When you build an RV, the instructions include the location and specify the material (simple POP rivets) for your static ports. From what I have heard, in most cases the static system works perfectly right away. That is to say, the altitude and airspeed are correct within some acceptable bounds. That's a fortunate situation, one that many builders of other craft, especially one-of-a-kind designs, don't find themselves in. Furthermore, I suspect that many homebuilts fly without the owners really knowing how accurate their airspeed and altitude are.

Altitude indication depends only on the static system. Airspeed indication, and thus accuracy, on the other hand, depends on both the pitot and static systems, since indicated airspeed is derived from the difference between the pitot ram and static port pressures. Airspeed and altitude accuracy correction and calibration both begin with basic system checks, such as airspeed indicator and altimeter error checks, and ensuring that there are no leaks in either system. Several articles detailing manometer methods for performing these checks may be found online, including a spreadsheet by KITPLANES contributor Kevin Horton.

As measurement and indication systems migrate to electronic ADAHRS sensors, indication errors are diminishing. Also, the pitot-delivered ram pressures are generally accurate and relatively independent of pitot alignment, though the pitot must still be located well out of the propwash and spaced below the wing sufficiently to avoid any disturbance by airflow over the wing—which are both relatively easy to achieve. Therefore, airspeed errors are likely dominated by static pressure errors, just like altitude errors. Optimal static port location is clearly important, but in practice is not easy. Our goal here is to hopefully simplify the process.[1]

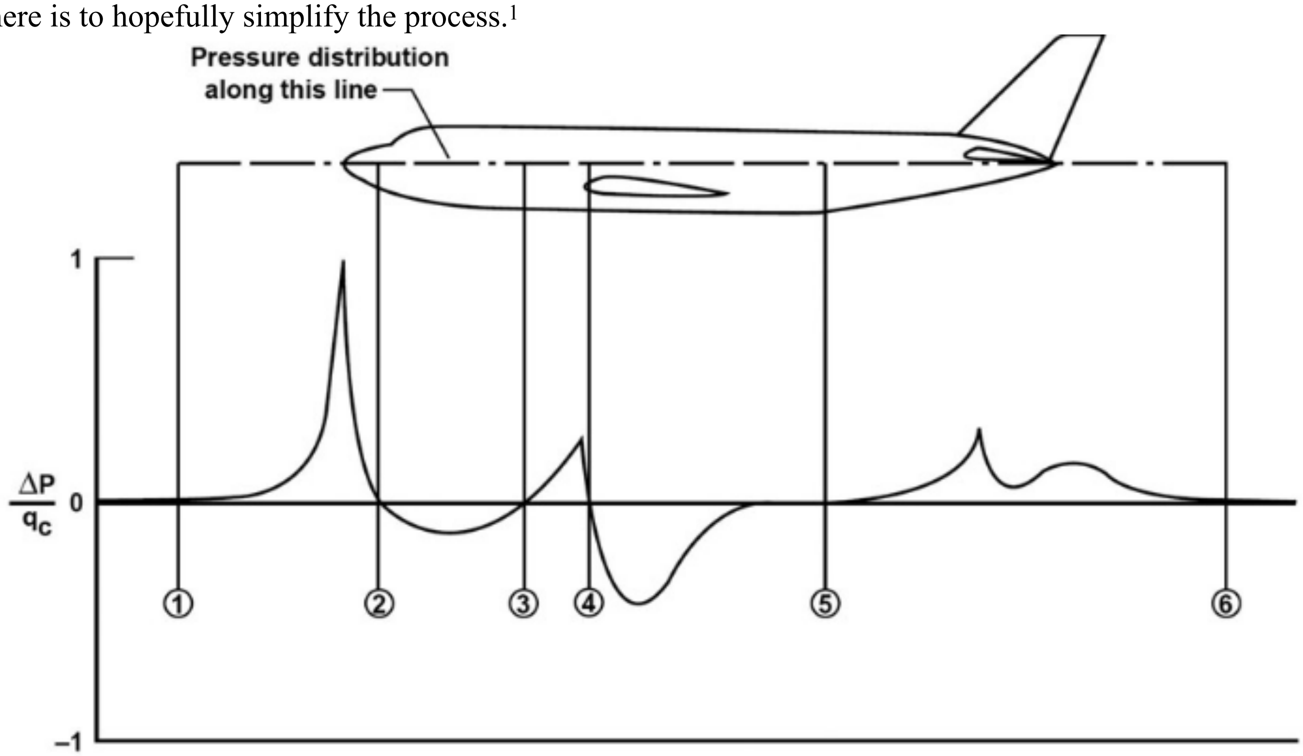


Figure 1: Surface pressure typical lateral distribution. The numbers in the circles (1-6) indicate places where neutral pressure exists, i.e., surface pressure is the same as static pressure at that altitude.

