Airspeed Calibration Made Easy

by D. B. RICHARDS / AOPA 402142

■■ *Dead reckoning is basic to all other forms of navigation.* Whether you're shooting a VOR approach, island hopping in the Bahamas, or just tooling around the countryside on a Sunday afternoon, it's nice to be able to predict your plane's speed and heading accurately.

Most general aviation planes that I've checked have large errors in both the compasses and the airspeed meters. Once you've swung (i.e., calibrated) your compass, the next most important navigational job is to calibrate your plane's speed performance. A static test of the pitot and airspeed system is no substitute for an in-flight test, since many factors affect the readings aloft. By use of a new technique, an accurate air calibration of both your airspeed meter and your plane's performance can be an easy job.

The majority of unsupercharged general aviation planes do most of their cross-country flying at altitudes between 3,000 feet and 9,000 feet. With a standard power setting, the indicated airspeed will fall off with increased altitude about as fast as the airspeed corrections increase, so that the plane with normal loading seems to have just one airspeed in this altitude range. While this is not quite true, it's close enough that the average of past level flight groundspeeds in this altitude range will often give you a better TAS than will an E6-B computer using indicated airspeed.

Check it out. After you've made five to 10 trips in your plane and recorded the level flight groundspeed in your logbook each time, you'll discover the winds start balancing out and the average of your groundspeeds is a pretty good figure to use for TAS in the same general altitude range.

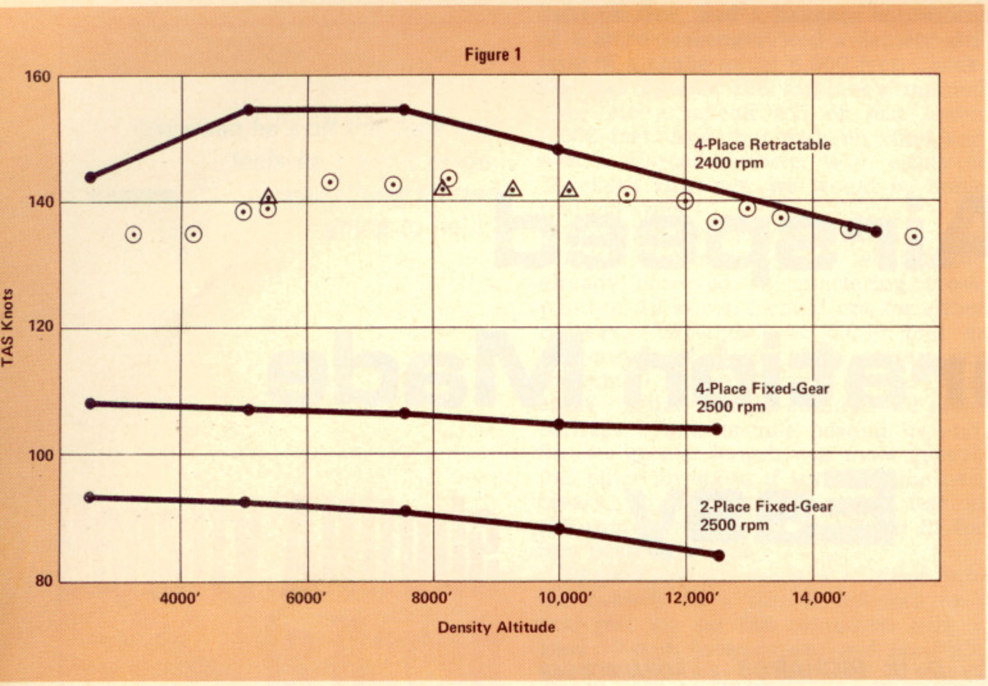
A look at Figure 1 will offer justification for the above groundspeed averaging technique, as well as for the airspeed calibration technique that I'll describe.

The solid lines in Figure 1 are from data taken out of the owner's manuals of several popular general aviation planes. My experience has been that if you run an actual airspeed calibration you will get a line that is even more horizontal than those out of the manuals. Figure 1's top line, which is the least flat of them all, is for a four-place retractable with constant-speed prop. The points below the line are for actual calibration runs I made in that plane. They represent runs made between 3,000 feet and 14,000 feet msl, but, because of the high summer temperatures during the runs, I converted to density altitude to demonstrate more accurately the effect of altitude on performance.

