Pelican's Perch #34: Those Fire-Breathing Turbos (Part 4)

In his fourth column of this series, AVweb's John Deakin invites you along in the right seat of his turbonormalized IO-550-powered V35B Bonanza, explaining each step of his powerplant-management technique from engine start to taxi, runup, takeoff and climb. (The Pelican promises to cover cruise, descent, landing and shutdown next time.) To help illustrate why he does what he does, John presents detailed CHT and EGT data on some actual flights, taken from the Bonanza's JPI data-logging digital engine monitor, and explains exactly what each squiggle on the graph means.

John Deakin September 18, 2000

We've now beaten the technical issues to death, let's go fly!

If you haven't read any of the prior material on this, please don't fail to see "Those Fire-Breathing Turbos (Part 3)."

This column is highly specific to the "turbonormalizer" systems as installed on Teledyne Continental Motors (TCM) "big bore" engines like the IO-520 and IO-550, most notably the "Whirlwind" system by Tornado Alley Turbo, in Ada, Okla. However, the general principles apply across a broad spectrum of engines, with and without turbos. If you have read prior columns, and understand them, you should be able to sort out the specifics from the generalities. I am deliberately avoiding Lycoming engines here, as I have little recent experience with any Lycomings with decent instrumentation. Try these techniques with your Lycoming if you wish, but if they don't work, go buy a TCM!

Seriously, I can throw bricks at TCM for some things they've done very poorly, but their basic engine is very well-done, and usually runs much smoother than most Lycomings. A well tricked-out TCM IO-550, preferably with Millennium cylinders, a JPI engine monitor and GAMIjectors, is a fine, fine powerplant. A turbonormalizer makes it even better. Much is made of modern automotive engines, but they really are not very good, or efficient. They are optimized for minimum emissions, at considerable cost to efficiency.

Starting

If anyone consistently has trouble starting any of these flat TCM engines (turbo'd or not) when they are cold, they are either doing something seriously wrong, or something in the engine is not right. Throttle cracked, mixture rich, a shot of boost (or prime) until the fuel pressure steadies, or about five seconds, and the engine should start and run on the first turn of the prop.

Hot starts are equally easy.

Yup, that's what I said, there's NO difference between a cold start and a hot start, PROVIDED you do it using science, not folklore. In fact, hot starts are easier. Everyone has a favorite method, and some of them even work on some airplanes, some of the time. Most often, you will hear of flooding the engine deliberately, then cranking with some combination of throttle and mixture settings until the engine starts. Generally, that's NOT a good idea, because most methods of doing this end up with copious quantities of raw fuel in various unknown locations, creating a fire hazard. Fuel on the ground can catch fire and cause the loss of the airplane, fuel in the exhaust manifold can "torch" and sear the paint above the exhaust pipes, and fuel in the induction manifold can do great damage to the tubing, much of which is not metal. Yes, many get away with doing this, some for years. But I've seen all three results, and in each case the pilots whined, "I did it the way I always do it!"

There is a bit more science involved with hot starts, because the heat developed by an engine that has just been shut down can have an undesirable effect. The key here is to understand that with the engine running just before shutdown, cool fuel is circulating through all the fuel lines and the engine-driven fuel pump, effectively keeping the plumbing AND THE PUMP cool from the inside. There is also some cooling airflow, blowing hot air out of the accessory compartment. Once you shut down and trap fuel in the lines, the large thermal mass of the engine transmits the heat throughout all metal parts of the engine and the engine compartment. This "cooks" the fuel in the lines, and more importantly, the heat from the engine "soaks" into the engine-driven fuel pump, warming that fuel. Since there is no cooling airflow to partially cool the outside of the fuel pump, the temperature of that metal assembly will actually rise after shutdown. The fuel trapped in the fuel pump heats up, slowly develops bubbles, and the engine-driven fuel pump becomes full of them after about 15 minutes.

One thing every new pilot on the old radials learned was that engine-driven fuel pumps don't work very well with mixed air (vapor) and fuel, they cavitate. On the other hand, electric boost pumps are quite happy to pump either fuel or air, or both. The two complement each other, with the additional benefit of having a backup if the engine-driven pump takes a break.

If you prime the hot engine, and turn the boost pump off, you'll probably get some fuel and air bubbles through to the cylinders. The fuel you injected into the engine is enough to make it cough to life, perhaps even run for a second or two. But as soon as that fuel and the little bit of fuel in the injector lines is used up, the engine-driven fuel pump is simply spinning its wheels in vapor, unable to move the needed fuel, and the engine dies. Repeat that, and the same cycle occurs until the battery goes dead.

