12.0	12.8	13.6	14.4
12.0	**136**	8.0	8.8	9.7	10.5	11.3	12.2	13.0	13.8	14.7
11.5	**132**	8.0	8.9	9.7	10.6	11.5	12.3	13.2	14.1	15.0
11.0	**129**	8.1	9.0	9.9	10.8	11.7	12.6	13.5	14.5	15.4
10.5	**128**	8.4	9.3	10.3	11.2	12.2	13.1	14.1	15.0	16.0
10.0	**125**	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5
9.5	**120**	8.4	9.5	10.5	11.6	12.6	13.7	14.7	15.8	16.8
9.0	**115**	8.3	9.4	10.6	11.7	12.8	13.9	15.0	16.1	17.2
8.5	**111**	8.4	9.5	10.7	11.9	13.1	14.2	15.4	16.6	17.8
8.0	**104**	8.0	9.3	10.5	11.8	13.0	14.3	15.5	16.8	18.0
7.5	**94**	7.2	8.5	9.9	11.2	12.5	13.9	15.2	16.5	17.9

One thing shines through loud and clear – tailwinds are better!

Graphically, we can show the no-wind data like this:



Click for higher-resolution version.

This relatively simple chart is pretty self-explanatory, the blue line shows the airspeed dropping as the fuel flow is reduced, and the MPG rising.

The good news is that we have a pretty wide range of options. The bad news is that for max range, we have to really, really slow down. I don't know about you, but I don't really enjoy seeing 110 knots on the dial, when I could be seeing 160!

On the other hand, this efficiency varies with INDICATED airspeed, so it'll be around 110 knots at all altitudes and temperatures (it will vary a bit with weight). At any given indicated speed, the higher we fly, the higher the TRUE airspeed. That's why jets fly so high, a 747 at Mach 0.86 at 41,000 feet might only be showing 250 knots, but will be truing more than 500. We can't get up there in our airplanes, but at 20,000 feet, 110 IAS is about 150 TAS, which isn't too shabby for really long-range cruise.

You may have heard the OWT ("Old Wives' Tale") that it is better to increase speed into a headwind, and decrease it with a tailwind. There is some truth to that, but it's only really effective if your starting point is your best no-wind cruising speed! Very, very few pilots have the patience to fly that slowly!

Note in the above chart, for ANY wind, miles-per-gallon improves with reduced speed, until in the very low-speed range.

The most efficient speed is higher when heavy, and lower when light. Go do your own testing, and come up with some rough numbers. This effect is really noticeable on the jets, where the fuel load can be more than half the total weight at takeoff, and it was quite noticeable on the prop transports and even fighters that were heavily overloaded with fuel and expendables. However, the effect of fuel burn is near-trivial on the average general aviation aircraft. On the Bonanza, the usual fuel load is only about 15% of the max weight. From the above data, I can assume that my best-range airspeed is about 110 knots indicated, and not worry too much about the variables.

Now, once you know that "best range IAS" number, you have the data to make a more intelligent decision about the power setting you want for any given mission.

Go-Fast Mode

Pssst. Nice little girl wanna go really fast? Run it wide open, ROP (yes, I said RICH of peak), leaned so that the hottest cylinder doesn't go over 400°F. But keep the thought firmly in mind, you're playing with fire, doing this. You're probably pulling more than the rated full power, the peak pressure pulses are occurring closer to TDC than they really should, and the engine is getting hammered. But this is the way people run races, and those who have participated in the long races across the USA report there is no apparent harm to their engines, even after many hours of this "abuse."

You can pull any lesser power, running ROP, and the more you pull the power back, the more you can lean to keep that CHT under 400°F. At some point around 65% or 70%, you'll find you can run the mixture anywhere you want without exceeding that temperature.

However, I don't like this ROP mode at all, because all the evidence indicates that over the long term, you will pay the price with premature cylinder wear and damage. You probably won't do much long-term harm by running a race or two, but the more you abuse the engine, the shorter your average TBO will be.

There are other downsides, previously covered.

Ahhh, but LEAN of peak! The above data was taken LOP throughout, and that 153 knots indicated was about 185 knots true. That TAS jumps quickly with increased altitude, but I wanted to do this data run at non-oxygen altitudes where many people prefer to fly. It's not a good chart for those able and willing to fly higher, and again, the MPG figures are not correct because I used IAS instead of TAS.

Exploring the LOP Envelope

So, now we have our range of power settings. On the low end, whatever power it takes to maintain the speed that gives maximum range, and on the high end, the power setting that produces 380°F on the hottest CHT.

When operating LOP, you can choose ANY power setting in between those limits.

As your fuel load burns off, your IAS will tend to increase, and you should gradually reduce power to maintain that IAS (or a bit less).

Now, how do we "reduce power?" First, we will probably NEVER touch the throttle to do so! We've already said that full throttle, full RPM and ROP (VERY ROP!) is okay (if you like a dirty engine), and full throttle, full RPM and LOP is fine ("leaner is cooler and cleaner, and cleaner and cooler is better"). If we want to use something less than that high power, we need to reduce RPM or lean the mixture, or both. Which do we reduce first?

It's easy to get all bound up in technical details of prop efficiency and other details that make a percentage point or two difference. The Black Mac is very slightly more efficient at higher airspeeds and lower RPM at low altitudes, but that seems to reverse at high altitude. There is a large increase in prop efficiency if you increase your climb IAS from the Vx/Vy range up to 120 knots or so. But that's climb, and we're talking about cruise.

Frankly, in the real world, I don't think it really matters in light GA aircraft; we're now getting down to arguing about angels dancing on pinpoints.