Note that my test run points have a similar but somewhat flatter hump than do the data points from the owner's manual, and that the top of the curve is 11 knots below peak manual performance. Even though this was purposely picked as the most humped line of the group, a fixed value of 142 knots would estimate the TAS within 1% for most points between 3,000-feet and 9,000-feet msl (i.e. 5,000-feet to 10,400-feet density altitude). This is still more precise than you can usually determine IAS, and is a much more accurate value than you would ever get by calculating TAS from an uncalibrated IAS. Need I add that in addition to being more accurate, it is also lots easier just to say 142 knots than it is to fiddle around with a TAS calculation on the E6-B computer while trying to fly the plane in rough air?

Even though there is curvature in the data in Figure 1, the curvature is not severe enough to cause inaccuracy in averaging two speeds, one from 500 feet above and one from 500 feet below an altitude level. This is borne out by the

Pilot-author of earlier article on 'air swinging' your compass details inexpensive do-it-yourself method to figure out your true airspeed, at various altitudes, without having to use your computer all the time



The airspeed of three "popular" general aviation planes, as computed from the owner's manual of each plane. Points below the line for the four-place retractable are from calibration runs at 24 inches manifold pressure, if attainable, otherwise full-throttle. The author obtained four triangular points by flying back and forth (IFR), at the same altitude, between two VORs. The 14 circular points were obtained by the VFR-altitude-averaging method, referred to in the article as the "Double VOR Method." In each case, the speed was correct to a standard load level, the author said.

data in Figure 1, since four of these points were obtained by flying back and forth, at the same altitude on an instrument clearance, in the uncongested hours after midnight. These four points show the same pattern as do the 14 points obtained by the VFR altitude-averaging technique that follows.

This new VFR altitude-averaging method not only calibrates your airspeed meter; it is also the most efficient way to calibrate your plane's performance over a range of altitudes. As I've already indicated, this performance calibration can be even more useful than the airspeed calibration.

The calibration, incidentally, is both easy and fun. All you have to do is fly the legal VFR altitudes (3,500, 4,500, 5,500, etc.) back and forth between two VORs. You then average the groundspeeds from two adjacent altitudes to get the TAS at the intervening whole thousands (4,000 feet, 5,000 feet, etc.). For obvious reasons, we'll call this the "Double VOR Method." Since this method averages the wind effect from altitudes 1,000 feet apart, don't try it on days with a wind that changes sharply with changing altitudes. It works best if both your compass and your VOR are accurately calibrated. If they're not, you'll have to fly a visual range and eyeball your wind correction angle.

First of all, secure a stopwatch. This need not be an expensive one—you can get one for around $10 or $15 from various mail-order or discount stores. Now select two VOR stations that are at least 15 but preferably 20 or more miles apart. (I'm lucky I have LEX and FFT which are 24.8 n.m. apart.)

Pick a day and a time of day with smooth, stable air conditions and light, steady winds (be a bit cautious of gusty winds, even if light, since their variability can cause trouble). You need stable air, as there's no point in trying to calibrate when the airspeed is varying plus or minus 10 knots and the compass is wandering back and forth 15° to either side of your heading. Even on a fairly good day there may be some error in any attempt to fly a constant airspeed; this can give all sorts of erroneous calibration values. Instead, it's best to do it just like you do on a cross-country—fly a constant power setting and a constant altitude, and let the airspeed values average out.

Before going aloft, make a data sheet consisting of as many double columns as is convenient on a page. At the top of each double column, leave space for air temperature, pressure altitude, rpm, fix, and manifold pressure; then label the left-hand column of each pair "IAS" and the right-hand column "MH." With the plane full of gas and a typical load of people and baggage, get clearance from ATC for your intended maneuver. It is also a good idea to check winds aloft so you can set in a drift correction on your first leg.

You can start your calibration at the lowest half-thousand feet that will allow a safe flying altitude. If this is 2,500 feet, take off and climb to 2,500 feet en route to the easternmost one of your selected VORs. (If this level is 3,500 feet, use the westernmost VOR as your number one VOR.) Make a procedure turn beyond it; then come back across it at exactly 2,500 feet at your selected power setting and headed on course to the second VOR. The magnetic course to the second VOR should be set on your OBS. As you cross the first VOR, start the stopwatch at the first clear-cut FROM indication. Fly straight and level directly to the second VOR by any combination of visual range, dead reckoning, and VOR radial that will keep you on course accurately. At the top of your double column, record the pressure altitude, temperature, rpm, and manifold pressure.

