Photos by James Williams

MEREDITH SAINI

Flying by the Numbers

A PRECISE APPROACH TO LANDING

During those first few hours of flight training, a student pilot is asked to memorize lots of numbers—airspeeds, power settings, runway headings, and traffic pattern altitudes for local airports, to name a few. In the approach and landing phase of a flight, airspeed numbers carry particular significance because minding or ignoring them can mean touching down safely on the intended point or overshooting and ending up in the weeds.

Then, just when the student has dutifully memorized the published numbers, it's time to learn that sometimes they are adjusted to handle a particular situation. For instance, final approach is flown a *little bit* faster on a gusty day to compensate for the variable wind.

But, how much is a little bit? Why do these numbers matter anyway? Why can't we just fly like the old timers did, by the seat of our pants, and not worry so much about all of these numbers?

The truth is that the more experience a pilot accumulates, the easier it is to control the airplane by feel because the numbers become, in a sense, ingrained in how we fly. We don't need to look at the tachometer while setting the throttle because we just know, using our tactile, visual, and auditory senses, that everything is configured properly. We set the power and pitch and then scan the instruments to confirm that we got what we asked for. Even while flying on instruments, we don't fixate on the airspeed indicator or the power setting—our primary focus is on the numberless attitude indicator, just as a student pilot's primary focus is directed outside the airplane, at the earth and sky.

Final Approach and Vref

To understand how final-approach airspeed is determined for a given airplane, we have to start with the landing—the stall, the moment the airplane stops flying—and work the problem in reverse, back up the final-approach course. In a general sense, the speed at which we want to fly the final approach is some airspeed above the stalling speed that will let

Photo by Meredith Saini

us stay aloft while we descend toward the runway, but not have so much excess lift that the airplane will not stop flying when we want it to touch down.

Part 23 of Title 14 Code of Federal Regulations (14 CFR), which deals with aircraft certification, states that “for normal, utility, and acrobatic category reciprocating engine-powered airplanes of 6,000 pounds or less maximum weight, the reference landing approach speed (Vref) must not be less than the greater of Vmc, determined in 14 CFR section 23.149(b) with the wing flaps in the most extended takeoff position, and 1.3 Vso.”

A common memory aid for Vso is that it is the stall speed with “stuff out,” meaning landing gear and flaps extended. The regulations define Vref as “the speed of the airplane, in a specified landing configuration, at the point where it descends through the 50-foot height in the determination of the landing distance.” You may have heard pilots refer to this point in the landing approach as when the airplane is “crossing the fence” or “over the numbers.” This is typically the point at which power is reduced, perhaps all the way to idle, and a smooth transition begins from a descent, to a level off, flare, and, finally, touchdown. (Vmc, or minimum control airspeed with the critical engine inoperative, refers to airplanes with more than one engine. For simplicity and brevity we’ll limit discussion in this article to single-engine operations.)

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Typically, we fly final approach at some airspeed greater than Vref, because in many light airplanes, Vref is just not a comfortable place to be. It’s too slow; it feels mushy. The manufacturer’s recommended final approach airspeed gives the pilot a generous cushion above the stall that allows for the bit of gentle maneuvering that is necessary to keep the airplane aligned with the runway centerline.

The pilot operating handbook (POH) for the 2001 Cessna 182S that I fly shows that Vso at maximum takeoff weight, zero-bank angle, is 49 knots calibrated airspeed (KCAS) at the most rearward center of gravity (CG) and 50 knots at the most forward CG position. Assuming that the average pilot cannot reasonably discern a one-knot difference, we’ll use the higher number of 50 knots which, when multiplied by 1.3, produces a Vref of 65 KCAS, or 61 knots indicated (KIAS). The POH suggests a final approach airspeed range of 60-70 knots KIAS with full flaps.

The Art of Interpolation

The numbers published in the POH were generated by an FAA-approved team of engineers and test pilots through a rigorous aircraft-certification process. These numbers exist to give the pilot a framework within which to create a stabilized approach and landing, but we need to read the fine print in order to use these numbers effectively.

Stall speeds and final approach speeds are generally published for the airplane at or near maximum gross weight. Yet, we rarely land an airplane when it’s that heavy, because presumably we have been flying around for a while, burning avgas at the rate of six pounds per gallon per hour. We know that an airplane’s stall speed increases with an increase in weight (or with an increase in load factor, such as during a turn; see “Getting It Right in Maneuvering Flight” on page 15), so this means that the actual Vso at the moment of landing is likely to be something lower than what’s listed in the POH. Turning the problem upside down, we can say that most of the time we have a greater margin between the airplane’s actual stalling speed and our final approach airspeed than what the POH would suggest.

The benefit of this wisdom is that if we follow the numbers and maintain the POH-suggested airspeeds for each phase of flight, we are in a position to make a stabilized approach and landing. The danger is that if we routinely tack on 5 or 10 knots under the false assumption that faster is always safer, we may be setting ourselves up for a go-around at best, or a very hard landing at worst.