The key to an accurate static system is the location of the port(s) in a place that ideally provides a stable rendition of the (static) air pressure at that altitude. Pressure on the outside of the fuselage varies substantially with position, and often unexpectedly. An ideal location should therefore be in a neutral pressure area, relatively invariant with airspeed, angle of attack, and altitude. Practical static ports may be included in the pitot mast itself, placing them presumably in neutral air. More typically, they are a pair of ports on either side of the fuselage somewhere between the trailing edge of the wing and tail. A typical variation of pressure along the side of a fuselage is shown in the figures. There's a transition from high pressure (above ambient pressure) to low pressure from wing to tail, and the neutral pressure area is most desirable for port placement. In reality, the neutral pressure zone is a line, as we will explore later, and port placement on that line will be the goal to achieve the best compromise for all important flight regimes.

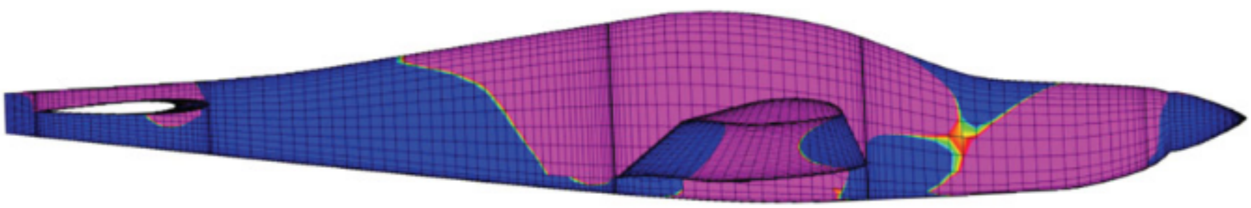


Figure 2: Yellow and green areas depict zero pressure. Magenta is low pressure, and blue is high pressure.

Regulations

While you would like to know your altitude and airspeed as accurately as possible, altitude is clearly the more important for separation safety reasons. The FAA requirements are scattered in a few places and a bit challenging to resolve as to the static port accuracy by itself, but here are the pieces:

14 CFR Part 23—"Airworthiness Standards: Normal, Utility, Acrobatic, and Commuter Category Airplanes," 23.1325 Static Pressure System, states: "(e) Each static pressure system must be calibrated in flight to determine the system error. The system error, in indicated pressure altitude, at sea level, with a standard atmosphere, excluding instrument calibration error, (my emphasis) may not exceed 30 feet per 100 knot speed for the appropriate configuration in the speed range between 1.3 VSO with flaps extended, and 1.8 VS1 with flaps retracted. However, the error need not be less than 30 feet."

Furthermore, per 14 CFR Part 43, Appendix E to Part 43—"Altimeter System Test and Inspection," the altimeter error limits shall be according to the provided table, ranging from 20 to 130 feet, corresponding to 0 to 20,000 feet of elevation.

Finally, the altimeter/transponder correspondence test requires the transmitted altitude to be within +/- 125 feet of the altimeter indicated altitude. For an ADAHRS-based system this error will be near zero. So, to some extent, it is up to the aircraft "manufacturer"—us—to decide how to add all these up and what tolerance to attribute to the port location. Having an ADAHRS-based system and a correspondence test error for the Garmin G3X Touch system near zero, I set a goal of being within +/- 50 feet at 3000 feet, and +/- 125 feet for the range of altitude from 0 to 10,000 feet and the airspeed range of 1.2 VSO to cruise.

It may be a bit surprising that the biennial altimeter/transponder correspondence test does not verify overall altitude reporting accuracy. The test applies pressures to the static port(s) corresponding to the standardized model of atmospheric pressure vs. altitude, and verifies that the system—altimeter and transponder—indicate and report altitude accurately with respect to the applied standard pressures only, independent of whether or not the static ports are accurate in flight. The static ports must be located optimally and supply neutral pressure (within tolerances).

