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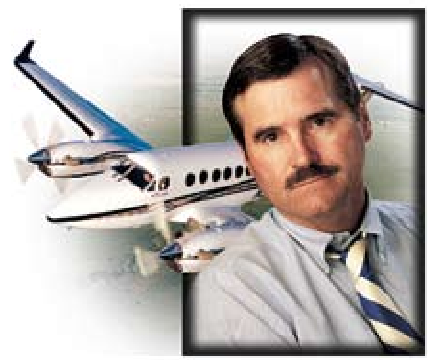

By J. Mac McClellan
Editor in Chief

Rating a Turboprop's Power

Based on the number of queries we receive here at the magazine there are a great many questions about how the power output of turboprop engines is determined. With ever more powerful engines being installed at the factory in the TBM and PC-12 singles, and conversions offered on existing twins by Blackhawk and others, it's understandable that pilots are confused.

To understand what's going on with the performance improvements from the more powerful Pratt & Whitney PT6 engines involved, you need to know that there are two fundamental measures of power. The most basic measure of power—and the one listed in the airplane specifications—is the maximum shaft horsepower (shp) of the engine. The other element in the power equation is how much power the engine can potentially produce at sea level on a standard 15° C day, which are the international standard atmosphere (ISA) conditions.

The TBM 850, for example, has a limit of 850 shp. That means the airplane is approved for 850 shp to be delivered to the propeller. A shaft horsepower is essentially the same as horsepower developed by a piston engine, or an electric motor, for that matter. Horsepower is a measure of power, or torque, over a unit of time. We could accurately call the power delivered by an aircraft piston engine shp because the power is being delivered to the shaft that drives the prop. But because there are other measures of power output for a turbine engine we specify that shp is power delivered to the prop.

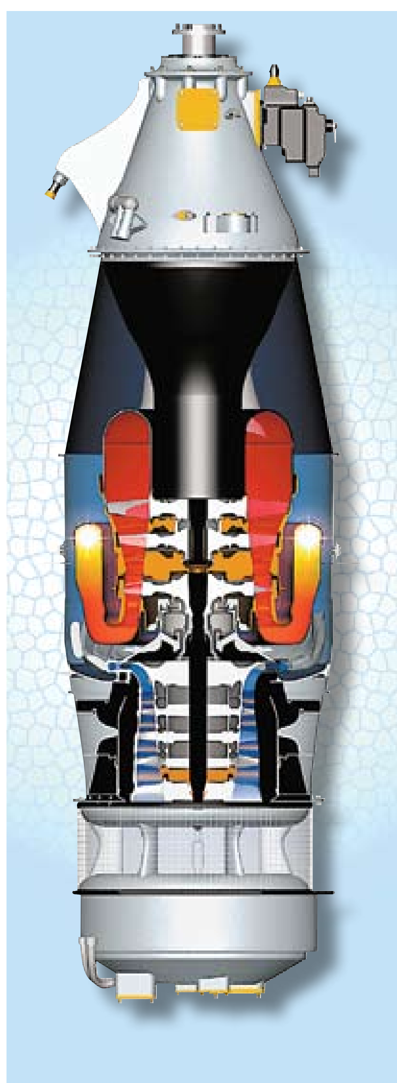

ILLUSTRATION: PRATT & WHITNEY CANADA

The shp of a turboprop engine is restricted by the strength of the gearbox that drives the propeller, and by the ability of the airplane to handle the thrust developed by the prop. So the maximum amount of power—thrust, actually—that a turboprop engine is approved to produce at any time on a specific airplane is stated in shp and is a certified limitation.

Okay, that's the same as in a piston-powered airplane where engine power is a certified limit. But in the case of turboprop engines the actual turbine engine can produce more power than the maximum certified under many atmospheric conditions. And thus the confusion.

The power output of a turbine engine, jet or turboprop is limited by internal temperature, pressure and the rpm of its rotating components. If the temperature is too hot the crucial engine parts will break, or melt. If the pressure is too great the parts can break, or the entire engine case can even fail. And if the rotating components spin too fast they will at some point fly apart with explosive force.

As pilots we monitor these parameters to operate a turbine engine. The temperatures inside a turboprop vary from one section of the engine to another, but in the PT6 we monitor, and limit, the interstage turbine temperature (ITT). The rpm is also monitored but instead of a gross number of revolutions, which is typically more than 30,000, we see a percentage of allowable rpm. There is no direct measure of engine pressure on a PT6 as there is on many large jet engines that use engine pressure ratio (EPR) as a measure of power output, but if the rpm and ITT are within limits the internal pressure of the PT6 will be, too.

There is another turboprop value—torque—that is also measured and reported to the pilot, and that is really just another way of measuring shp. The engine actually twists against the resistance of the propeller and the twisting force is measured and shown as a torque value. Torque is the limit of power the airplane can actually use, while temperature and rpm are limits on how much more or less power is available from the engine.

The PT6 is a free turbine engine, meaning the components of the turbine engine that actually generate the power are not physically linked to the propeller. The part of the engine that burns the fuel and makes the energy is called the gas generator, and the section that transforms that energy into shp is called the power section.

