Pelican's Perch #36: Those Fire-Breathing Turbos (Part 6 – and FINAL!)

AVweb's John Deakin concludes his six-part powerplant management series with a discussion of the procedures he uses during descent, approach (including missed-approach), landing, and shutdown. In the process, he debunks some Old Wives' Tales about

John Deakin November 12, 2000

Okay, let's tie the ribbons on this series by discussing the right way to manage our turbocharged powerplant at the end of our flight when it's time to get our airplane down from altitude and back on terra firma. (We've been airborne for five months now, and frankly I'm ready to stretch my legs and take a pit stop!)

Descent

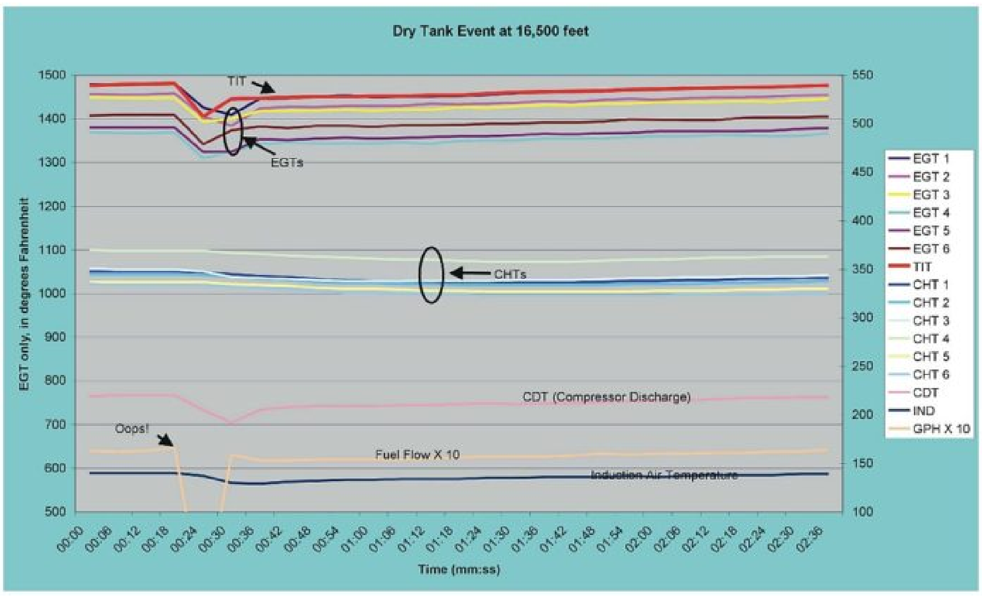
Some will call it heresy, but I'm not a big believer in "shock cooling," and I'm certainly not a fan of some of the exaggerated techniques used by some to combat it. I was amazed the first time I heard of the technique of limiting MP reductions to not more than one inch in two minutes. I can sympathize with owners who will go to extreme measures to protect their very expensive engines, but I've always felt that an inch of MP per two minutes goes well beyond extreme.

There's no data, of course. With large fleets of airplanes, highly standardized operations and detailed record keeping, we might come up with some evidence one way or the other on this issue, but that's simply not going to happen.

But that doesn't mean I yank power off, or move any controls in a rough or abrupt manner, either! With a little knowledge, and decent instrumentation, it's pretty easy to control the engine temperatures, and still get the job done with very little extra workload.

[I am a real fanatic about reducing workload, but some will call that laziness. I hate "busy work." One of the things I like about lean-of-peak (LOP) operation is that it's less work, once you know how, and become accustomed to it.]

Speaking of shock cooling, I'd like to show you a related graph of some very recent data from my own airplane. I was at 16,500 feet, normal cruise when a fuel tank ran dry. It caught me by complete surprise, the engine quit, sputtered halfway to life on a little bit of extra fuel, then quit cold again. I had a bottle of water sitting on top of the fuel selector, so I had to move that before selecting the other tank. I just happened to have my computer running, and logging data at the time. I snipped out a couple of minutes of that data around the event, and graphed them for you.



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On this chart, the left side scale shows only EGT and TIT. All other data is referenced to the RIGHT side of the chart. All data is read directly, except fuel flow, which I have multiplied by 10 to get it on the chart.