Yes, you can run the electric boost pump for the start, but it's so good at moving fuel (and air), even with bubbles in it, it's very hard to control the actual flow, and the mixture will probably become too rich to run. Some master the trick of running the boost pump, and slowly moving the mixture control or the throttle until a viable mixture exists, but it's a difficult trick, and different for every engine. Some push the throttle in and run the boost pump before hitting the starter, but this pumps raw fuel into the engine, and possibly overboard, creating a very real risk of fire. Just because you've never seen one, don't think this cannot happen! Even if you get the engine started, the fire can do damage, scorching paint at best, and burning up the airplane at worst.

A better starting method is needed, and there is one, at least for the TCM engines. We haven't had much chance to try it on the Lycomings.

For starts within the first 10 or 15 minutes after shut-down, just put the mixture rich, crack the throttle, DON'T prime, or just a tiny shot, and go. If that fizzles once, don't run your battery down with further attempts, just go right into a hot start.

Simply leave the mixture in full lean ("idle cutoff"), and run the electric boost for one full minute. Sixty seconds. Time it, by the clock. More won't hurt a bit, but less may well not be enough. A full 60 seconds, not a second less. The first few times you do it, it will seem interminable, but there's no reason you have to just sit there. When you know you're going to use this procedure, flip the pump on early, hit the stopwatch, and go ahead and do your cockpit setup, or study the instrument departure, or brief your passengers (you DO brief passengers, don't you?)

This little trick uses the ELECTRIC pump to pressurize the lines to the engine pump and the chamber inside the pump case itself. Since that fuel can't go beyond the fuel control with the mixture shut off, the only way out is through the rather small "vapor vent return" line. This is the exact purpose for which this line is provided.

Once this "cooling" step is done, the start is identical to the cold start, and just as easy. At the end of the sixty seconds, let the electric pump continue to run while you push the mixture in until the fuel flow stabilizes (as for the cold start), flip the boost off, and hit the starter. Instant gratification. Well, sixty-second gratification, anyway. In effect, this procedure converts a hot start into a cold start. (Actually, it may be better than a cold start, because the engine is warm, and the fuel will vaporize better.)

What's the magic behind 60 seconds? Well, if you lay your hand on the fuel pump of a recently shutdown engine – ouch, you'll burn yourself. Run the boost pump, and you still won't be able to touch the fuel pump until about 60 seconds have gone by, and then you'll actually feel the case cool off from the fuel running through it. There isn't a lot of fuel passing through it, because the vapor vent return line is fairly small. But new, cool fuel IS coming in, and it IS driving out those nasty little air bubbles, and it is cooling the pump from the inside out. Patience, take the full 60 seconds. Works great.

I have heard people complain that this longish use of the boost pump will run the battery down. Maybe, but so will repeated attempts to start a hot engine using any other way, and the starter is a LOT more load than the electric boost pump! Also, your battery is an important reserve of electrical power, and if it cannot perform this function briskly, then I think the airplane is unsafe for any flight beyond a simple hop around the pattern in good weather. Remember, the engine is hot, implying a very recent flight, and that battery should be fully charged.

You may have your own way of doing the hot start. It may work for you, in your airplane, most of the time. That's fine, use it. But the method above works in ALL these TCM fuel-injected, flat-engined airplanes, ALL the time. It has the advantage of leaving the engine in a known condition, fully equivalent to the cold engine. I may not have seen all the methods out there, but I'll bet I haven't missed many. I like this one best of all, for it uses science instead of oaths and imprecations. Credit George Braly with this one, not me.

Ground Leaning

Why not? Hey, if you want to foul your plugs and worse, by all means, go ahead, be lazy, and leave the mixture full rich for ground operations. There are also rumors that this is a stunt invented by cheap airline captains, trying to save a little fuel, but I discount that. On the other hand, I'm a post-60 co-pilot now, and I'd believe anything about those dreadful captains! I never realized how bad they were when I was one. Terrible people. Just terrible.

Remember, idle mixtures are universally set up for easy starting, and are universally richer than necessary for any RPM below roughly 1200 to 1500 RPM. If the engine is set up for sea-level airports, then the idle mixture will get REALLY rich at higher elevation airports. On the other hand, if an engine is set up at Crede, Colorado (9,000 feet MSL), and then flown to a low-elevation airport, it will be hard to start from a mixture that is much too lean.

You can prove this to yourself by leaning the engine after you start it, and watching the RPM very closely. You should, with considerable leaning at 1,000 RPM, see a definite RPM rise and peak, as the mixture goes from "too rich" to "just right." If you lean for maximum RPM at this point (on the ground), you're actually setting a "best power" mixture at that throttle setting. It is impossible to hurt the engine by doing this. Remember, TCM says any mixture setting is okay below about 65% of rated power, and Lycoming says 75%. Ground running is a LOT less than 65% power, unless you're trying to taxi to the ramp after landing gear up, when all your power is converted to noise.

