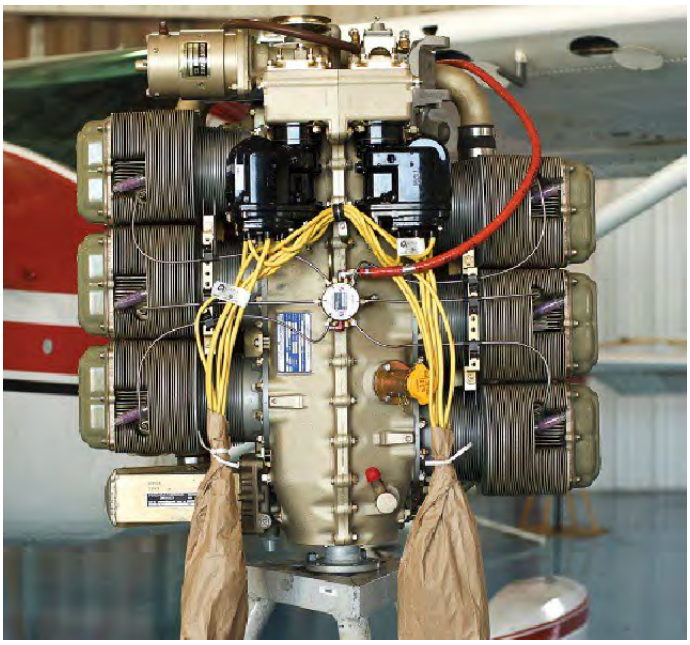
OPINION

Differential diagnosis

Figuring out what's wrong is the hardest part

BY MIKE BUSCH



A FUNNY THING HAPPENED on my way to Milwaukee. It was 2013 and I was flying my trusty 1979 Cessna T310R to speak at the annual national convention of the Flying Physicians Association on the subject of troubleshooting. Little did I know that my troubleshooting skills were about to be put to the test.

I went wheels-up from my home base in Santa Maria, California, about 8 a.m., and stopped overnight at Denver's Front Range Airport. The next morning, I taxied out for takeoff, destined for Milwaukee's Timmerman Airport. I was cleared for takeoff, released the brakes, smoothly advanced the throttles to the stop, and started my takeoff roll on Runway 17.

Something felt wrong. It was taking way too much right rudder to hold the centerline. I scanned the engine gauges and noted a big split in the manifold pressure needles. The right engine was showing 32 inches as it should, but the left engine was only 24 inches. I retarded both throttles to idle, advised the tower I was rejecting the takeoff, and pulled off the runway at the next intersection.

I taxied back to the run-up area and tried a full-power runup with the brakes set. The same thing happened: 32 inches manifold absolute pressure (MAP) on the right engine, 24 inches on the left. A moment of reflection revealed that 24 inches is roughly what one would expect from a normally aspirated engine on takeoff from a field elevation of 5,500 feet.

It appeared that the left engine's turbocharging system had stopped working, seemingly overnight. Why? I didn't really have a clue.

WHAT COULD BE WRONG?

As I taxied back to the ramp in search of a shop where I could borrow some tools, I started making a mental list of all the things I could think of that might produce these symptoms. (Making such a list should always be the first step in troubleshooting.) Visualizing how the turbo system works and considering its various failure modes, I came up with six possibilities:

1. Failed turbocharger.
2. Stuck-open wastegate.
3. Failed controller.
4. Big induction system leak.
5. Big exhaust system leak.
6. Big oil leak in controller/wastegate system.

I taxied past the open door of a hangar, inside which I saw two guys in work suits wrenching on airplanes, each with a big red Craftsman tool cabinet. I shut down the engines, climbed out of the airplane, introduced myself, and explained my predicament. They seemed happy to help.

I removed the top cowling from the left engine and looked around for something obviously wrong. I saw no signs of oil or exhaust stains where they didn't belong, so I crossed items 5 and 6 off my suspect list. I went over the induction system with a flashlight and mirror and couldn't see anything untoward, so I crossed off item 4, too.

I popped open the cover of the induction air filter canister, removed the filter element, and inspected the turbocharger's compressor. It looked pristine, with

no hint of foreign object damage. I reached in and spun the rotor with my fingers, and wiggled it to check its radial and axial play. It turned freely and felt normal. I crossed item 1 off my list.

Now I'd whittled my list of six suspects down to two likely culprits: the wastegate and the controller. I spent a few minutes thinking about how I could determine which one was the bad guy. I came up with a plan: By removing the oil-return line from the controller to the engine and capping it off, I could effectively disable the controller and force maximum oil pressure to the wastegate actuator. If the wastegate was working, then this should result in a fully closed wastegate and maximum turbo boost. If red-line manifold absolute pressure still wasn't available, that would prove that the wastegate was bad.

We rummaged around the toolboxes until we found some suitable caps to cap off the oil line. I reinstalled the top cowling, climbed into the cockpit, and started the left engine. When I advanced the throttle, manifold absolute pressure climbed to the red line. I grinned, then shut the engine down and climbed back out of the cockpit.