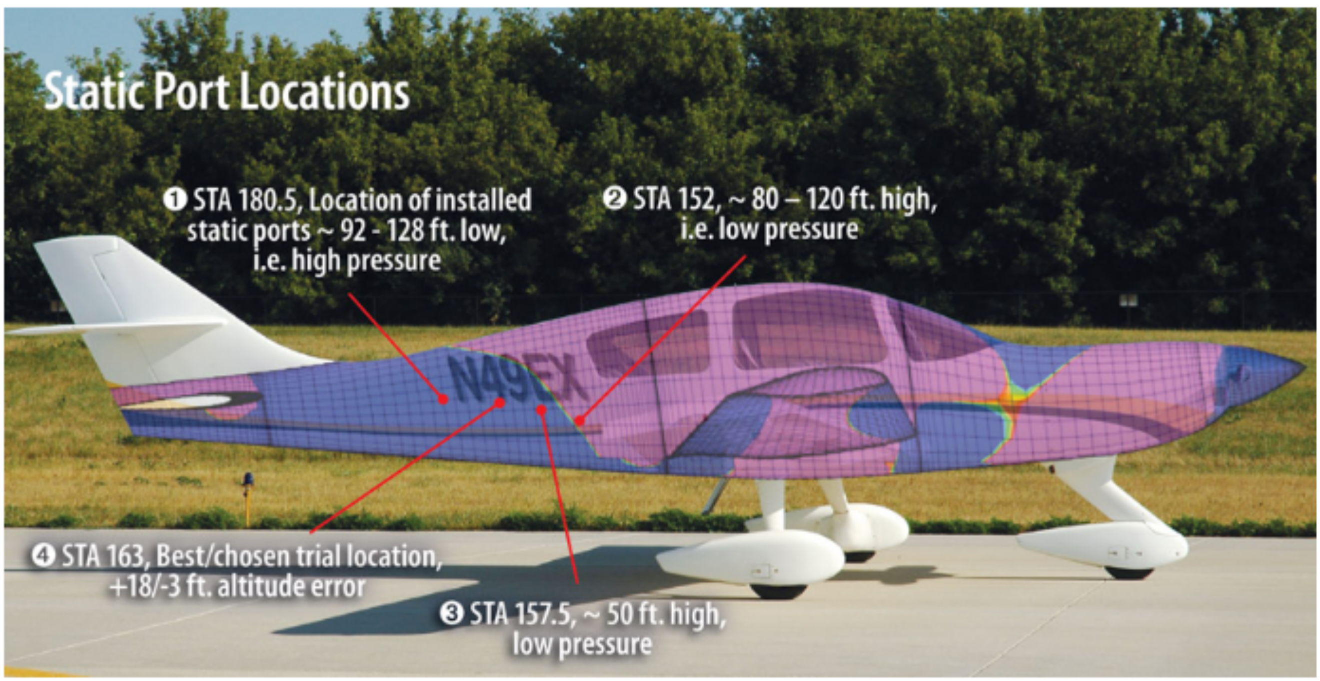


Figure 3: Tests were conducted with the movable static port plates in several different locations on the aft fuselage.

How My Trouble Started

Our Wheeler Express N49EX was originally built with a combined pitot/static probe, which when calibrated was sufficiently accurate for both altitude and airspeed. All was fine until my recent glass panel upgrade, including a Garmin autopilot, which uses the static pressure data for altitude capture and hold. It turns out that the pressure supplied by the static port on the pitot is slightly sensitive to angle of attack, which while not noticeable in the altitude display, makes the autopilot hunt some +/- 30 feet, a nauseating experience! So, a more stable static port location was needed. A quick trial with cabin static pressure stabilized the autopilot, but was substantially off in altitude, as is typical due to lower pressure in the cabin, not to mention variations from the air vents. After several failed attempts to improve the pitot probe static performance, I decided to move the ports to the fuselage.