To me, the most remarkable thing about this chart is how little change there was! At the 18-second mark, the fuel runs out, as evidenced by the red fuel flow line dropping sharply. Within six seconds, I got the fuel back on, and within another six seconds, the engine was running normally again. I put the boost pump on low for a moment, until the engine caught, but it wasn’t really necessary.

The TIT and the EGTs dropped only about 50°F or 60°F, the CDT (Compressor Discharge Temperature) dropped about 20°F, probably from the turbo slowing down a bit. The IAT (Induction Air Temperature) dropped only slightly, following the CDT.

But, look at the CHTs! They hardly moved at all, dropping slowly about 10°F, and then recovering very slowly.

The most severe case is the need for a rapid descent from high altitude, and if we run through some of the techniques for that case, then we have covered the bases. Once you understand how to handle this “crash dive,” the methods for doing the gentler descents should be obvious.

The first rule in avoiding “shock cooling” is to not let the CHTs get too hot to begin with! It is physically impossible to “shock cool” anything that is not already “too hot.” If there is any merit to the conventional wisdom about “shock cooling,” I suggest that is probably mostly based on experiences in which the engine, at cruise, at the point of the initial power reduction, was already operating well into the 410°F to 440°F range, which is much “too hot.” If you keep the CHTs cooler, say down around 380°F, then it becomes very much harder to accept the idea that you are going to “shock cool” the CHT by even large power reductions. If you understand and follow the practices outlined below, I believe “shock cooling” will become a much less common subject for hangar talk.

A Word About Descent Speeds

Many believe it is safe to fly at airspeeds in the yellow arc if conditions are smooth. That’s not what the FAA intends – the regulations say the yellow arc is for “for inadvertent, momentary overspeed only.” *(2004 correction by the author: That language does not currently appear in the FAA regulations. It does appear in several operating manuals, but those are not regulatory. My opinion of trespassing into the yellow remains unchanged, but I do apologize for misquoting the FAA regs.)*

Talk to anyone who has ever crossed the wake of another airplane. Some of those encounters have produced 10g on recording g-meters, and some may have been responsible for a few of the more mysterious in-flight breakups. Also, how many times have you seen turbulence go from “none,” to “ouch, that hurts” almost instantly? This is very common over mountainous terrain. What do you do when that happens, you’re “too fast,” and you want to slow down? Why, you pull the nose up, right? Wrong, maybe, that just adds to the loading on the wings, even if only momentarily. My suggestion is to stay out of the yellow in the first place, and if you need to slow down, get the power back. Be VERY careful raising the nose in a sudden turbulence situation.

Turbulence speeds are not chosen because they feel good, they are mathematically calculated, and it’s fairly straightforward. You take the square root of the design load factor (3.8g in most of our small airplanes, only 2.5g in transports), and multiply the result by the stalling speed. The square root of 3.8 (roughly 4) is (roughly) 2, so your turbulence speed will be (roughly) twice the clean stalling speed in almost any general aviation aircraft in the “Normal” category. 60 knots at the 1g stall (straight and level) means that you will stall at 120 knots if you pull 4.0g … for any reason. In effect, if you are at or below the published turbulence speed for your airplane, the wings will stall before anything on the airplane breaks.

What is REALLY scary is if you run some of the higher numbers. Suppose you are at 160 knots in the same airplane, and hit the wake from a 757 that passed a few minutes ago? It will now take 7.0g to stall the wings! Will your forty-year-old airplane take 7.0g without damage? Suppose you’re at 180 knots? Your wings will not stall until you hit 9.0g!

Pay attention to that yellow arc, and in general, stay out of it.

Let us assume we are cruising merrily along at the usual 17,500 feet, 210 knots true, with the hottest CHT around 380°F, and the TIT around 1550°F. Everyone aboard is experienced at clearing his or her ears during a rapid descent. Of course, we're LOP. We know there's turbulence at lower altitudes, or there's a thick layer of icing conditions, or perhaps you know that Center is going to keep you high, then give you a "crowbar."

"Crowbar," you ask? That's where you open the cockpit window, throw a crowbar out, and then try to beat it to the ground. Just consider one of those times you've looked longingly at the ads for speed brakes. Now, let me show you why you don't need them!

As a point of reference, no matter how you handle the engine during descent, approach, landing, and taxi to the hangar, you'll rarely find your CHT very far from 290°F or 300°F, as you get ready to shut down. That means a gradual cooling from about 380°F to 300°F should satisfy even the most particular pilot, right? That's only 80 degrees!