(If you want to really get into all this, I recommend John Eckalbar's superb text "Flying High Performance Singles and Twins," (ISBN 0-9616544-2-2). Published in 1994, he obviously knew the principles of LOP operation, but did not approach engine management with LOP in mind, probably because so few could do it, at that time. With what we know now, we could pick on that book a little, but I'll bet he'd be the first to agree.)

Roughly speaking, changing from 2700 RPM to 2100 RPM causes a reduction in "friction horsepower" of about 10 HP. In other words, the same fuel will give you 10 more HP delivered to the prop, or at the same HP, you'll burn less fuel at the lower RPM.

If you are looking for best economy with a non-supercharged engine, all things considered, you're probably better off reducing RPM first to attain your selected IAS, while keeping roughly 20°F LOP. If that doesn't do the job for you (maybe it's not the smoothest RPM, or you're not comfortable reducing RPM further), then leaning further to reduce IAS (remember, on the lean side, leaner is "less power," and "cooler.") Conversely, to increase your IAS, first enrich (380°F CHT as a limit, or to 20°F LOP), then increase RPM. Turbocharged engines will be run best just a bit leaner, between 40°F and 100°F LOP.

There is the school of thought that considers "miles of piston travel" important. I'm not so sure. If we keep the stresses and temperatures in line, and we don't run cold engines at high power settings, most all those flying parts inside the case are running on a fine film of oil, and never actually make metal-to-metal contact. Would miles of piston travel really matter a lot?

If your engine runs smoothly at all RPMs, then you probably ought to reduce RPM first, and increase it last. On the other hand, if you have some favorite RPM that seems to be a "sweet spot," feel free to lean for less power until the engine doesn't like it, then reduce the RPM to the next lower "sweet spot," and reset the mixture as needed. This is an example of the flexibility you gain with LOP operation.

What Power Setting Is That?

You may have noticed that I don't pay much attention to percentages of horsepower, particularly the common "65%," so beloved by many. That was a setting favored by the marketing departments, and also it had the benefit of being about the practical long-term limit on power when operating ROP (though the factories will never admit it). That all goes out the window with LOP operations. Throw away all those power charts, they are totally inaccurate, useless and unnecessary when LOP.

May pilots will ask, in confusion, "But what power setting is that?"

My usual answer is, "Who cares?" Or, "It's the best power setting for the job you want done."

However, if you really, really must know the HP you're pulling, there's an incredibly simple trick to find out. On the flat, horizontally opposed, air-cooled aircraft engines with 8.5:1 compression ratios (including TCM IO-520/550 and Lycoming IO-540), simply multiply fuel flow in GPH times 14.9. The result is HP. If you insist on percent, divide that by the rated power of the engine. For the same engines with 7.5:1 compression ratio (most factory-installed turbos), the numbers are worse, and the multiplier drops to about 13.7.

IMPORTANT NOTE: This formula works only at LOP mixture settings! When operating ROP, the excess fuel is largely wasted, not burned, so the linear relationship between fuel flow and horsepower breaks down.

For LOP operation, the result is horsepower being produced to a high degree of accuracy. Certainly far more accurate than any charts! For example, if I'm running LOP with my 300 HP IO-550, which, even though it is turbonormalized, still has 8.5:1 compression ratios, and have a real fuel flow of 16 GPH, my actual HP is 238 HP, or 80%, regardless of altitude, temperature, MP or RPM. Repeating, this formula ONLY works when LOP!

If you're curious why this multiplier works so well, check the TCM power charts (or previous columns) and note how the power drops off from the peak EGT point, or a bit leaner. You will see that drop off is very nearly a straight line, which makes it linear with the fuel flow plotted across the bottom of the chart. Stated yet another way for the engineers among us, the BSFC is nearly constant across a broad range of mixture, MP and RPM settings, WHEN LEAN OF PEAK.

High and Hot

There's another hitch in the git-along, with turbos. There are several conditions where they sort of lay down on the job, and you'll see the MP running lower than it ought to. While your engine is converting dollars to noise, it's also converting fuel to energy, and a large part of that energy (and noise) goes out the exhaust stack. That's the whole idea behind the turbo, to recapture some of that lost energy in the exhaust. Anything that reduces that exhaust energy deprives the turbo of its driving force, which causes a loss in turbo RPM, which causes a loss of upper deck pressure, which (you guessed it) causes a loss of MP. If you took the engine into outer space, it couldn't produce any power at all (no air), and the turbo couldn't produce any increase in the MP at all. We don't need to go that high to see the effect, an altitude in the high teens will do it, and the warmer the OAT, the more loss you'll see. On a really hot day on my engine, you might see the full-throttle MP start dropping off at 15,000 feet, on a cold day it might hold full MP to some altitude above 20,000 feet. TATurbo now has an improved intercooler and induction system that is making full redline manifold pressure, at 22,000′, lean of peak, even on very hot days. I'll be getting one installed later this month.

Hot days and flight level altitudes will adversely affect any engine, including those with superchargers of any kind. These effects can cause a fair loss of power, which you may not like. Just think of ways you might increase the exhaust energy. Increasing the RPM will do it, as will enriching the mixture to whatever your limit is (but not more than 380°F CHT, of course).

The JPI engine monitors have a really neat feature if you can tie in a signal from the GPS (two wires). It will show predicted fuel remaining at the next waypoint. If you set that next waypoint to the destination, you have your predicted fuel on landing. If it looks a little skinny, reduce power a bit to extend your range, and let it stabilize. It'll show a bit more fuel remaining. Continue this until you get the reading you want, and that's your power setting. Small power (and airspeed) changes early in the flight make the biggest difference, but you can fine-tune this for the whole flight, if you want.

In summary, if LOP, cruise the engine anywhere you want, as long as the hottest CHT doesn't go over 380°F. Cut it back to go slower, and extend your range.

Descents, approaches, landings, and shutdowns next month!

Be careful up there!