If your VOR receiver is not accurate (and many are not), I suggest that immediately on crossing the first VOR you tune in the second station and turn the OBS to center the needle. Use this radial to fly to the second station, rather than setting the magnetic course on the OBS, since, if it differs from the magnetic course, either your set or the ground station is in error. Regardless of whether you fly visual range or VOR, at frequent intervals (preferably every minute or oftener but at least every two minutes) write down the IAS and the MH in the appropriate columns of your data sheet. Fly your course, altitude, and power setting with precision. You'll get your IAS by averaging the recorded values.

Upon crossing the second VOR, stop your stopwatch at the first clear-cut FROM signal. Immediately add climbing power and set up a climb to the next level. Record your stopwatch reading (double-check the reading) and clear it for the start of the next run. As you approach the next level (3,500 feet, in this case), do a procedure turn and head back toward the second VOR on course toward the first VOR, with the correct magnetic course set on your OBS. Trim up your plane and get the selected altitude and power settings well established before crossing the second VOR. At the first clear-cut FROM signal, start your stopwatch and head on course back to the first VOR. Record the pressure altitude, temperature, rpm, and manifold pressure at the top of a new double column, then start recording the IAS and MH regularly as before.

Again fly direct to the VOR by the best means available, but be sure to tune in the new station (in this case the first station) en route with the appropriate course on the OBS, so you can get an accurate time by stopping your stopwatch at the first clear-cut FROM signal. Immediately after station passage, start a climb to the next altitude and record your stopwatch reading.

Continue in this manner, flying odd-thousand-plus-500-feet eastbound and even-thousand-plus-500-feet westbound, until you've reached your highest probable cruising altitude (for example 10,500 feet). You may not want to complete the work in one flight. Instead, you might make two flights. By the time you start the second flight though, the winds may well have changed, so rerun the last altitude before starting on up to higher altitudes on the second flight.

Back on the ground, you now have all the information needed for your calculations except distance between VOR stations. This distance must be determined very accurately on a sectional chart. Values to the whole nautical mile, as on instrument charts, are not good enough, nor can you be absolutely sure of measurement on a sectional with a plotter. Be sure the map is flat and free of intervening creases, then pick off the distance with a divider. Compare the divider with the latitude scale of the map, approximately bracketing the latitude of the midpoint between the two VOR stations. Each minute of latitude is equal to one n.m. Your groundspeeds will come out in knots (nautical miles per hour), but this is the most generally useful form anyway. You can easily convert to miles per hour on your computer, if you wish.

Get IAS for each altitude by averaging the IAS values recorded. Get the average of the MH values also. If you've flown a relatively straight course (no dogleg) and the MH averages within 4° of the magnetic course between VORs, you can ignore the drift factor. Calculate your groundspeed (GS) for each altitude. Now get the data for each whole thousand feet of altitude by interpolating between the data 500 feet above and the data 500 feet below. Thus, for 3,000 feet of altitude you get the temperature, IAS, and GS by taking a value midway between the 2,500-foot value and the 3,500-foot value of each item. In a similar manner you get each value for 4,000 feet by averaging the 3,500-foot and the 4,500-foot values. You don't average the MH values between two adjacent altitudes because they were flown in opposite directions and the average would have no meaning. You do, however, average the wind correction angles (WCA) if it appears they will average 5° or more in absolute value (i.e., value without regard for plus or minus signs). If they average 5° or more, correct the average GS by dividing by the cosine (cos) of the WCA to get the true airspeed (TAS). (Don't do this unless you're sure you have an accurate WCA!)

$$TAS = GS \div \cos(WCA)$$

You can get the cosine out of any trigonometry book. The ones you're most likely to need are as follows:

cos 5° = .9962
cos 6° = .9945
cos 7° = .9925

cos 8° = .9903
cos 9° = .9877
cos 10° = .9848

cos 11° = .9816
cos 12° = .9781
cos 13° = .9744

You now have a calibrated airplane. You can say with confidence that, for the power setting used and typical load, the TAS will be so many knots at all cruising altitudes up to 8,000 feet (or 9,000 feet or 10,000 feet or wherever the noticeable falling off of TAS occurs) and above that altitude it falls off by such-and-such number of knots per 1,000 feet. This information is really more accurate than any calibration values you get, because time, distance, and altitude were determined more accurately than you could determine your average IAS. However, if you expect to fly at power settings, loads, or altitudes noticeably different than those used in the calibration run, then you should calibrate your airspeed meter too. With the data you have, this is easily done.