Air in the PT6 flows from rear to front. A compressor section in the aft part of the engine draws in air and compresses it through several stages. The hot compressed air enters the burner section where fuel is injected and ignited. The rapid expansion of the burning fuel-air mixture generates a powerful gas that forces its way forward over a turbine wheel. The turbine is connected directly to the compressor wheels to spin them and thus sustain the process. This rotating section is called N1.

As the expanding gases continue their rush forward toward the exhaust they force their way past another turbine, and this one is connected to the gearbox that turns the propeller. The gearbox is both complex and sturdy because it must reduce the many thousands of revolutions of the power turbine down to the 1,500 to 2,500 rpm that a propeller can effectively use. The rpm of this section is called N2 or prop rpm.

The power potential of the gas producing section of the engine is totally dependent on the density of the air it is operating in. When air is dense, on a cool day at sea level, for example, the turbine section loafs along. The compressor has plenty of air to work with so it feeds the burner section its maximum charge of air using only low rpm and relatively low compression ratios. But when the air is less dense, at high altitude, or when air temperature is above ISA, the compressor struggles to ram the same air charge into the burner. The air is hotter exiting the compressor and burns hotter. The compressor must spin faster to do its work. And at some point the density of the air available to the compressor just isn't enough for it to deliver the full charge of air into the burner before reaching the rpm limits, or the temperature limits, or both.

When the engine reaches its limits of temperature or rpm it is at its thermodynamic limit. Thermo, obviously, being temperature, while dynamic refers to the rotating speed of the components. That's why you'll see that a PT6 will have a limit of, say, 850 shp in the TBM, but have the thermodynamic rating of about twice that. The difference between the low and high power ratings is called flat rating, or de-rating. I like the term flat rating best because it accurately describes what is happening. The airplane and engine gearbox can only take so much shp, so the engine is capped at that value. Its power is held flat.

But the magic of flat rating is that you can use the extra thermodynamic power to increase climb and cruise speed. As the airplane climbs into less dense air there is plenty of margin in the compressor section to keep packing a full charge of air into the burner before rpm and temperature limits are reached. Just as a turbocharged piston engine continues to make full power as it climbs, the flat-rated PT6 delivers full-rated power at altitude by having the margin to increase rpm and ITT. The result is higher climb rates and true airspeed.

It wasn't always this way with the PT6. An early version of the engine in the King Air 90, for example, couldn't make full-rated power on the runway if the air temperature was hot, or the airport elevation high. Gradually Pratt improved the design and materials of the engine to make it ever more powerful, even though certified shp remained the same. And over the past several years versions of the PT6 are almost twice as powerful even though the external size and shape is about the same.

This available increase in thermodynamic power is what makes the engine conversions of existing airplanes so attractive. The new engines fit right in the space of the originals, are limited to the same maximum power to the propeller, but produce that power to a much higher altitude or air temperature. The results are many, many knots of increased cruise speed, much higher climb rate, and often a fuel flow increase that essentially matches the speed increase so range remains about the same. It is not a free lunch because the new engines are more expensive, but it is as close to a free speed increase as there is in aviation.

The reason newer PT6 engines can produce more power is better materials to withstand higher temperatures and pressures, and much improved aerodynamics that make the compressor and turbine more efficient. The same improvements have taken place in all turbine engines, but it's so remarkable in the PT6 because the engine has been used on the same airframes for more than 40 years.

I hope this explains flat rating, shp, thermodynamic power, and why turboprop airplanes continue to gain in climb and cruise speed. Flat rating puts power in the bank that you can draw on when conditions are less favorable. I think that's something we can all appreciate these days.

Beware the Clear Key

I have been flying with a Garmin 430 since, well, the very first days after it was certified. Same for the 530. You would think that I would know everything about them by now. But the "clear" key tripped me up recently.

I noticed on my 530 that some of the usual information was missing from the page one and two map displays. Even the XM Weather was missing from those pages, though it appeared normally on the dedicated Nexrad page. I went through the setup pages and all of the data I want to see was turned on. I even tried resetting to the factory defaults, and still nothing changed on the map pages.

I was talking to some Garmin guys about the mystery and we all scratched our heads until somebody thought of the "clear" key. The only time I typically use the clear key is when there is a traffic call and the full screen traffic display overrides whatever I had showing on the 530. A press of the clear key returns the display to the previously selected. However, the clear key also is used to de-clutter the display. If you press it when there is nothing new to clear, it will remove data from the map pages. Repeated presses remove more and more data.

It turns out that I had accidentally pressed the clear key when there was nothing to clear. Maybe a double press when I was trying to clear the expanded traffic. Who knows? But a couple presses of the key cycled through the de-clutter modes and everything was back to normal. So, if stuff you expect to see on your 430/530 isn't there, press the clear key until it comes back.

Winter Extremes

The mission was to fly from New York to Wichita in late December. Almost always a challenging trip, but this time it was really extreme. It was more than 60° in New York, and only in single digits in Wichita. That was more than enough information for me to know awful flying conditions were waiting for me en route.