The Gust Factor

One of the few times we want to fly faster than published on final is if it's a really windy, gusty day. The FAA *Airplane Flying Handbook* ([FAA-H-8083-3A](FAA-H-8083-3A)) recommends adding one-half of the reported surface-wind gust to the normal final-approach airspeed when landing in turbulent conditions to compensate for any sudden loss of headwind component. But, why not add the whole gust amount, or double it? Why add anything, if the published final approach airspeed already has a built-in cushion above the stall?

The simple answer is that gusts are variable and unpredictable, and we want to ensure that we can outsmart them by carrying enough speed to get us to the pavement safely despite them. The airspeed indicator can fluctuate wildly and be difficult to read on days when we're getting batted around like a beach ball, so we'd rather overestimate our airspeed than underestimate it and risk a stall. If we discover during the approach that adding half the gust factor to our speed on final was too much and we end up too high and too fast, we can go around and try the approach again at a slightly slower airspeed.

The POH for the Cessna 182S states "normal landing approaches can be made with power on or power off with any flap setting desired. For a short-field landing in smooth conditions, make the power-off approach at 60 KIAS with full flaps. (Slightly higher approach speeds should be used under turbulent conditions.)" For normal landings on longer runways, final approach should be flown at 70-80 knots without flaps, or 60-70 knots with full flaps. Though the POH does not suggest what flap setting to use in turbulent air, it leaves the door open for the pilot to use any flap setting from 0-30 degrees that will get the job done.

If we follow the numbers and maintain the POH-suggested airspeeds…we are in a position to make a stabilized approach and landing.

Here's where experience and the art of interpolation comes into play, and why adding half the gust factor is a good compromise on a gusty day. Let's say we're approaching a 5,000-foot runway—more than twice what this airplane requires—on a very turbulent day, with surface winds reported as 20


Photo by Tom Hoffmann

knots gusting to 30 knots with a variable crosswind that is typical when such conditions exist. The gust factor is the difference between the gust and the sustained wind, in this case 10 knots. So, we plan to fly final approach five knots faster than normal.

What's normal? The published range for a normal approach is 60-70 knots, so to what number within that range do we add the five knots? Is using full flaps a good idea on a day like this, in this airplane? Probably not, because the wind can reach under those flaps and grab hold of the wing like a professional wrestler flipping his opponent to the mat.

Recall that the airplane's actual stall speed is probably lower than advertised due to its lighter weight. Start with the lower number, 60 knots, and add five to that. Try flying final approach at 65 knots with just 20 degrees of flaps and see how that works. If at any point the gusts are so strong that you hear the stall horn squeak or have any trouble controlling the airplane, given your level of experience, then go around and try the next approach at 70 knots with 10 degrees of flaps, and see if that feels better.

Pilots who "fly by the numbers" are…not reinventing the propeller on each approach.

It's a Wing Thing

An airplane's wing design and resultant stall characteristics also play an important role in determining Vref and final-approach speed, as well as the airplane's relative tendency to remain in ground effect during the landing.

The Cessna 182S uses a conventional, riveted aluminum wing that is twisted slightly along its length so that the wing tips present a lower angle of attack than the wing root, allowing the ailerons to remain effective well into the stall. This design has been proven for many decades and is still being produced. Now, consider the seamless, composite, laminar-flow wing of a 2007 Cirrus SR22 G3. The G3 wing is also twisted to maximize aileron effectiveness during the stall, but employs additional features such as stall strips and a two-section leading edge.

The SR22 is flown at 77 KIAS for short-field landings and 80 KIAS for normal approaches, always using full flaps if available. The SR22 POH for the G3 wing lists Vso at maximum gross weight as 60 KCAS for the most forward CG position and 58 KCAS for the most aft CG position. If we take the median, 59 KCAS, and multiply by 1.3 we get a Vref of 76.7 KCAS or approximately 77 KIAS, which is the short-field approach speed.

Though these airplanes are of similar size, weight, and performance, the wing design is the primary reason for the difference in their stall behavior and recommended landing speeds. One wing is not better than the other; they are just different. The Cessna 182S wing creates more drag than the SR22 wing, and this allows for a steeper and shorter approach and less of a tendency to float in ground effect. The SR22 G3 wing (as well as its more powerful engine) allows it to cruise about 30 knots faster than the Cessna 182S, but the G3 wing (and the overall body design of the SR22) results in a faster final-approach speed and longer required landing distances than the Cessna 182S.

Final Thoughts on Final Approach

Pilots who "fly by the numbers" with precision and accuracy are able to fly stabilized approaches, and make consistently smooth landings, because the numbers they follow provide a proven framework for success. These pilots are not reinventing the propeller, so to speak, on each approach. This methodology is what makes airline travel so safe, and it can work for general aviation pilots, too.

Meredith Saini is a flight instructor and active general aviation pilot. She works as a contractor supporting the Flight Standards Service, General Aviation and Commercial Division at FAA Headquarters in Washington, DC.

For More Information

FAASTeam online courses "Maneuvering: Approach and Landing" and "Normal Approach and Landing" can be found at:

http://www.faasafety.gov/gslac/ALC/course_catalog.aspx

***Airplane Flying Handbook* (FAA-H-8083-3A) can be found at:**

http://www.faa.gov/regulations_policies/handbooks_manuals/aircraft/airplane_handbook/