If you're really worried about this, why not "pre-cool" the engine? There are several easy ways to do this:

1. Drop the nose and begin a very gentle descent a little early with no power change. You'll see the CHT drop with the increased cooling airflow.
2. Lean the engine even more, in small stages, remembering, "Leaner is cooler." Also note that a bit leaner at this point will produce less power, which will help you get down.
3. Reduce 100 RPM at a time, to 2100 or even less (unless your tach has a yellow or red arc that prohibits this, of course). This will further cool the engine, and reduce power.
4. Open the cowl flaps a little.

Any of those will start the "pre-cooling" process, and they may be used together, in any combination to get the job done, to reduce your engine temperatures at any rate you want, to any value. You can easily drop the CHTs to 290°F or so, and keep them there all the way to the hangar.

When you are happy with the results, and cannot reduce power any more with leaning and/or lower RPM, it's time for yet another "Big Pull," but this time it's the throttle. Just firmly pull it right back to 18 or 20 inches of MP (from 31 inches), within a few seconds.

Let us pause here a few minutes, to give the "inch in two minutes" folks a chance to recover, for most of them have fainted dead away at this thought!

On my airplane, this particular "big pull" will hardly change the EGT, TIT, or CHT at all! How can this be? Well, either by serendipity or good design, if I am running WOTLOPSOP ("Wide Open Throttle, Lean of Peak, Standard Operating Procedure"), and simply pull the MP back to 18 inches or so, the linkages are just about perfect to leave me at the far lower MP setting, but just on the RICH side of peak EGT, without ever touching the mixture control. I'm usually unable to resist fiddling with the mixture a bit (Hmmm, what DID I just say about workload?) I enrich a little and see the EGT fall (indicating ROP operation). I'll turn the knob back towards lean a bit, find peak EGT (or TIT), then I enrich it slightly, usually ending up right where I was, right after the big throttle pull.

This leaves us with about 18 inches of MP, 2100 RPM, and stable engine temperatures. You will need the usual further reductions in throttle during the descent, as increasing atmospheric pressure causes the MP to rise, and as the IAS increases towards (or into) the yellow arc.

Rapid descent is the one time you WANT the absolutely hottest temperatures you can get, to go along with the very low power you need to get down. By controlling the POWER with the THROTTLE, and the TEMPERATURE with the MIXTURE, you can very neatly accomplish a descent of up to 2,500 FPM in a Bonanza!

Many general aviation pilots customarily just push the mixture to full rich when beginning descent. I shudder at the thought! They are not only getting the cooling from the low power and excess airspeed, but they are throwing all that extra fuel in, adding to the cooling! Furthermore, if they have been cruising at high altitude in a turbocharged aircraft, the fuel in the tanks has cold soaked, and it may now be -10 or -20°C, itself. And you are spraying gobs of that fuel out of a fuel injector, directly onto the cylinder head structure in the area around the intake valve. Would you go out to a very hot engine and deliberately squirt a stream of cold water on one of the very hottest parts of the engine? That is precisely what you do when you decide to run move the mixture to full rich under those conditions.

Now THAT is "shock cooling," if you want to believe in the concept at all!

These tricks will easily give us about 1,000 fpm descent. Want more? Slow down, extend the gear, then descend at the maximum gear speed. (This works best if you have a fairly high gear speed, and may not be effective at all with a low gear speed.) One word of caution here, if you expect ice that you will not shed before landing, you might want to reconsider gear extension. It may get you down through the icing layer more quickly, but it may also leave you with a lot of ice on the gear, adding drag, and the gear may foul it if you try to retract it. This one is best used if you expect to keep the gear down all the way to the landing, or you're SURE there's no ice in the descent, or there is a known warm layer to melt the ice off. Like so many things in aviation, it's a judgment call.

Approach

The approach is nothing more than a continuation of the descent, as far as engine management goes. By the time you arrive at the approach fix, or the beginning of your pattern entry, your engine (and your turbo) should be cooled to just about the coldest it's going to get. My CHTs run a consistent 290°F at the end of this cooling process (during descent). You can mess this up by boring holes in the sky with your gear down and high power, which runs the temps back up again, or you can use just enough power to sneak around in the clean configuration until you need the gear.

How Cold Is "Too Cold"?