I'd just proven that the wastegate was fine. In fact, I'd proven that all the turbo system components were fine except for the controller (which I'd disabled). It was now the only remaining item on my list. By the process of elimination, it must be the culprit.

FIX-IT TIME

How the problem was resolved

The good news was that through differential diagnosis I was now confident I knew what was wrong: the controller was malfunctioning. The bad news was that it would take at least 48 hours to get a replacement controller overnighted to me in Denver, and by then it would be too late to make my speaking engagement in Milwaukee. It was looking like I might be forced to abandon my trusty Cessna in Denver and *(gasp!)* catch an airline flight to Milwaukee.

In an attempt to avoid this unspeakable fate, I started giving serious consideration to removing the controller from the airplane and disassembling it, hoping I could figure out what was wrong with it, and maybe even coax it into working. This is not something an A&P would normally do, as it's considered a highly specialized procedure. But I figured since the controller was already broken, I had little to lose by taking it apart.

Another thought occurred to me: *What if the only problem with the controller was that it had become contaminated with some sort of debris that got stuck in its poppet valve and prevented it from closing?* If the valve couldn't close, the controller couldn't work. That would account for the symptoms I was seeing. I wondered whether there might be a way of cleaning any debris from the poppet valve without taking the controller apart.

I had a sneaky idea: I disconnected both oil lines from the controller, and asked my new mechanic friends to borrow their air compressor for a few minutes. Using a rubber-tipped air nozzle, I hit the controller's oil output port with several shots of 80-psi air while holding a shop rag over the oil inlet port to catch any expelled oil. My idea was to "backflush" the poppet valve with an air blast and hopefully dislodge any debris that might be stuck. Sure enough, some flakes of what looked to be carbonized oil wound up in the rag.

I reconnected the oil lines, reinstalled the top cowling, climbed into the cockpit, murmured a silent prayer, and started the left engine. After letting it warm up for a few minutes, I slowly advanced the throttle while watching the MAP gauge. The needle advanced smoothly up to 32 inches.

I said my goodbyes to my mechanic friends, re-filed my IFR flight plan, and taxied out for takeoff. Everything worked as advertised, and I arrived at Milwaukee only two hours behind my original schedule. Upon checking into my hotel room, I pulled out my notebook computer and revised my PowerPoint presentation, because the story of my little turbo system adventure was just too apropos not to share. —*MB*

DIFFERENTIAL DIAGNOSIS

What I just described is a textbook example of what doctors call differential diagnosis (DDx). It is defined as "the distinguishing of a disease or condition from others presenting with similar signs and symptoms."

Every physician receives extensive training on this technique in medical school. It typically involves five steps:

1. Gather information about the symptoms.
2. List candidate conditions consistent with these symptoms.
3. Prioritize the list of candidate conditions.
4. Rule out candidate conditions (through testing or therapy) until a definitive diagnosis has been established through the process of elimination.
5. Verify that the surviving diagnosis is correct.

The application of the differential diagnosis technique is hardly limited to medicine. It is, in fact, the way all troubleshooting of complex systems should be done, whether dealing with human bodies, household plumbing, cars, boats, or airplanes.

Unfortunately, A&Ps tend not to be nearly as well-trained in the DDx technique as doctors are. In lieu of performing proper differential diagnosis, I see a lot of mechanics using two alternate techniques that I like to call shotgunning and overkill.

Shotgunning occurs when, instead of methodically analyzing and eliminating possible failure modes, a mechanic simply replaces components on a trial-and-error basis, hoping to get lucky. If the mechanic guesses right the first time, he comes out looking like a hero. If he doesn't, the aircraft owner often winds up passing out from sticker shock. The mechanic's initial guess might be whatever component turned out to be the culprit last time he saw a similar problem, whatever component he happens to have on the shelf, whatever components is easiest to replace, or whatever component is most expensive. Regardless of the exact algorithm,

shotgunning is based on guesswork, not analysis. It happens way too often.

Overkill occurs when a mechanic elects a corrective action that goes far beyond what is required or appropriate to deal with the problem at hand. One all-too-common example is the A&P who finds a small quantity of metal in the oil filter and immediately concludes that the engine must be torn down. Or when a mechanic reacts to an owner's report of increasing oil consumption by recommending a top overhaul. Do you think the mechanic would take these costly, invasive actions if it were his own airplane and he were footing the maintenance bill?

In my experience, shotgunning usually results from a mechanic's lack of training

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and/or systems knowledge. Overkill, on the other hand, is usually prompted by a mechanic's fear of being sued if something goes wrong, and his consequent desire to transfer the liability burden to someone else (e.g., the component manufacturer or overhaul shop).

As aircraft owners, we can and should protect ourselves from being victimized by shotgunning or overkill. It's really not that hard. The next time a mechanic troubleshoots your airplane and renders a diagnosis that calls for something expensive or invasive to be done, simply ask him to explain to you in detail how he arrived at his differential diagnosis. What are the possible failure modes he considered, and how did he eliminate all but this one? If your mechanic fumbles his explanation, it's time for you to seek a second opinion. **AOPA**

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