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TIME TO OVERHAUL?

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Engine problems need to be taken seriously, but let's not overreact.

by Mike Busch

The engine problem surfaced just 11 hours after the aircraft came out of annual. The owner had crossed the Sierra Nevada Mountains VFR at 12,500 feet westbound en route to the Bay Area, and was descending through 11,000 feet when he felt a bit of engine roughness. After doing an in-flight mag check and studying his engine data - which showed elevated EGT on cylinder #3 - his initial reaction was that he probably had a bad spark plug.

But the problem became worse; after landing, the pilot took the airplane to a local mechanic and asked him to perform a compression check. The #3 cylinder measured 20/80 with air whistling past the exhaust valve. Clearly the cylinder was going to have to come off and the exhaust valve and seat replaced.

Nothing unusual here; exhaust valve problems in TCM engines are commonplace. It happens all the time. More interesting by far was how the owner reacted to this burned valve episode. Here's a brief excerpt of the email he sent to the Director of Maintenance at his service center:

> *"I think the valve may have been burning itself (or the valve seat) to a worse condition as I continued to fly. I am glad I did not tempt myself with the idea of flying it home. It may have burned right through and started an engine compartment fire. No thanks!*
>
> *"At annual, you told me one of the cylinders had a hint of exhaust leak and that the TCM service bulletin said this was okay, but that we should keep an eye on it. Which cylinder was that? I could not find it in the logs.*
>
> *"Assuming a stuck exhaust valve, how do we determine if the cylinder can be saved for a while longer? If it can't, I think our cylinders are old enough that we should do all six, and the bottom is far enough along toward TBO, that it might be time for a major overhaul."*

Whoa! Change all six cylinders because of one burned exhaust valve? Pull the engine for major overhaul? Wow, talk about an overreaction!

Clearly this owner did not have even the most rudimentary understanding of exhaust valve failures in TCM engines, or the consequences of such failures.

Failure Mode

For one thing, exhaust valves fail quite slowly. When an exhaust valve starts to leak, it develops hot spots that create an asymmetrical pattern of exhaust deposits on the face of the valve, and later a distinctive greenish color. Both are quite obvious during borescope inspection of the cylinder. Typically, these telltale signs become visible under the borescope roughly 100 hours before the problem progresses to the point where the valve actually fails in flight.

The owner's expressed belief that "the valve may have been burning itself (or the valve seat) to a worse condition as I continued to fly" was simply wrong. Exhaust valve failure simply does not progress that rapidly.

FIGURE 1: *A "swallowed" exhaust valve, like this one, is very unlikely if you have regular borescope inspections and keep an eye on your engine monitor. But if it happens, it will definitely get your attention.*

A cylinder with a compression measurement of 20/80 has so little leakage past the exhaust valve that no pilot could possibly perceive it in flight, other than by studying his engine monitor. The effect on engine performance would be so slight as to be imperceptible. The only way exhaust valve leakage would produce perceptible engine roughness would be if the valve was leaking so badly that the cylinder was no longer capable of combustion. That can happen in one of two ways: either the valve fails completely by shedding a chunk of metal ("swallowed valve"), or the valve gets stuck in its valve guide and cannot close ("stuck valve"). However, if either of those two things had occurred, the cylinder would have measured 0/80, not 20/80. So clearly they didn't.

Big-bore TCM engines do have leaking exhaust valve problems quite regularly, and if they are not detected in a timely fashion, through regular compression tests and borescope inspections, they can progress to the point of actual valve failure ("swallowed valve"). But that progression is relatively slow - occurring over a period of many hours, not in a period of minutes. A leaking exhaust valve can typically be detected via borescope inspection on the order of 100 hours before the valve fails. It can also be detected via the engine monitor perhaps 25 hours before the valve fails, provided the pilot knows what to look for, and most don't.

By contrast, stuck valves are extremely rare on big-bore TCM engines. They are quite common on Lycoming engines, whose exhaust valve and guides are constructed quite differently, but we seldom see this kind of failure on TCM engines. The owner's email makes it sound like he did not understand the distinction between a burned valve and a stuck valve. They are entirely different phenomena.

Failure Consequences

What are the consequences of an exhaust valve failure (or a stuck valve)? Very simply, it will shut down the cylinder (no compression or combustion) and turn your six-cylinder engine into a five-cylinder engine. The result is obvious engine roughness, a noticeable loss of power, and an EGT in the bad cylinder that drops suddenly off-scale low, followed by a CHT that does the same but much more slowly.

You will not fall out of the sky. You should probably land at the earliest opportunity. You might even key your mike and say the M-word or the E-word to ATC. If you're the nervous type, there's a chance you'll need a change of underwear. But in the overall scheme of things, it won't be that big a deal.

The owner was clearly concerned about the possibility of an in-flight fire, but there's almost no risk of that happening. The failed (or stuck) exhaust valve shuts down combustion in the cylinder. Fuel and air will continue to flow into the dead cylinder and then proceed unburned into the exhaust system, where it will merge with, and be ignited by, the hot exhaust gas from neighboring cylinders. You may experience an abnormal popping noise, technically known as an "after-fire" inside the exhaust system, that might add to your anxiety and perhaps your undergarment situation, but the phenomenon will remain fully contained by the exhaust system and not create a fire hazard. The likelihood of any consequential damage to the exhaust system, muffler, or turbocharger (if you have one) is extremely remote.