The subject of minimum CHT comes up fairly often. Few manuals show a real limitation. In the big radials, you will often find a figure somewhere around 100°C (212°F) as minimum for takeoff. The metallurgy isn't much different, and the principles are the same, so that would seem to be pretty strong evidence. If an engine can go straight to full power (sometimes 60 inches of MP, 2800 RPM) with a CHT that low, then there can't be much worry about damage to the engine! Some of the big radials have suggestions to maintain CHTs within a fairly narrow range in cruise, but that is for efficiency, not to "save the engine."

According to George Braly of GAMI:

> *Many POHs give the normal "operating range" for CHT for TCM engines as being between 240°F and 460°F. The operating specifications in the TCM manual do not even list a "minimum" temperature for CHTs, although in one place, TCM suggests not going below 300F for more than five minutes. It is hard to reconcile these various different recommendations. It is even harder to reconcile this discrepancy when one considers that a number of big bore TCM engine installations, in a variety of well baffled aircraft, will cruise with several cylinder heads at temperatures as low as 280°F to 290°F, even at high power settings. Some of these engines have lots of time on them with absolutely no engine problems.*
>
> *One set of cylinders we have some data on were used for customer demonstrations in a turbo engine installation. The aircraft was repeatedly climbed at full power to 18,000 feet, operated at very high power cruise for 30 minutes or so, then put through a low power, high rate of descent, "slam dunk" back to near sea level. The CHTs were often down to the 250°F to 260°F range during the later portion of those demonstration descents. The descents were otherwise conducted in a manner very similar to that described in this article. Those cylinders were pulled for detailed dimensional inspection after 800 hours of that kind of severe operation. The cylinder barrels and pistons all remained within new dimensional limits, including the critical choke areas of the barrels. The cylinders were completely free of cracks of any kind. Due to the operating environment, these cylinders probably experienced several times the aggregate "cold shock" abuse than would any normal private owner's engine during even two or more TBO runs! But note, those cylinders were not typically operated over 380°F during cruise, and the low power descents were managed in the manner described, so as to not dump cold fuel into the cylinders and so as to maintain the EGTs and TIT at maximum values during the descents, all of which had the overall effect of minimizing the rate of change in the cylinder head temperatures.*

PLEASE don't run your prop up to high RPM in the pattern, or you'll contribute to the ill will at the next town meeting to close the airport.

Landing

If you haven't touched the prop and mixture controls prior to the landing, there's no need to mess with them now. If you have reset them, take a moment to re-lean the mixture as suggested for taxi-out.

Go-Around (Missed Approach or Rejected Landing)

You need to fix the power management for this procedure firmly in your mind, practice it thoroughly, and stick to it every time. The traditional method is “Mixture (rich), Prop (full forward), and Throttle (full forward),” in that order.

The most conservative method is to set your mixture to full rich before you enter the pattern (after you’ve cooled things down as above).

You may wish to modify this slightly with some engines at some airports, as they may be set up a bit too rich for full power at sea level, and the non-supercharged engines will definitely need to be leaned for best power at higher airports.

It is more important to be mentally prepared for this perfectly normal maneuver than to have all the controls in the cockpit set for it. It is perfectly safe to make the approach AND landing with the prop set to a low RPM, and the mixture set to LOP, PROVIDED you train yourself to take the above actions in a reasonably expeditious (but not rushed) manner. You MUST practice this, until it becomes second nature. For many pilots, just jamming the throttle in is about all they can be expected to remember, and for them, the classic approach is best.