The real danger here is forgetting the leaned mixture, and attempting to take off with it leaned. THAT could be bad news! To prevent this from happening, EITHER leave the mixture full rich (and pay the price in fouled plugs), OR lean it so brutally that you can't even get runup RPM without the engine wheezing for air, and quitting. (No, this won't hurt it either.) Don't ever put the mixture in some indeterminate position, in between "full rich" and "brutally lean." So many pilots will grab the mixture levers and just pull 'em back by feel, figuring that improves things, and it's "good enough." IT ISN'T. I don't care how good your checklist is, and how religiously you use it. If you do this, sooner or later, you'll try a takeoff set that way.

Can you run up while leaned? Sure, why not? Even a runup is well under 65%, isn't it? If the mixture is so lean you can't get your runup RPM (as it should be), you may need to bump the mixture up a little, or even go full rich for the runup, if you feel better with that. One advantage of doing a leaned mag check is that it is a much more demanding test of the ignition system, and may well reveal faults that the normal runup won't! I like that. If you have an all-cylinder engine monitor (and you should), monitor the graphic display during the mag check, rather than worrying so much about the RPM. The RPM drop on one mag will be MUCH greater when leaned (200 RPM is common), and that's perfectly normal WHEN LEANED BRUTALLY. You should see all EGTs RISE during single-mag operation, because with only one plug per cylinder firing, it takes longer for the mixture to burn, and it will be much hotter when it leaves the combustion chamber. So when you select one mag, you should see all the EGT bars jump up. Switch back to "both," and see them drop back, then repeat for the other mag. If you see one or more EGTs fall during single-mag operation, SOMETHING IS WRONG. That plug is NOT firing properly, and combustion is not developing fully before the exhaust valve opens.

There is a tendency by many pilots to spend only a second or less on one mag during this check. Sometimes I wonder if they've checked all six plugs on that mag, they're so quick! Please, leave it there for several seconds. On the old engines, 30 seconds or more on one mag was recommended for a really good mag check, monitoring for the usual "fast drop" in a second or two, followed by an abnormal "slow drop" over a longer period of time. Excessive "fast drop" meant bad plugs or ignition, while any further "slow drop" might mean bad timing, or improperly adjusted valves. There is no need to do such a long mag check on every flight, but it's not a bad idea before and after maintenance, and there's no need to be quite so quick on the everyday mag check, either. Remember, you're LOOKING for an abnormal condition, here! Give it a few seconds to show itself, and a few seconds to see the normal EGT response.

On the other hand, excessive ground time and runup time can be harmful in the long term, because the engine temperatures do build up in many engines without the cooling airflow of flight. Even if the CHT doesn't show this, "hot spots" can develop, which are not measured by normal instrumentation. On the normal runup, get the RPM up to APPROXIMATELY the figure called for, but anywhere within 100 RPM, or even 200 RPM is just fine. DON'T sit there and twiddle with the throttle, trying to get exactly 1700 RPM, or whatever. Get it up into the approximate range, do a quick prop check, do your mag check with a few seconds on each mag, note the engine instruments are all in the proper range, and pull it back to normal ground RPM (usually 1,000). With practice, this whole procedure shouldn't take more than about 20 seconds from the time you leave 1,000 RPM, to the time you return to it. Properly done, there isn't enough time for the CHTs to rise much, and that's good.

Takeoff

DON'T INVENT POWER SETTINGS, unless you have the data and the knowledge to back it up! Please, do your engine a favor, and USE the specified MP and RPM! In general, if you have a power setting for takeoff, and another power setting for "maximum continuous" or "climb," the engine has not been tested much at the in-between settings. In MANY engines, by reducing the throttle, you also lean the mixture, and this is NOT recommended, and usually NOT tested. Additionally, less than full takeoff power increases the time it takes to get to an airspeed that will properly cool the engine. In the single-engine airplanes, it leaves you lower longer, and in the twin, it will immensely complicate your problems if an engine fails.

In theory, given enough MP, all these engines can produce the same power for takeoff when lean of peak, and with cooler cylinder temperatures, too. Some of us have experimented with this, but it is not for the faint of heart, and you risk very serious and immediate damage if you make a mistake. In the future, special systems may make this the preferred method, and there is even talk of a "Full Time Lean Run" engine (FTLR) that will do it automatically. No, I'm not talking about TCM or Lycoming. For now, the risk-reward ratio is not good enough for most pilots.