Basically, your mechanic will have to remove the cylinder, have its exhaust valve and guide replaced and the valve seat reground, reinstall it on the engine, and you're good to go. The total repair cost, parts and labor combined, will typically not exceed two Basic Airplane Units ($2,000).

Unless, you turn this molehill into a mountain...

Top Overhaul?

When a mid-TBO engine is found to have one or two bad cylinders, owners and/or their mechanics often overreact by replacing all six cylinders - a procedure commonly referred to as a "top overhaul." The cost of "topping" an IO-550-N with six new TCM cylinders is generally about 13 BAUs - six new cylinders at $1,900 each, plus around 20 hours in labor for removal and reinstallation. (If you install ECiTitan cylinders or reconditioned TCM cylinders, the cost might be as little as 9 BAUs.)

The assumption implicit in an owner's decision or a mechanic's advice to "top" an engine is that if one or two cylinders are unairworthy and require replacement now, the other cylinders are likely to follow suit shortly, and so the owner would be wise to "bite the bullet" and replace them all at once, rather than prolonging the agony by doing it on the installment plan. It's not uncommon for mechanics to tell owners that it's "normal" or "typical" for big-bore TCM engines (particularly turbo-charged ones) to need a top overhaul at mid-TBO.

In my experience, such advice is simply wrong. I've owned a turbocharged TCM-powered twin for more than two decades, and put 4,500 hours on its two engines during that time. Over the course of those 23 years, I've repaired or replaced four cylinders (out of twelve). Each of those four cylinder changes occurred hundreds of hours and many years apart, and were done for a variety of unrelated reasons.

A Tale of Four Cylinders

The first of these cylinders was replaced nearly 20 years ago when a sharp-eyed IA discovered a faint blue fuel stain on a cylinder head during an annual inspection. (This was long before I became an A&P/IA myself.) Dye-penetrant inspection revealed clearly that there was a crack in the cylinder head between the fuel injector boss and the top spark plug hole, a very common place for TCM cylinder heads to crack. (We see such head cracks in Cirrus aircraft on a regular basis.)

Naturally, when this head crack was discovered, I wondered how long it would be before head cracks started showing up on my 11 other cylinders. As it turned out, those 11 cylinders ran another 20 years and 2,500 hours before another head crack occurred.

FIGURE 2: *Cylinder head cracks are not uncommon, and become increasingly likely with increasing operating hours.*

The second cylinder was replaced about five years later when it "swallowed" an exhaust valve. (This was back in the Dark Ages before we used borescopes and modern digital engine monitors. Today, the problem would have been detected long before the valve failed.) When " removed the cylinder and extracted the broken exhaust valve, it was apparent that the valve failed because of an improperly manufactured exhaust valve guide that had gouged large quantities of chrome plating from the exhaust valve stem.

Naturally, when this defective exhaust valve guide was found, I wondered how long it would be before my other 11 cylinders started to swallow their exhaust valves. After all, they all had the same kind of valve guide, probably from the same box. As it turned out, I didn't have another exhaust valve problem for the next 2,000 hours.

The third cylinder was replaced in 2002 when a compression check at annual revealed compressions in the high 50s with air audibly leaking past the exhaust valve. In accordance with TCM's then-current service bulletin M84-15, which stated that no leakage past the valves was acceptable, I removed the cylinder but couldn't see anything wrong with it. Nevertheless, I had a local cylinder shop re-valve the cylinder, and I reinstalled it.

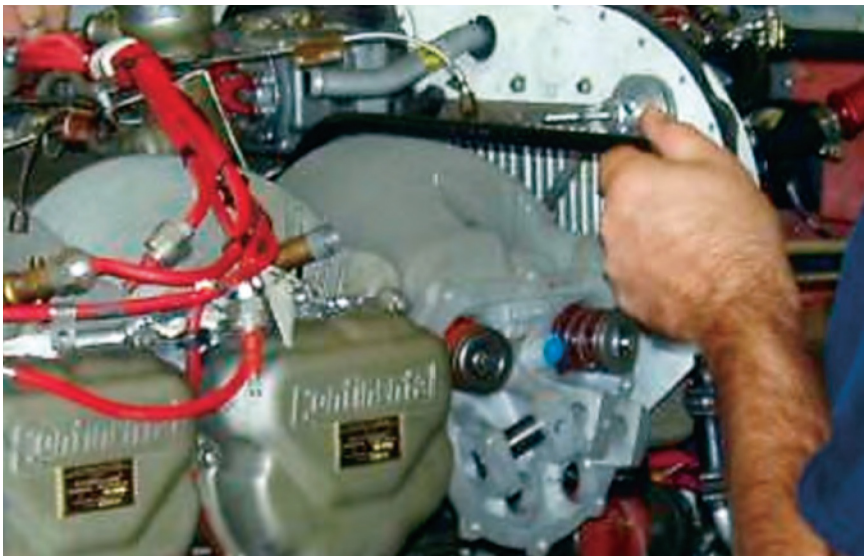

FIGURE 3: *Repairing or replacing a cylinder is no big deal. However, replacing all six ("top overhaul") is rarely warranted.*

Naturally, this made me wonder whether this was the portent of leaky exhaust valves in my other 11 cylinders. As things turned out, it was not. In fact, over the next several annual inspections, my compression readings actually **improved** each year. As I write this, my engines are now at 185% of TCM's recommended TBO and all 12 cylinders still have compressions in the 70s.