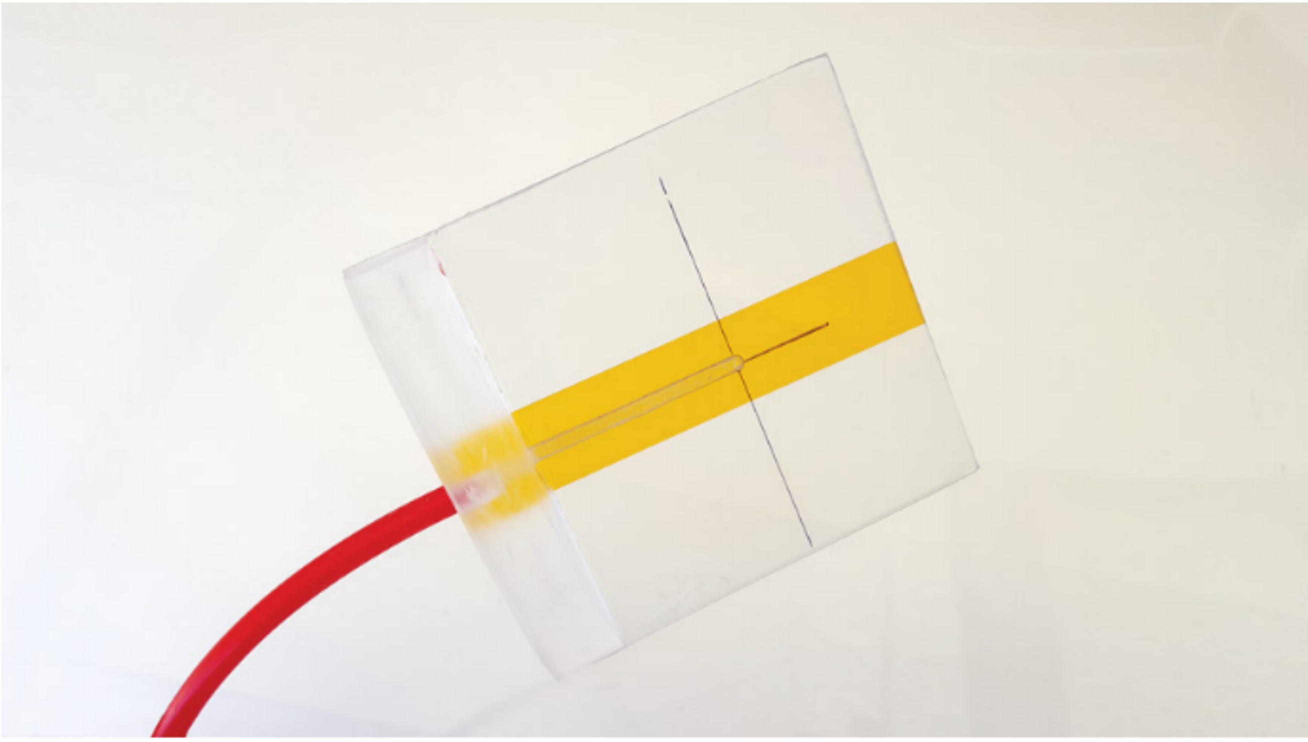
GPS Altitude Error Calculations

Inputs 1	2	3	4	5	6	7	11	12	
			$h_T$ind	Ind. Temp.					
Field Elev. Ft.	Field Press. In HG	Field OAT F	Test Alt. Ft.	Test Alt. OAT F	GPSA	TAS kts	h_T Feet	Ind. Alt. Error, Ft.	Date and Test
758	30.15	42.8	3000	35	3000	161	3092.5	92.5	2/27/2017 STA 180.5
758	30.54	36	3000	19	2874	161	3018.5	18.5	3/3/2017 STA 163
758	30.38	24.6	4000	17	3768	161	4016.3	16.3	3/15/2017 STA 163
758	30.39	32	6000	8	5666	164	6000.0	0.0	3/12/2017 STA 163
758	30.38	24.6	8000	7	7526	162	7996.6	-3.4	3/15/2017 STA 163
758	29.67	66	3000	58	2995	161	2948.6	-51.4	2/22/2017 STA 157.5
758	30.17	40	3000	30	2828	161	2933.0	-67.0	3/9/2017 STA 152
758	30.17	40	6000	28	5760	161	5938.4	-61.6	3/9/2017 STA 152

Figure 4: Test flight ground and altitude temperatures and altimeter setting were used with atmospheric pressure and altitude equations to adjust the GPS (true altitude) to what the altimeter should indicate for the test flight atmospheric conditions. This made it possible to calculate indicated altitude error.

First Fuselage Static Ports

I hate to admit the naivet with which I first installed static ports on the fuselage: I simply looked at a number of factory-built planes, such as the Cirrus and Bonanza, and measured the relative distance from tail and trailing edge of the wing, and chose a similar location on my plane. Completing the installation, which of course included making holes in the fiberglass, I was dismayed that, although the autopilot was now stable, the altitude and airspeed were substantially off (by about 130 feet and 10 mph respectively, cruising at 3000 feet). That's when it became clear that the location of the static ports requires more than guesswork, or even good intuition. After extensive investigation and discussions with several experts, I learned that finding the best location was not easy and, even with commercially produced airplanes, involves a significant amount of trial and error—hundreds of hours as Paul Dye has put it. The prospect of turning my plane into Swiss cheese did not sit well; there had to be a better way!



he relocatable static port plate is made from 1/16-inch thick polycarbonate and is attached to the fuselage with aluminum foil tape.

When the movable plate is in the same location as the existing static ports, the altitude and airspeed errors are the same as the ports by themselves.

The process, in any case, assumes and requires a starting point set of static ports, which as described below, may be done with something better than guesswork hole drilling. Then, the next challenge is to determine the error in altitude for any particular port location and how to improve it.

Determining Altitude Error

With an initial pair of static ports (which may be the “moveable trial static ports” described later) and then further trial locations, the first thing is to determine the altitude error (which correlates with port position error). One approach is by inference from airspeed error, since airspeed may be relatively accurately determined with GPS, as described by Kevin Horton in “Flight Testing: Static System Error, Theory and Practice,” which appeared in KITPLANES in October and November 2009. Kevin also provides a spreadsheet at to analyze flight data.

Another way to determine altitude error is to derive it from WAAS GPS altitude. The WAAS specification requires a position accuracy of 25 feet or better, for both lateral and vertical measurements, at least 95% of the time. Actual performance has been shown to be better than 5 feet vertical. That makes it an acceptable source of true altitude for static port evaluation, assuming one has a WAAS-enabled GPS.

That said, it is well known that the indicated altitude will generally not be the same as the GPS altitude unless you have standard atmospheric conditions: temperature, pressure, and lapse rate. Indicated altitude is the universal reference used by all, whether or not it happens to be the same as true altitude—for separation it matters most that everyone is using the same relative altitudes. However, test flight ground and altitude temperatures and altimeter setting can be used with the atmospheric pressure and altitude equations to adjust the GPS (true altitude) to what the altimeter should indicate for the test flight atmospheric conditions, which then allows one to calculate the indicated altitude error. Caveats are that the method will not work with a temperature inversion, and your OAT measurement capability must be accurate. A spreadsheet for the approach is included on the KITPLANES website and is shown in Figure 4.

Now, the problem remains: How to correct the port position error? The assumption by some is that may be achieved by placing dams ahead of or behind existing ports, but I have found that often does not work adequately, especially if the port is too far from the actual neutral pressure zone. It also does not make for a very aesthetically neat solution.