Tornado Alley installs a two-speed electric boost on all their turbonormalizer systems, and they recommend its use in the "Low" position for takeoff and climb. On mine, turning it on at low power while entering the runway will make the engine run a bit rough from a too-rich mixture, so I generally wait until I've got full throttle, then I flip it to low. DO NOT use "High" for takeoff, and if you have only a single-speed pump, DO NOT use it for takeoff either, unless you have a failure of the engine driven pump.

As on all takeoffs, you should take a quick peek at the engine instruments right after setting full power. Fuel flow is especially important, but look at RPM and MP, too. Next, take a quick glance at the engine monitor, to see what the graphical bars are doing. Very early on, you should develop awareness of what "pattern" you should see at takeoff power, so that you can recognize abnormalities when they occur.

During this instrument check on takeoff with the turbonormalizer, you will probably see a slight overboost on the MP if the engine oil temperature has not yet come up to full normal operating temperature. This is perfectly normal, very common on these engines, and an inch or two over redline MP won't hurt a thing. If it goes above that, go ahead and reduce the MP to approximately redline, but not below. As the oil warms, you'll need to add throttle again, to maintain that redline MP.

In summary, for takeoffs, full throttle, full redline RPM, and full redline fuel flow.

Climb

Unless you want to be a test pilot with your very expensive engine, climb should be at the power setting recommended by the manufacturer. That's generally a full rich mixture, and some specific MP and RPM. On any engine, if the manufacturer approves or permits full throttle, USE IT, all the way to cruise altitude. You won't hurt a thing, and it is probably better for your engine than some lesser power setting. If the manufacturer approves or permits full RPM, use that, too. Just like takeoff, resist the temptation to invent your own power settings.

With the Tornado Alley Turbo (TATurbo), more refined testing has been done on heavily instrumented engines for FAA certification, and a few minor exceptions result. During certification tests, in order to keep the CHTs down at altitudes around 15,000 feet, the fuel flow at the full rich position had to be set up so high that it is somewhat too rich at the lower altitudes. The result is that a little leaning at low altitudes is a good thing, as it will give you full rated power and a cleaner mixture, without getting too hot. I cannot tell you if other systems react the same way.

TATurbo has done a lot of research, and has developed what they believe to be the best way to operate the turbonormalized IO-520/550 engines in climb. I've found it works very well.

First, set the throttle to wide open for takeoff. You don't have to tease it in, and you don't have to baby it, just a nice, steady push, taking perhaps three to five seconds from idle to full power. Once fully open, LEAVE it there for the entire flight until time to control the speed during descent, or until time to reduce to traffic pattern speeds. Simple.

Just forget the throttle. Experienced pilots find this VERY difficult! One very senior pilot has flown my airplane a number of times now, and he knows I want full throttle, full RPM, and full rich mixture on takeoff. Instinctively, his hand will sneak towards that throttle at about 1,000 feet AGL, and he'll start backing it out, heading for the classic 25 inches. When I rap his knuckles, he'll say, "Yeah, yeah, I understand, but MAN, that's hard to get used to." He probably never will, the habit is so ingrained.

In addition to the wide-open throttle (WOT), use full RPM (generally 2700) for all takeoffs, and all climbs. Do your engine a favor, and check the tachometer for accuracy. If nothing else, use the strobe effect from the ramp lights at many airports. They flicker at 60 Hz, so you will see the prop "stop" at night from this effect at common multiples of this speed (check it at 2,400, for example). Or borrow a cheap optical RPM checker. If you're not an airline captain, heck, BUY one as a backup. Once you know what your tach is really reporting, have your mechanic adjust your maximum RPM on successive flights until it's as close to the redline value as you can get it. Certainly within 25 RPM. Go on, test his patience, it's good for building character.

In a Bonanza, I like to climb at about 120 knots IAS, for cooling. I like to do a gentle climb AND a gentle acceleration right from liftoff, while accelerating to 120. If you want to climb at lower speeds, be my guest, but I don't think it's worth it. And yes, I've heard all the arguments in favor of clawing for altitude, so you can turn back to the runway. Hogwash, most of it. By heating up your engine with a slow speed climb, you increase the chances of an engine failure at some time in the future, in my opinion. But that's just my opinion.

TATurbo says, for climb, rich of peak EGT (ROP), with their turbo installation, use the mixture, and:

- Below 10,000 feet MSL, adjust the Turbine Inlet Temperature (TIT) to about 1290°F.
- Above 10,000 feet MSL, adjust the TIT to about 1270°F.
- Above 17,000 feet MSL, adjust the TIT to about 1250°F.