The most obvious issue was the wind. It doesn't get to the mid-60s in New York in December without air from someplace else being transported in very quickly. The forecast was for 80 knots and more of headwind at 8,000 feet.

FltPlan.com does a terrific job of calculating flight times even when winds are extreme and forecast to change a lot in direction and velocity over the route. And FltPlan.com—which is a free website—said I couldn't make it to my usual Indianapolis fuel stop with my one-hour reserve. That is the first time in 18 years of flying my Baron 58 out of New York that I couldn't make Indy. But when the true airspeed is 194 knots, and groundspeed can't make 110, Indy is a long way away, and that's what I saw over Pennsylvania.

There was a powerful front, obviously, between me and Wichita, and its leading edge was in eastern Ohio. Its location was marked on the Nexrad radar with a line of precipitation that stretched from somewhere in Canada nearly to the Gulf Coast. Most of the returns were Level Two, with some small areas of Level Three, or Level One green. There was nobody on the frequency on such a miserable day, so when I asked the controller if he had any ride reports through the weather he said he was going to ask me since I would be first in a long time.

By this time I was west of the ridges and had descended to 4,000 feet to try to get out of some of the headwind. The descent helped only a little, but the air was above freezing and the ride tolerable. The controller, looking at his version of the Nexrad returns, suggested a turn around a stronger return, and I agreed looking at my picture.

The Nexrad mosaics that are delivered by XM or Sirius to the cockpit are different from the full Nexrad return you can see on a computer. The full Nexrad display uses about 19 colors or shades of color to present gradations in the intensity of the radar return. For simplicity and viewability in the cockpit the Nexrad image is presented in three or four color gradations. The intensity of the return is intended to represent the same level that the weather radar in the airplane would show. However, the technologies are not the same so green Level One on Nexrad will not be exactly the same intensity of precipitation as a green return would be using your own radar.

In addition, avionics companies apparently use slightly different thresholds to set the levels. I have XM Weather playing on my Garmin 530 and Sirius WSI weather displayed on the Avidyne FlightMax. Often large areas of Level Two yellow on the Avidyne will be shown as Level One green by Garmin. Small areas of Level Three red will often be embedded in Level Two yellow returns on Avidyne, but only yellow with no red on Garmin. Sometimes big areas of green Level One on the Avidyne are really virga that is above or below me and I fly along in totally dry air, but there may be no return on the Garmin.

It's over the top to have both systems in one airplane, and they are only there for me to try to compare. In general I like the extra information on the Avidyne FlightMax, even though it may be accused of sometimes crying wolf. I have found that Level One precip on the Avidyne is not a concern, and Level Two yellow, so long as the gradient, or distance, over which it has changed from green is shallow, is also not much to worry about. But Level Three red is always worthy of avoidance, and the magenta Level Four deserves a wide berth.

So for the trip through the front I dodged all Level Two shown by Garmin, and the bits of Level Three on the Avidyne, and the ride was okay. Both systems showed Nexrad images of frozen precip over Dayton, my refueling stop. Radar has a hard time with frozen precip because snow or ice crystals just are not very reflective. But this time the radar got it right with the ATIS for Dayton reporting light snow.

After a cold stay in Wichita where we had to delay flying the new Cessna Citation XLS+ for a day because freezing rain had glazed the taxiways and ramp, more weather treats awaited my departure. The ATIS reported the ceiling as 100 feet—vertical visibility—with one-eighth of a mile in freezing fog. But a couple thousand feet up the air temperature was well above freezing and airframe ice was not forecast or reported. The very cold air was being held at the surface, a not uncommon situation in the Great Plains.

The traditional definition of freezing fog is that the fog droplets are supercooled, meaning they are liquid but will freeze on contact with an object. Using that definition freezing fog is actually uncommon, but with the new automated reporting equipment it appears that any time there is fog and the temperature is below freezing, it's called freezing fog. Real freezing fog is a problem because it will create airframe ice when the droplets are disturbed by the airplane. But fog with already frozen droplets is not an icing issue, only a restriction to visibility.

The fog was not really freezing, ice was not forming on anything, and the runway visual range (RVR) value was more than 3,000 feet, a far cry from the reported one-eighth mile. It was an easy decision to depart but again reminded me of the value of a flight director, and why they are used routinely on every takeoff in turbine airplanes. The accident record shows that the big risk in a low visibility takeoff is sinking back into the ground after rotation. Our senses fool us into thinking that the normal acceleration of the airplane is actually a pitch increase so the human inclination is to lower the nose. If you get used to rotating to the flight director command on the attitude indicator for every takeoff, the low visibility takeoff is no different and it's easy to ignore the incorrect signals your senses are sending to your brain.

About half of what had been the headwind was waiting for me as a tailwind on the return trip, but that was welcome, and enough to shorten the time by almost half. The evening after I got home we had seven inches of snow, followed by a bout of freezing rain. It was good to have the hangar door closed and locked in time for Christmas.