Movable Trial Static Ports

What if one had a moveable static port—one that could be placed in multiple locations, gathering data to converge on the best location? There are two challenges in creating such a tool: First, it needs to be thin and flexible enough to conform to the fuselage at the area of attachment and not materially affect the local airflow as regards the pressure at its port. Second, a tube must be able to be routed from it into the plane and connected to the rest of the static system. This was accomplished with an approximately 4×4-inch, 1/16-inch thick polycarbonate plate with a 0.035-inch hole for the static port. The hole was in turn routed near to the edge of the plate with a 1/8-inch-wide milled channel on the back side, with a depth about half the plate thickness. At the edge of the plate, a 1/2-inch-wide piece of contoured Plexiglass is glued to provide a place for a 1/4-inch access hole that in turn connects to the channel with a small perpendicular hole. The channel is covered and sealed with a piece of Kapton tape. The plate assembly is attached to the fuselage with aluminum foil tape, with the Plexiglass piece parallel to the airflow. Connection from the port plate to the static system is accomplished with a length of 1/4-inch nylon pitot/static tubing, contoured along the side of the fuselage, held in place with a cover of foil tape, and entering the cabin through an available location. The latter, in my case, was at the gear leg, following the route of the brake lines.

Now, one obvious concern might be, can this arrangement fly without fear of it coming off at cruise speed? Well, the answer to that came to me while walking under the Airbus A330 at Oshkosh a few years ago where I saw a bunch of aluminum foil tape on the wings. Talking to the Airbus folks, I was told, “Oh yeah, we do that all the time in development, no problem.” If it works for them, it will certainly work at 160 knots!

Altitude and Airspeed Errors

Port Location	Indicated Altitude	GPS Method Altitude Error	Airspeed Method Altitude Error	TAS Error
❶ STA 180.5	3000 ft.	+ 93 ft.	+ 129 ft.	- 9.8 mph
❹ STA 163	3000 ft.	+ 18 ft.	+ 4 ft.	+ 0.3 mph
	4000 ft.	+ 16 ft.	+ 6 ft.	+ 0.4 mph
	6000 ft.	0	+ 1 ft.	0
	8000 ft.	- 3 ft.	+ 9 ft.	+ 0.6 mph
❸ STA 157.5	3000 ft.	- 54 ft.	—	—
❷ STA 152	3000 ft.	- 67 ft.	- 98 ft.	+ 8.3 mph
STA 163 with installed port	3000 ft.	- 0.8 ft.	- 13 ft.	- 1 mph
	6000 ft.	+ 26 ft.	+ 40 ft.	+ 0.2 mph

Figure 5: Through trial and error, STA 163 was determined to be the best location for the static ports. The bottom rows show the data for STA 163 with the actual ports installed there.

Pressure Profile Modeling

Relocatable static ports in hand, the first test was to place them directly over the existing installed ports and verify that they delivered the same incorrect altitudes and airspeeds, which they did. This looks like it might work!

Just before proceeding with more guesswork placements of the newly crafted moveable static ports, I lucked into a bit of marvelous scientific method and rigorous engineering that anchored the process in some real data. In an email discussion of my problem and mission with Peter Garrison, who writes the “Technicalities” column for Flying magazine, Peter mentioned to me that he had the CAD model for the Express aircraft and would gladly run a surface pressure analysis for me. That predicted where the areas of zero error should be, providing a starting point for locating the ports. You can see in the pictures the line where this is expected to be, back of the wing. Superimposing the model on a picture of the plane provided guidance for new trial port locations.

Trial Results

Starting with the predicted neutral pressure zone, the first test flight data made my day! Whereas the original ports were in a slightly high pressure area, resulting in airspeed 9 knots low and altitude indication 129 feet low, the new location was now in a slightly low pressure area. The model was not perfect, but I knew the best location was somewhere in between, and in fact can be approximately predicted by interpolation of data points.

Of course, it’s never quite that simple. The pressure gradient is not linear, and in addition a vertical position needs to be found that minimizes the effects of angle of attack, altitude, and airspeed, while avoiding any significant errors in landing configuration with flaps down.

Data/Analysis

After three new trial locations using the moveable port plates, I found what looked like an acceptable final location. Figure 5 shows the altitude and airspeed errors at 3000 feet cruise for the four port positions as shown in the pictures, and at 3000, 4000, 6000, and 8000 feet for STA 163. From the data, it looks like a slightly better position might have been about 1 or 2 inches forward, but that would have put the right port in the baggage door, so I decided that within a few feet and less than 1 mph error was good enough. The bottom rows show the data for STA 163 with the actual ports installed there.

Additional tests at lower and higher altitudes, lower speeds, and in landing configuration all confirmed errors within the original goals. One insight is that the pressure gradient is not linear. With multiple points, a curve fit could be created, but you may find an acceptable location with a few iterations. Note that whereas the plates delivered nearly identical data when installed over my original ports, when the STA 163 ports were installed, there was some difference, though probably acceptable. One refinement may be to make the plates with ports that are more like the contour of the port to be installed.

Summarized Procedure

1. Verify that your pitot/static system does not have any leaks.

2. Determine any calibration errors in the altitude and airspeed indicators.

3. Establish a set of test conditions, including various combinations of airspeed/power settings, altitudes, and flaps extended/retracted for the slow speeds.

4. If a surface pressure model is available for your plane, use it to determine the initial placement of the static trial plate. If not, pick a location roughly 1/3 of the distance from the trailing edge of the wing root to the tail. For vertical position, locate roughly at the vertical tangent point.