In my opinion, those are GENERAL recommendations. There are variations between engines, so you will need to watch CHTs closely for a few times, to get a "feel" for what YOUR engine needs. In my airplane, those TITs put me pretty close to the self-imposed 380-400°F "limit," so I'll probably aim for a few degrees on the low side.

Notice the pattern? 1290, 1270, 1250. Five or ten degrees off the target probably won't matter, but 15 degrees off the target EGT can put your CHTs well over the limit. You may need to tweak the mixture a couple times during the climb, but basically, it's a very simple operation, and pretty easy to remember. Put a little Post-It note somewhere on your panel, until this is imprinted in your wetware.

In fact, I suspect that pilots could just use 1250°F during ROP climbs, with very little "cost." The higher the TIT you choose, the closer attention you'll have to pay to CHT. The lower the target TIT, the more you can relax. Experiment with yours, determine a number, and use it thereafter.

This concept of a "Target TIT" works very well in a very wide variety of turbocharged engines, not just the normalized versions. The "Target TIT" will be a bit higher in lower compression engines, as found in factory installations of the TSIO (turbosupercharged injected opposed) variety. There are at least three very beneficial results in using "Target TIT":

- First, the "Target TIT" will remain constant over a very wide range of outside air temperatures.
- Second, TIT reacts very quickly, allowing very positive control, and immediate detection of problems and abnormalities.
- Third, bubbles in the fuel from vaporization will show up immediately as a fast-rising, very much out-of-place TIT from the effective leaning (more air, less fuel). This vaporization is not abnormal, you'll see it a lot when operating these fire-breathers, and correcting for it is a perfectly normal, straightforward procedure. Fuel can get quite hot while an airplane bakes in the summer sun on the ramp, and if you climb to 18,000 feet, you're cutting the ambient pressure in half. Also, the climb rates are so much faster with turbos, the fuel doesn't have as much time to cool.

There's an exception. IF you have an all-cylinder monitor that shows CHT in one-degree increments, you MAY prefer to monitor the hottest CHT, instead. Pick a number, and try to maintain it somewhere near that number. Some might like the hottest CHT at 360, some might prefer to "push it" to 380 or even 390, for max performance. The JPI EDM-700 will show CHT in one-degree increments, and it reacts very quickly to mixture changes. I've tried both methods, and I think I prefer the CHT method myself. But without that one-degree capability, the “Target TIT” method is clearly superior. Take a peek at the CHTs once in awhile, to make sure they’re normal.

With ROP climbs and my IO-550 (TN), I find that I need a fair amount of manual leaning (still ROP!) during the early climb at low altitude (or even during takeoff), and then I have to slowly enrich during the climb, ending up at or near full rich at 15,000, in order to keep the CHTs where they should be (380). I may need to have my “maximum full rich fuel flow” tweaked a little, to give me some additional fuel flow at the full rich position. That will mean a little bit more leaning on the takeoff and early climb.

(Remember the mantra, “rich of peak (ROP), richer is cooler but lean of peak (LOP), richer is hotter.”)

If cooling requirements permit, you can get a better rate of climb above about 15,000 feet by reducing that 120-knot climb speed a little at a time, eventually dropping to around 105 at very high altitudes. It’s not necessary to memorize numbers, just realize that when you see the performance (climb rate) drop off, reducing the IAS a bit will help. This can be a subtle balance of climb needs and engine cooling. If CHTs are a problem up there, you may need to increase airspeed for cooling, and take the “hit” on climb rate.

At those TITs, you should never see a problem with CHT, unless there is a serious problem with the engine, but some problems can cause changes in the CHT, so don’t fail to monitor that parameter.

If you’re concerned about the performance for a short-field operation, you can lean it during takeoff just a bit more for maximum HP, to about 1310 to 1380. This will result in a fuel flow of as little as 24 GPH on a hot day (less power), to 30 GPH on a cold day (more power). Once performance is not a concern, you can return to the 1290, 1270, 1250 settings, as soon as you can, because CHTs will be rising slowly. If you leave the mixture set there, you’ll eventually see more than 400°F.

At no time should you EVER allow any CHT to go above 400°F, and this makes 380°F a good “target.” If your engine monitor has alarms (and it should!), then set it to reach out and hit your knee with a hammer if the CHT goes over 400°F. While climbing with the TIT showing, it wouldn’t hurt to note the hottest CHT, and check that from time to time. Don’t depend on the “missing bar,” as it is NOT RELIABLE for showing the value of CHT, at least on the JPI! It will show the hottest cylinder, in my experience, but it also wouldn’t hurt to do a quick scan of all digital CHTs, just to be sure you know which is the hottest. On some engines, the TIT may not be as accurate as you might like, and checking the CHTs will prevent this from causing a problem.