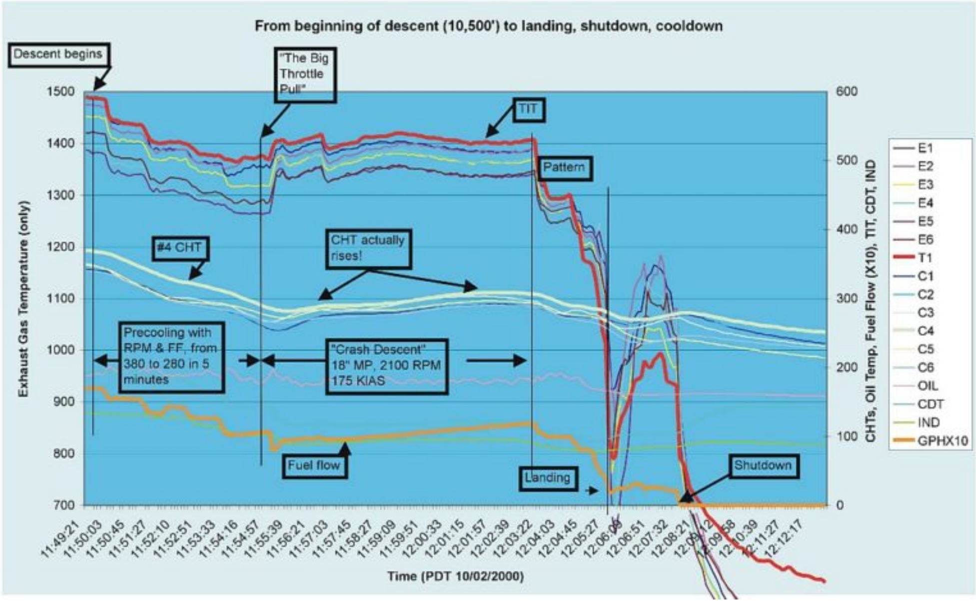
Cooldown/Shutdown

I would guess that when you see (and hear!) someone running their engine in the parking spot after landing “to cool the turbo,” you are almost always seeing someone who is getting it hotter than it was when he arrived at the spot. If you don’t make the high-drag approaches, and you lean brutally after landing, that turbo will be just about as cold as it will ever get, short of a shutdown. On the other hand, if you’ve made a long, high-drag approach with high power, or you’re one of those dreadful types who taxi with cruise power while dragging the brakes to keep the speed down, or you have a long, sharply uphill taxi to the ramp, you may need the cool down. A tip that might do your engine more good is to hop right out after shutdown, and pop the cowling open (or even just the oil access door) if you can. That will let a LOT of heat out of the accessory section, avoiding “cooking” the components, hoses, and seals there. But even that little tip is probably completely unnecessary if there is more than 3-5 knots of wind blowing in the general direction of either the front or the back (cowl flaps open, please) of the engine.

George Braly again:

> *We know of one operator of a turbo twin Cessna. He owned the aircraft for 15 years before the issue of “turbo cool down” ever showed up in the aviation literature. Through three full TBO runs, with almost no premature engine or turbo problems, this operator would routinely land at his uncontrolled airport, turn off at mid-field, taxi about 100 yards, and immediately shut down both engines. The aircraft was then promptly pushed into a T-hangar, where it could not benefit from any natural wind for a further cool down. These would have been ideal conditions to promote problems with turbochargers not being properly allowed to cool down, if there was any truth to this OWT. This operator, in more than 8000 engine hours, never experienced any problems with the issue of “coking” a bearing on a turbocharger.*

Finally, here’s a graph of the type of descent I’ve just described.



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The chart begins at 11:49:21 PDT, on 10/02/2000, at 10,500 feet. Note that TIT and EGT is read against the left side numbers, while all other parameters are read against the right side. For the first five minutes, I pre-cool the CHTs by beginning a gentle descent, and reducing RPM and fuel flow on the lean side. That CHT drop too fast for you? Fine, you have complete control over how fast you drop the CHTs, take all the time you want.

At about 11:55:00, I simply pulled the throttle back, and dropped the MP from 31.0″ to 18.0″. In order to demonstrate where the mixture ended up to a passenger, I fiddled with it a bit, and added just a bit of fuel. In fact, it would probably have been better if I'd just left it alone (as I usually do) because that extra tweak actually caused the CHTs and EGTs to RISE! Uhh, what WERE you saying about "shock cooling"? We have just pulled off 12 full inches of MP in one swell foop, and all engine temps go UP! The reason is, of course, we have gone from very LOP (and relatively cool CHTs) at a very high power setting, to just ROP at a very low setting. The linkages in my engine are "just right" for this purpose, yours may vary, but at worst, you'll need to fiddle with the mixture once, to get it just ROP, or wherever you want it.

For the next 10 minutes on the chart, we descend at about 1,000 fpm, at about 140 knots, gear up. If I'd wanted more descent, all I had to do was run the IAS up to the bottom of the yellow arc, or put the gear down, or even pull off more MP. For a couple minutes in the pattern, the CHTs dropped very gently and then they rise a bit while taxiing in. At shutdown, they begin a long, slow cooling process.

Well, we've gone from startup to shutdown, with a "flight time" of five months! I hope I've not led you too far astray, and above all, I hope I've made you think.

I think I'll take a break from engines, for a while!

Be careful up there!