5. Preferably on smooth days, fly your test combinations holding at each of the altitudes (easiest if you have an autopilot), and record indicated altitude, GPS altitude, indicated airspeed, true airspeed, OAT on the ground and at altitude (and some intermediate altitudes to verify there is no inversion).

6. Determine the altitude errors for the various tests using either the inference from airspeed error or adjusted GPS altitude method. If you use the airspeed inference method, your test flights need to include a three course pattern, as described in Kevin Horton's spreadsheet.

7. If the altitude error is such that the actual altitude is higher than indicated, then the static port pressure is lower than standard for that altitude and likely the port is too far forward, and vice versa. Relocate the trial port in the direction appropriate for a correction.

8. Use the data from the second port to determine a rate of correction per inch of port relocation to predict a better location. The pressure gradient may not be linear, but within just a few locations, the altitude and airspeed errors will likely be reduced into the range of +/- 30 feet and +/- 1 mph.

9. Determine the trial location that provides the best compromise overall results.

Once you've found your best locations, it's time to take the plunge and put holes in the fuselage. One last thought: You may wish to start with just the first port on one side and make sure nothing has changed before proceeding with the second port on the other side.

Pressure, Altitude, Temperature, and Airspeed Math

Here is the atmospheric and airflow physics used in the spreadsheet to determine altitude error.

Pressure as a function of altitude can be calculated with the equation

$P_h = P_0 [1 + (L\ h)/T_0]^{-0.03416/L}$ where:

P_h is pressure at altitude h in Pascals (Pa)

P_0 is the pressure at sea level in Pascals

h is altitude above sea level in meters

T_0 is the temperature at sea level in K (= C + 273.15)

L is the temperature lapse rate per meter (negative number)

If the conditions are standard, T_0 is 288.15 K = 15 C, the lapse rate is -0.0065 K/meter, and P_0 is 101325 Pascals (= 29.92 in. Hg). An error-free static system in standard atmospheric conditions would then indicate actual height above sea level. With typically non-standard conditions, the altimeter setting will offset the difference from standard pressure, and the indicated altitude difference from actual altitude will be dominated by the difference of the temperature and lapse rate from standard, for which altimeters are not compensated. The temperature component will typically dominate, as, except for days with inversions, the lapse rate does not vary so much.

Complementary to the pressure equation, the height above sea level is given by:

$$h = (T_0/L)\,[(P/P_0)^{-0.19026}L - 1]$$

OAT at altitude and airspeed may be calculated as:

$$OAT = OATI / [1 + 1.6 \times (TAS/750)^2]$$

Where TAS is in mph and OATI is the indicated OAT at the test altitude. The sensor recovery factor is assumed as 0.8, and the speed of sound at the altitudes we fly is assumed as an average of 750 mph.

Airspeed may be calculated as:

$CAS = a_0\,[5\,(q_c/P_0 + 1)^{2/7} - 1]^{1/2}$ where:

a_0 is the speed of sound at 15C
q_c is impact pressure
P_0 is standard pressure at sea level.

Finally, pitot impact pressure may be calculated as:

$q_c = P\,[(1 + 0.2M^2)^{7/2} - 1]$ where:

P is static pressure
M is the Mach number, which in turn is CAS/Speed of Sound (at altitude).

The pressure and altitude equations are used in Figure 4, the error calculation spreadsheet, to adjust GPS altitude to what the indicated altitude should be for a given set of test-time atmospheric conditions. They may also be applied to calculate the rate of change of pressure per change of altitude, and then predict the error in airspeed for a given error in altitude.

For example, at 3000 feet the change in pressure is about 3.35 Pa per foot, and change in airspeed for a given change in pressure is 0.022 mph/Pascal, so the airspeed error for a given altitude error is 0.074 mph/foot. In other words, if the altitude is off by 100 feet, the airspeed will be off by about 7.4 mph and vice versa.

—R.M.

Does This Really Work?

OK, I know what some of you are thinking! Having read most of the pitot/static system threads on the Van's Air Force forum, there are many tales of extraordinary sensitivity to minor variations of the static ports. Narratives abound of 10-knot airspeed errors or variations associated with minor static port features/changes, even due to N-number decals or paint interfaces in the vicinity of the ports. Given such discussions, I can imagine you might have serious doubts about how well a moveable static port on a plate structure like I have described might work. Can it really perform like a fuselage port at the same location?

To address that concern, I offer the following:

1. Bernoulli's principle says that the static pressure at any location along the fuselage is inversely proportional to the velocity of the air at that location. That is why, per the figure, the static pressure has a low to high gradient as it moves from the fuselage area behind the wing to farther back; it was moving faster to get past the wider portion of the fuselage and slows down as the fuselage gets thinner. So, for the relative part of locating a static port, one that delivers a lower altitude and airspeed than actual needs to be moved forward and vice versa.

2. While I am not a fluid dynamics expert, it appears that pressure at any given location will be the same on the surface of the thin plate port described because it maintains essentially the same contour of the underlying surface, and being thin enough, it maintains the same flow velocity and thus the same static pressure.