If you should happen to see one or more CHTs creeping up over 380, don’t panic, don’t flinch, and don’t scare your passengers with your reaction, but quietly DO SOMETHING about it! Open the cowl flaps more if you can, or increase the airspeed as necessary for cooling. If this fails to keep the CHT below 380, your fuel flow is not sufficient, and needs to be adjusted. If this happens consistently, and you have trouble keeping it down, it needs adjusting by a mechanic. Many/most of these engines absolutely require redline fuel flow, and many knowledgeable people, even at the factory, will quietly suggest just a tiny smidgeon more. Some engines will run nice and cool for the early climb, but you’ll see CHTs go up at some point on the way to cruise altitude. Engines with the TATurbo are usually the exception, they’ll be properly set up with a bit too much fuel flow at sea level, and a little leaning is usually beneficial.

If CHTs still persist above 380°F, with the mixture full rich, cowl flaps open, and airspeed higher than the normal climb speed, then as a final resort, go to first LOW boost (if it’s not already on from takeoff), and see what happens. Obviously, if you have only a one-speed electric boost pump, use that speed. If that doesn’t do it, then try HIGH on the electric boost, while remaining very alert to what the engine is telling you. High boost and full rich can flood the engine with too much fuel, and in some cases, can make you think you’ve lost the engine. Not good, at low altitude, so save this trick for well after takeoff.

Think about this “High” position, just in case you ever do need it. If despite your best efforts you’re “too hot” on the rich side of peak EGT, AND flipping the electric boost from LOW to HIGH gives you “too much” fuel, then the only remaining thing you can do is leave the boost pump on, but manually lean the mixture to the point where the engine does run properly, without getting too hot. In the end, the only thing that matters is how much fuel you are getting into the engine, and it matters not at all how it gets there.

By using TATurbo's "Target TIT" method, you will see fairly large variations in fuel flow, depending on the OAT. On very cold days, you'll see high fuel flow, perhaps as much as 35 GPH, on very hot days as little as 24 GPH. This is quite normal, a BENEFIT of using the target TIT method. On cold days, your engine will produce more power, which needs more fuel. On hot days, the reverse is true. This technique handles both, without thinking about it.

In summary, for climb, full throttle, full RPM (or maybe 200 less, but no less than that!), and mixture adjusted to 1290, 1270 and 1250.

Test Pilots

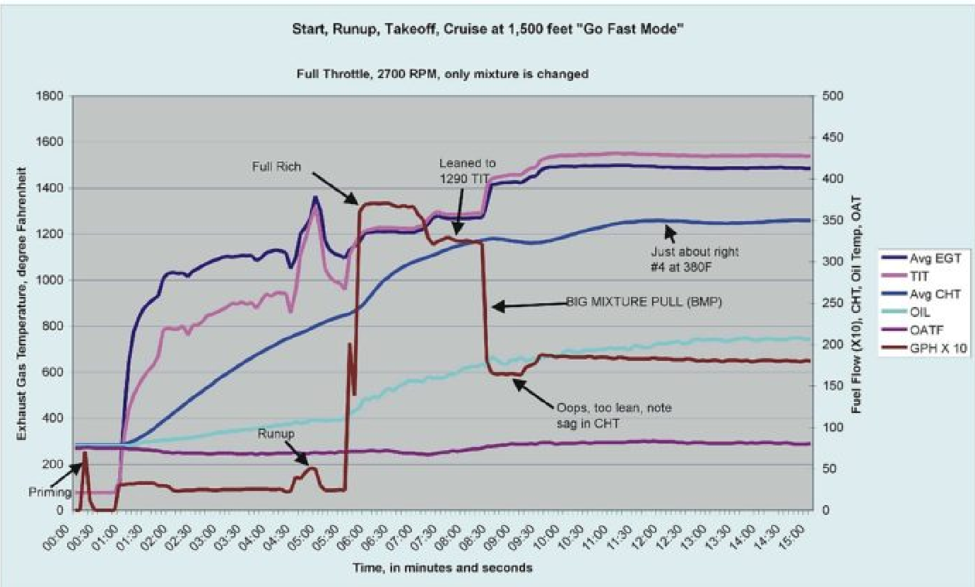
Now, it's true, you may have heard of some of us who will climb to some low altitude (1,000 feet AGL is common), and then do "The Big Pull," or the "Big Mixture Pull" (BMP), drastically reducing the mixture to a setting very lean of peak EGT, and climbing to altitude that way. Again, this is not for the faint of heart, for it puts us in the test pilot category. More than any other phase of flight, you really, really need to know exactly what you're doing, have the instrumentation to do it, and pay close attention, for this procedure operates much closer to the edge. In the future, this may become a common procedure, but it's still too new, with too many unknowns, to recommend it for the average user.

