Speaking Truth to Power

More than a few eyebrows developed an arch when Van’s Aircraft announced a new RV-14/14A firewall forward package. Per the published gross weight performance data, sea level top speed gained 13 mph, 75% cruise (at 8000 feet) rose by 10 mph and the rate of climb jumped from 1500 fpm to 1680 fpm. Wonderful stuff, but inevitably some wondered if it was true. After all, the new IO-390-EXP119 is rated at 215 hp, only 5 more than the 210-rated IO-390-A powering the existing fleet. Is the new speed realistic, given the modest power increase?

The answer is found in fundamental relationships. The analysis task is greatly simplified because both old and new performance were determined using the same airframe, the same propeller and the same gross weight. Start with an estimation of installed horsepower. The fundamental equation is:

Rate of Climb (ROC) = (Excess Thrust HP x 33,000) / Weight

Here, “excess” means horsepower above what is need to maintain level flight. “Thrust HP” usually requires a propeller efficiency factor, but since our subject used the same prop with both engines, we can ignore it. The 33,000 value is one horsepower expressed as foot-pounds/minute. It converts Thrust HP into units matching the ROC units (feet per minute) and weight (pounds). Simplified and rewritten to find Excess HP when ROC is known, the equation becomes:

Excess HP = (ROC x Weight) / 33,000

…thus the change in excess HP would be…

Excess HP Change = ((new ROC – old ROC) x weight) / 33,000, or…

((1680 – 1500) x 2050) / 33,000 = 11.2 HP

It is important to note the equation does not assign a specific HP to either engine, only a difference. Actual output could be 210 vs. 221.2 or 190 vs. 201.2 or any other combination with a 11.2-hp difference.

Obviously, 11.2 is somewhat more than the 5-hp difference in rated power, but don’t be confused. Ratings are averaged power as determined by the manufacturer on a dyno, then set in stone with the accordance of a regulatory authority. Installed power can be quite different, with induction and exhaust as major factors. Further, it is entirely normal to find significant differences in output between two engines that are, in theory, identical.

Example: The small-main, circa-2005 IO-390 Marc Cook had installed in his Sportsman dyno’d at 215 hp, while my own pulled 205 after a short run-in. Both engines were built in the same shop with the same Lycoming kit parts and tested on the same dyno. Even if they had measured the same, the dyno figures would not have told us their installed output.

With comparative horsepower in hand, let’s look at speed. The fundamental principle is power required is proportional to velocity cubed. There is a small increase in form drag, which rises with speed even as induced drag falls, but it’s not worth addressing in this tiny corner of the envelope. The equation is:

New Power = Old Power x (New Speed / Old Speed)³

Assume the A’s rated 210 hp as “old power”:

210 x (216 / 203)³ = 253 HP

To reach the stated 216 mph on power alone, the new EXP119 would need 43 additional horses…very unlikely given we already know the actual increase is 11.2 hp.

How fast will it actually go if the sole change is 11.2 more horses? Spin the equation around, and we have…

New Speed = Old Speed x (New Power / Old Power)1/3, or…

203 x (221.2 / 210)1/3 = 206.5 mph

The extra 11.2 hp only adds 3.5 mph. Clearly we must look elsewhere for the source of the reported speed. That elsewhere is drag, a function of the new cowl and cooling system arrangement.

The fundamental expression is Drag = Power / Velocity. To make it work, we first convert power and velocity into compatible terms—feet and seconds. The engine power should be discounted by a known propeller efficiency factor if the actual drag values are to be accurate. However, we’ll again skip it, as doing so will not affect the result when expressed as a percentage.

The full power, sea level values are:

210 HP = 115,500 ft-lbf/sec  
221.2 HP = 121,660 ft-lbf/sec  
203 mph = 298 feet per second  
216 mph = 317 feet per second

So, Drag = Power/Velocity, or…

115,500 / 298 = 388 lb with the prior cowl and cooling flow.

Knowing this prior drag and both speeds, we can determine what drag would be if we merely increased the speed without changing the airframe. Note another fundamental principle, drag rise is proportional to velocity squared:

New Drag = ( New Speed² / Old Speed² ) x Previous Drag, or…

(2162 / 2032) x 388 = 439 lb

Again apply Drag=Power/Velocity, this time with the new power and velocity:

121,660 / 316.8 = 384 lb

As a percentage, the drag reduction is…

1 – (384 / 439) = 12.6%

The new configuration incorporates improvements to the cowl’s external shape and cooling path. To illustrate the effect of just one of those changes, tests with the variable exit area (aka the “cowl flap”) fully open, then fully closed, without changing power (approximately 75%) or altitude were 197 and 200 mph, respectively. Repeat the drag calculations, and we find the variation in exit area alone, with its corresponding exit velocity increase and mass flow decrease, changes drag by 4.4%. Need a real-eye-opener? Consider how much power would be required to gain the same 3 mph without a drag reduction:

215 x (200 / 197)³ = 225 HP  
225 – 215 = 10 HP

Merely moving the cowl flap from open to closed has about the same effect as the new engine. Determining how much each of the many changes contributes to the total drag reduction will keep speed fans talking for some time. For now, the takeaway is classic; horsepower sells, but drag reduction is king. Someone at Van’s deserves a raise.

—Dan Horton