3. When I have placed the moveable plate in the same location as the existing static ports, the altitude and airspeed errors are the same as the ports by themselves. Further, when I finally determined the best port location and took drill to the fuselage, the final ports again provided the same altitude and airspeed results as the plates.

The nagging and remaining question then is how and why have some RV owners had such radical differences in altitude and airspeed resulting from minor port changes, particularly at the same location? Perhaps it is that the rivet ports are not actually at the best neutral pressure location, but their particular shape and hole entry curvature have local flow altering effects that result in good measurements?

I am using Cleaveland Aircraft Tool aluminum ports bonded into the fiberglass, which have a minor outward curvature, but otherwise are generally flush. Their holes are flush and sharp, similar to what NASA testing showed to be ideal hole shaping.[2,3] Perhaps the moveable plates would not perform the same as the Van's rivets.

The general method is still applicable even if the first static location ends up not quite right on. The difference from the moveable plate and other plate positions can then be used to calculate a new, and hopefully final, location. It's still better than the many trial and error holes!

—R.M.

[1]NASA Technical Memorandum 104316, Airdata Measurement and Calibration, Edward A. Haering, Jr., 1995

[2]NASA Reference Publication 1046, Measurement of Aircraft Speed and Altitude, 1980

[3]Final Report, FAA Contract No. FA64WA-5025, Project No. 320-205-02N, Flight Calibration of Aircraft Static Pressure Systems, 1966

Installing a Pitot-Static System

By Tony Bingelis

AMONG THE MINIMUM instrumentation required for VFR (Visual Flight Rules) flying are two flight instruments - the airspeed indicator and the altimeter. While a small number of builders might think a rate of climb (vertical speed) indicator is essential, it is not one of the mandatory VFR instruments. Nevertheless, the three instruments do have something in common - each must be vented to a source of atmospheric (static) pressure for proper operation. In addition, the airspeed indicator requires a source of ram air (pitot) pressure. These two air pressure sources, and the interconnecting plastic tubing, constitute the aircraft's pitot-static system.

Calling it a "system" when little more than a bent aluminum tube and some plastic tubing embody the main elements may be a bit grandiose. However, you can make your own installation of the pitot-static system into a big deal or keep it on a modest minimum effort level.

Static Pressure Sources

Some pitot tubes contain both an inlet for the pitot or ram pressure, and another for the static pressure. These pitot tubes are, therefore, more correctly identified as "Pitot-Static" tubes. In such installations the pitot-static tube is a dual-function unit providing both ram (P) air and static (S) air for the instruments connected to it.

Although the static pressure is not always obtained at the pitot tube head assembly, it would seem that such an arrangement where both ram air and static air are taken from the same source area is a good one. It could assure a higher degree of accuracy in instrument performance than might a static air pressure source remotely located. On the other hand, one fairly reliable source location for a static pressure vent, remote though it might be from the pitot tube area, is the fuselage . . . somewhere in the side of the fuselage, that is.

There you will often find one to three small vent holes, in a flush-mounted fitting of sorts, serving as a static air inlet. Actually, static ports are ordinarily installed on both sides of the fuselage to minimize the effects of slipping or skidding flight resulting from sloppy or unintentional rudder inputs.

Brief transgressions from coordinated flight will affect your instrument readings only momentarily unless you habitually fly the airplane in a constant skid.

Both static vents, when located on opposite sides of the fuselage, must be manifolded (connected together by a "T" or a "Y" fitting).

One advantage of a separate static source remoted from the pitot tube is the theoretical assurance that your altimeter and vertical speed indicator will continue to function even though the pitot tube may become blocked by mud daubers, ice, dirt or a forgotten pitot tube cover . . . and this is worthy of your consideration.

The remoted static pressure vents, when installed, should be located in an area of air flow unaffected by wing junctures or fuselage bumps and irregularities. Even though the fuselage sides may seem to be uniform in the area selected for the static vents, a future relocation of the vents could become necessary because of erratic or unreliable instrument readings.

If the static source is located in an area producing higher than true (surrounding atmosphere) static pressure, your altimeter will read lower than it should. Conversely, a static source producing lower than true static pressure will cause the altimeter to indicate higher than it should.

A poor static source also affects the airspeed indicator's readings. For example, a static source co-located with the pitot head positioned just ahead of the wing but too close to its under surface could be in an area of slightly higher pressure than that of the surrounding air. This is an area of higher pressure induced by the flow of air around the leading edge of the wing. In such a case the airspeed indicator will be induced to read slow since the pressure differential between the ram and static air would be less in that area.

A location too high could induce the reverse effect causing a too fast indication by the airspeed gauge. Similar errors can occur with the remoted fuselage static ports if they are located in a disturbed pressure field.

Carrying this static error subject a bit further, we can see where the same errors could result in a biplane installation where the pitot-static tube assembly is mounted too high or too low on an interplane strut. If too high the static port could pick up a slightly higher pressure under the top wing and give a resultant slow reading. If the static tube is located too low on the strut, the static source will pick up a lower than true pressure because of the induced airflow over the top of the bottom wing. This would result in an airspeed indication that is too fast. Remember, the airspeed indicator measures the differential between the ram air and the static air.