In 2003, less than a year after that third cylinder was removed, TCM issued service bulletin SB03-3 (superseding M84-15) removing the prohibition against minor valve leakage and permitting such cylinders to continue in service. Had SB03-3 been effective in 2002, that cylinder would never have come off.

Last year (2009), I spotted another head crack, once again in the usual place between the top spark plug and the fuel injector bosses. This cylinder, like all but one of my other cylinders, was by this time 30 years and more than three TBOs old, having been re-used during a major overhaul two decades ago. By any measure, it was fully depreciated, so the fact that it cracked didn't trouble me a bit.

As a result of this experience over a period of many years and thousands of hours, I've become convinced that trying to use what happens to one cylinder to forecast what's likely to happen to its neighbors is an exercise in futility. I've come to believe that a six-cylinder engine is best thought of as six one-cylinder engines flying in close formation. What happens to one cylinder has little or no predictive value with respect to the other five (or in my twin, the other eleven).

Consequently, my advice is that when a bad cylinder shows up, the best course is simply to repair or replace the jug in question and leave the others alone.

Major Overhaul?

The idea of majoring a near-TBO engine because it has one bad cylinder (as our misguided owner suggested in his email) is even more ludicrous. TCM and Lycoming cleverly built their engines with bolt-on cylinders for a good reason: so that bad cylinders can be replaced without having to remove the engine and split the case.

Cylinders should be thought of as bolt-on engine accessories, just like alternators, vacuum pumps and magnetos. Would you major overhaul your engine just because an alternator failed? Of course not! You'd simply replace the bad alternator. A bad cylinder is no different. Just replace the jug and keep flying.

The principal reason for removing an engine for overhaul is when it develops a problem with some bottom-end component - crankcase, crankshaft, camshaft, main bearings, accessory gears - that cannot be repaired without pulling the engine and splitting the case. Overhauling because of a problem with a bolt-on accessory - cylinder alternator, magneto, prop governor, vacuum pump, etc. - makes absolutely no sense at all. Cylinder problems should **never** influence an aircraft owner's decision about when to perform a major engine overhaul.

Let's do the math. If a TCM IO-550-N costs $40,000 to overhaul (including removal and installation labor, new engine mounts, new hoses, etc.) and has a 2,000-hour TBO, then each hour the overhaul can be prudently deferred is worth $20. If it costs $2,500 to replace a cylinder ($1,900 for the new TCM cylinder plus six or seven hours of labor), then the break-even point for cylinder replacement is $2,500/$20 or about 125 hours. Thus, if you can extend the life of the engine by more than 125 hours by replacing a cylinder and continuing to fly, you're money ahead to do so.

If you can repair your cylinder or install a reconditioned cylinder instead of buying a new one, which is what I've always done when I needed to replace a jug, the cost can be

as little as $1,200 and the break-even point drops to about 60 hours. The cylinder repair or replacement literally pays for itself in just over one oil-change interval!

Let's keep things in perspective. It is not unusual for a cylinder to go south from time to time. Nobody likes it, but it's hardly a major catastrophe. When it happens to you, and it will, simply change the cylinder and keep flying. That's why they bolt 'em on.

If your mechanic suggests that it would be a good idea to replace all six, he's probably not doing you any favors.

If the engine is nearing TBO, but still running well and not making metal, and he suggests majoring the engine now instead of just replacing the weak jugs, he's probably giving you terrible advice. In either case, you'd be wise to seek a second opinion from an engine expert before you decide how to proceed. If you can't think of one, feel free to drop me an email. COPA

About the Author

Mike Busch - honored as "National Aviation Maintenance Technician of the Year" for 2008 - has been a pilot for more than 44 years and 7,000 hours, and an aircraft owner and CFI for more than 40 years. He became increasingly interested in the maintenance aspects of aircraft ownership about 20 years ago, and ultimately earned his A&P/IA. Mike is also a prolific aviation writer, with hundreds of technical articles published in *American Bonanza Society Magazine, Aviation Safety, AVweb, Cessna Pilots Association Magazine, IFR, Light Plane Maintenance,* and *The Aviation Consumer*. He co-founded AVweb in 1995 and served as its editor-in-chief for more than seven years. Mike conducts weekend "Savvy Owner Seminars" at which aircraft owners learn how to obtain better aircraft maintenance while spending a lot less money (http://www.savvyaviator.com/). He is founder and CEO of Savvy Aircraft Maintenance Management (http://www.savvymx.com/) that professionally manages the maintenance of owner-flown aircraft including Cirrus SR20s and SR22s. Questions for Mike Busch may be emailed to mike.busch@savvyaviator.com.