So, in summary, climb at WOT, ROP, full RPM, and leaned slightly to a TIT of 1290, 1270, and 1250 (or what YOUR engine likes), cowl flaps open, and keep an eye on the CHTs. DO NOT use partial throttle settings, unless there is a serious overboost, and then only until it goes away. You will almost certainly need to tweak the mixture a few times during the climb to maintain these values. In general, there are very few cases where precise temperature control really makes much difference, but TIT during climb is important. Only 15 or 20 degrees of error may produce CHTs in the danger zone, over 400°F. With a little practice, monitoring the TIT during climb will become very natural, and remember, you no longer have to worry about anything else! If you have a monitor with an alarm set to warn you of anything over 390 or 400, you need only watch the TIT. If there is no warning, I suggest you set fuel flow by the TIT, but continuously monitor the hottest CHT at all other times.

Remember too, this climb is ROP, where "leaner is hotter, richer is cooler." Later, we will get into LOP operation, where "Leaner is cooler, richer is hotter." For most pilots, this is a very new concept, and very alien!

How does all this look when the data is charted?

Here is the data from a flight I did on September 9, from Camarillo, Calif., to Santa Barbara, cruising at 1,500 feet. This is "Go REALLY Fast" mode!



Click for higher-resolution image.

For a less complex chart, I have plotted the AVERAGE EGT and the TIT (Turbine Inlet Temperature) against the scale on the left side of the chart. I have also plotted the AVERAGE CHT against the scale on the RIGHT side. I have multiplied the fuel flow by 10, in order to make it much more obvious, and I have plotted it against the scale on the right. OAT (Outside Air Temperature) and oil temperature are also plotted against the scale on the right. Data was recorded at six-second intervals.

Note this plotting exaggerates the CHT trace a bit, but even so, it shows a nice, steady, smooth rise, leveling out at an AVERAGE of about 360 or 370. The hottest CHT (#4 on my engine) was right at 390, and stable after the BMP (Big Mixture Pull). What you are looking at here is my engine run at the absolute maximum power I'll run it, WOTLOPSOP (Wide Open Throttle, Lean Of Peak, Standard Operating Procedure). Multiplying the fuel flow (18.0 GPH) by 14.9 (the constant for this engine), we know this is 268 HP, or a whopping 89%. Indicated airspeed was in the 180 knot range, but the flight was too short to nail it down.

In the lower left corner we start the engine, cold. The spike to about 6 GPH is with the throttle cracked, mixture full rich, and high boost for a few seconds. The boost was turned off, and the fuel flow drops to zero. The engine starts at the 1:00 (one minute) point, and the EGT and TIT rise quickly to normal ground operating temperatures of just over 1,000°F. CHT starts up much more slowly, as it takes time to heat the mass of the engine. The "bump" in the fuel flow at the five-minute point is the runup, also shown by TIT and EGT spikes.

The sudden steep rise at about six minutes is the takeoff, rising quickly to about 38 GPH.

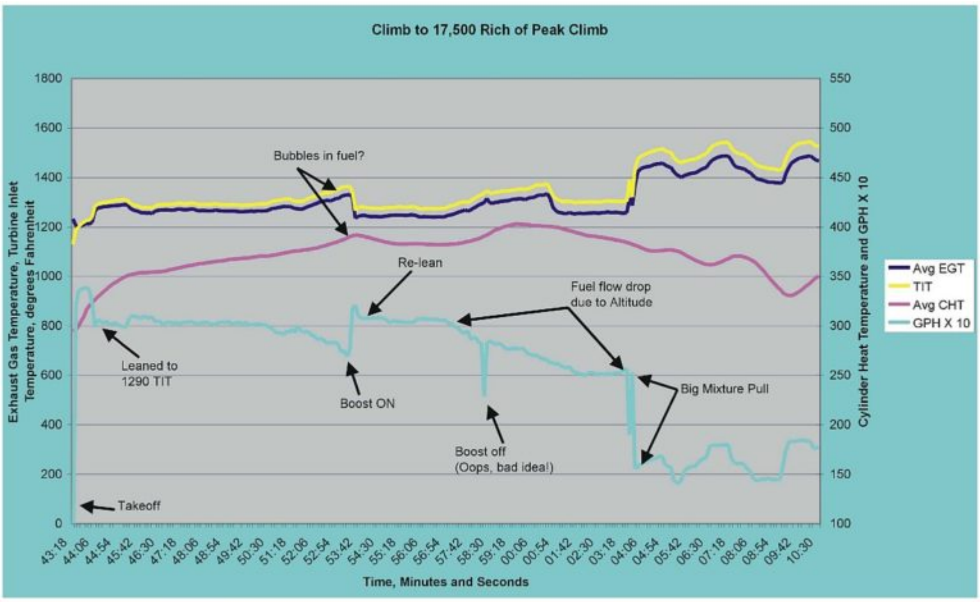
The little "jaggie" at the halfway point is interesting. Test data has a way of showing pilot screw-ups, and this was a minor one. We were on the runup pad and called "ready." The tower controller came back with "I have a Cessna on a one-mile final, if you can take off without delay, absolutely without any delay, you're cleared for takeoff."