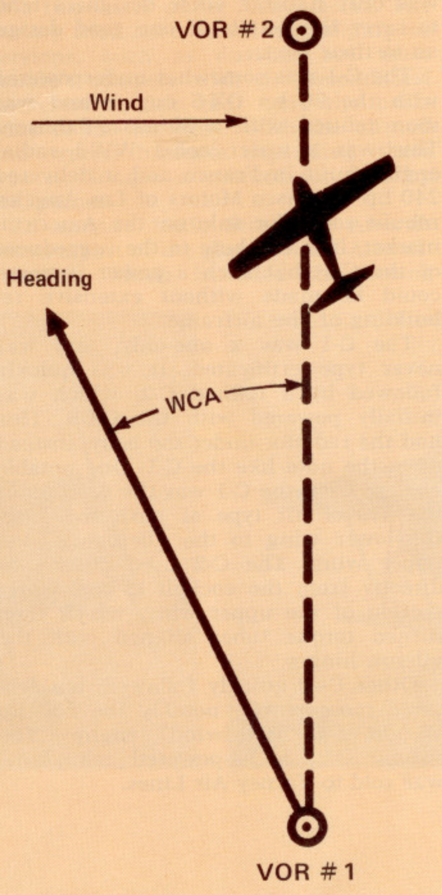
Convert your TAS in knots to TAS in miles per hour (mph) if your IAS is in mph. With the speeds in the same units, set the pressure altitude opposite the temperature on your computer. Opposite TAS on the outer scale read calibrated airspeed (CAS) on the inner scale. Now subtract IAS from CAS to get calibration correction. This calibration correction will usually be fairly constant or else change only gradually within the range of cruising speeds of most lightplanes.

I've tried to reduce the complexity of things by sliding over the load factor with an admonition to use "typical loading." If you want to be a bit fancier, you can correct for the load factor, including gas consumption during flight. I made such corrections for all the values in Figure 1. If you're carrying an unusually light or unusually heavy load, you should correct your "typical load" values for TAS up or down accordingly. If your aircraft manual doesn't give you such a correction, it will be approximately right to add or subtract one knot for each 100 pounds of load change in a typical four-place plane.

Your results may or may not resemble mine but, however they come out, they represent how *you* fly the airplane. Try out your new TAS with the forecast winds on your next cross-country. If things work out, you might even have a kind word for the weatherman now.

The "Double VOR Method" of airspeed calibration. All you need is a stopwatch; two VORs, preferably at least 20 miles apart; smooth air conditions; steady winds; and the ability to fly a constant heading at a constant power setting.

Figure 2



The old pro with a thousand or so hours in a type can pretty well tell you how it flies. While there's no real substitute for experience, you can at least get your navigational experience more rapidly by keeping a few records in your logbook. Record the level flight groundspeed, density altitude, power settings, and load (particularly if untypical) in your logbook for each cross-country flight. If, after five to 10 trips, your logbook groundspeeds don't average within a few percent of your correct TAS, then you'd better start looking to the factors you can control: wandering or doglegging your courses, sloppy bracketing of VOR radials, excessive porpoising up and down in your altitude control, etc.

Remember, we haven't dreamed up some impossible standard set by a test pilot in a freshly waxed and polished plane with no nicks in the prop and an engine tuned to a fare-thee-well. You yourself flew the calibration and demonstrated what the plane can do under normal operating conditions. Let's be realistic, however; you don't always fly the same on a long cross-country as you do on a calibration run. So I have a simple suggestion to make. If, after a fair trial, your level flight groundspeed average doesn't approach your TAS from your calibration run, then start using your average level flight GS from past trips as your TAS. Even if you do this, the time and trouble to calibrate your plane's performance is not wasted. If nothing else, it shows you that within a couple of percent, at least, your plane's mid-altitude TAS values were close enough to each other that the averaging of trip groundspeeds was a sensible way to get a measure of your plane's performance.

Equally as important, it shows you what you yourself can do in the plane and should therefore encourage you to improve your cross-country flying technique to approach or even equal the performance done on the calibration run. □

THE AUTHOR

D. B. (Boyd) Richards, former navigator and pilot in the Air Force and now a professor of forestry at the University of Kentucky, will probably be remembered by PILOT *readers as the man who wrote the October 1971 article, "Keeping Your Compass Accurate." His first "how to" article generated such interest among AOPA members that we readily accepted his offer to try and explain his technique that allows the average pilot to do his own airspeed calibration. His earlier article, as its title implies, told readers how to "air swing" their standard compasses.*