I was crossing the yaller lines about sixty degrees to the runway heading, when he said "absolutely," with the power coming up hard, and realized maybe I ought to back off just a little, or I'd have a tough time staying on the runway. The "jaggie" is the result. As soon as it felt "better," I shoved it in all the way, the airplane drifted in a big arc to nearly the far side of the runway, and away we went.

I held that full-bore power setting to gear up, then leaned to about 1290 TIT for the short climb to 1,500 feet. I leveled out, closed the cowl flaps, let the speed build (to over 180 knots), and then did the BMP, as shown, right back to roughly 16 GPH. I cycled the JPI to show the hottest CHT, and #4 showed about 360, and falling. Here's where that one-degree resolution is so neat, it shows the trend instantly! So I enriched to almost 18 GPH, and the CHT started tick, tick, ticking up towards my target of 380. In the final stage of this short flight, #4 was right around 380 to 390, which is "close enough."

It is also impressive how solid the Bonanza feels at 180 knots indicated!

After landing at SBA and dropping my passenger, I did a special data-gathering flight. While we are not suggesting LOP climbs, I do them routinely myself, so this was my first experience at doing a ROP climb. I find the resulting data absolutely fascinating from many standpoints, and I hope you do, too.



Click for higher-resolution image.

The time across the bottom of this one is actual time, with the hour dropped. I meant to convert that to start from zero and show elapsed time, but by the time I'd done the chart and realized that omission, I was out of time. The chart actually starts at 17:43:18, and runs to 18:10:30.

The takeoff is at the extreme left, and shows the initial flow of 34 GPH, somewhat too rich. Right after liftoff, I leaned to 1290 TIT for the ROP climb. Rate of climb was within a second or two of 1,000 feet every minute, so the time across the bottom can also be read as altitude. 120 knots IAS for the entire climb, except after 16,000 feet.

Right around 10,000 feet, EGT and TIT started rising abnormally. It was a hot day on the ground, and the fuel in my tanks was quite warm, so I'm theorizing that with the drop in pressure at 10,000 feet, the fuel was beginning to develop tiny bubbles. Tiny bubbles in champagne make the nose itch, and tiny bubbles in avgas makes the engine's nose itch, too. More precisely, the fuel and bubbles don't change the indication of fuel flow nearly as much as the bubbles effectively lean the mixture. Air is air, no matter how it gets to the combustion chamber. It took me almost two minutes to catch on to this, and I finally hit the boost pump at about 53:42.

As you can see, the effect of the additional fuel flow (or "more fuel, less bubbles") was immediate. EGT/TIT dropped instantly, and CHT started ticking right back down again. In fact, low boost resulted in too much fuel, so I had to lean it out some more with the mixture control.

At 58:30, I momentarily turned the boost off to see what would happen, and didn't like it. EGT/TIT instantly started up, and I discovered that by this time I was getting very close to full rich on the mixture control, with no further control left. With the boost on, mixture full rich, the fuel flow continued to drop off with altitude due to the altitude compensating fuel pump (I think), and the CHTs started a slow rise that I could not control without changing airspeed. Cowl flaps were fully open, at this point.

For the purposes of this test, I let it go until the hottest CHT (good old #4) was 421, and that was all the testing I was interested in subjecting my engine to, thank you very much. There IS a limit on what I'll do for my readers! I pushed the nose over to 140 knots, and the CHT came right back down, average 380, hottest just over 400, while I continued the climb to 17,500.

Once stabilized at 17,500, I did the BMP, and monkeyed around with it for a time to show the effects. Note the EGTs go much higher, with the TIT higher still. This is probably because the TIT probe is seeing the full heat all the time, and is not seeing the hot, cold, hot that the EGT sees for each cylinder, as the exhaust valves open and close. At about 05:42, I got it really lean, about 14 GPH (196 HP, or 65%).

Next column, we'll get into cruise and descents, including a neat method for descending at 2500 FPM, without shock cooling the engine, and without speed brakes. Sorry, I don't like speed brakes.

Be careful up there!