Pitot or Ram Pressure Sources

As previously stated, only one of the three VFR flight instruments, the airspeed indicator, requires ram (pitot) pressure. Its source of ram air pressure is a pitot tube mounted parallel to the longitudinal axis of the aircraft and in line with the slipstream (relative wing). The location of the pitot tube is no less important than its orientation on the aircraft.

All this really means is that the pitot tube should not be located inside the propeller blast area or any place where its pick-up opening might be in air disturbed by the influence of proximate aircraft structure. Although some airspeed error is no big thing for the weekend aerial putt-putt, it can be a serious matter for a fast high flying homebuilt or one used occasionally in IFR excursions.

It seems as though the only thing standardized about pitot tube head locations is that, for some reason unknown to me, more pitot tubes are located somewhere in the left wing than elsewhere. But you are just as apt to see pitot tubes installed almost anywhere on the aircraft.

In a twin the fuselage nose location is quite suitable because it is not within the propeller blast area.

The most serious boo-boo you can make in locating your pitot tube is to place it in the leading edge of the wing. Yes, in spite of the effectiveness of that location. It is so easy to install a pitot tube there that it is almost irresistable for the first time builder to ignore. Unfortunately, it is such a good location that almost anyone walking by will notice it after he has bumped into your pitot tube or has broken it off. Even more unfortunate - the builder himself may be the very first one to ruin it. One builder told me his was broken off so often that now, just before he flies, he slips a drinking straw into the hole once occupied by the original pitot tube.

Of course, the leading edge location is not too bad in a high wing aircraft . . . if that wing is high enough off the ground.

Maybe Molt Taylor has the solution for vulnerable pitot tubes sticking out where they can get bent or broken. He has installed, in his MicroIMP, a flexible pitot tube that merely gives way under impact and twangs back good as ever. (I wonder how he does that?)

It becomes obvious then that the safest location for a pitot tube is beneath the wing. Almost anywhere under the wing is O.K. for aircraft utilizing the older airfoils (Clark Y, etc.), just so long as the pitot tube opening is about 5" or more below the surface of the wing. An aircraft with a laminar flow airfoil should have its pitot tube located further aft to some point where the maximum camber of the wing occurs.

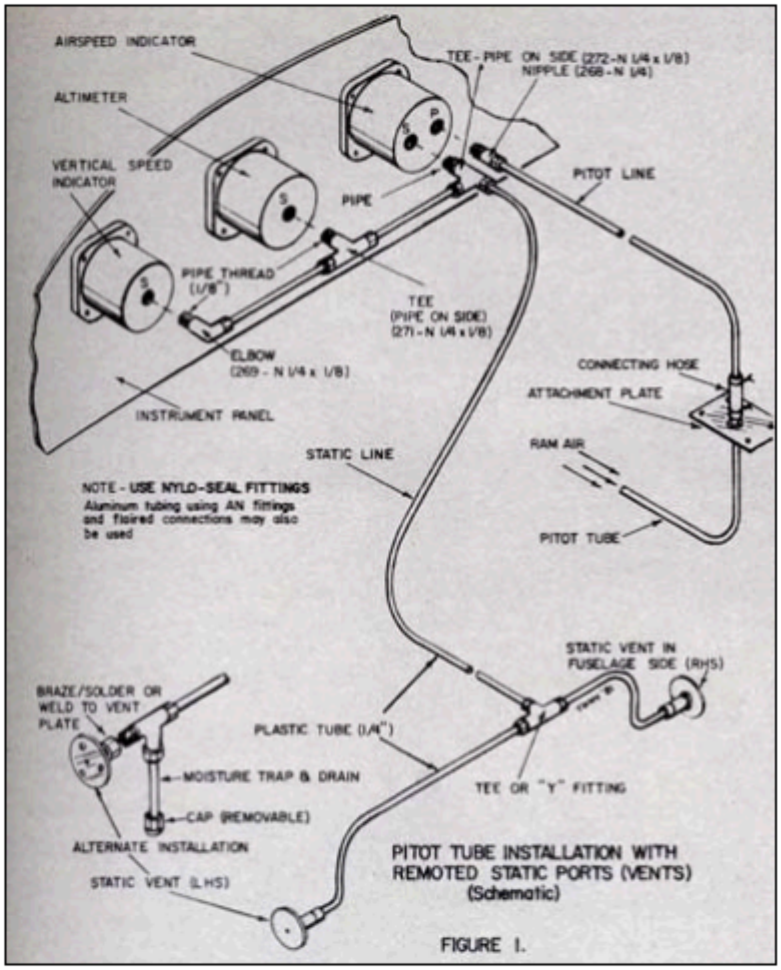
Pitot-Static System Installation Notes

Some pitot static tubes are made with built-in heater elements. These are electrically powered and must be hooked to the electrical system. The pitot heat would then be controlled by an appropriately labeled instrument panel switch . . . but why a heated pitot-static tube if you don't fly IFR?

When the static source is to be obtained at the pitot tube head, you can make your own assembly using two aluminum tubes attached to a mounting bracket.

One of the tubes in the pitot head assembly will have an open end for ingesting ram air pressure. This tube should be connected to 1/4" polyethelene (plastic) tubing routed to the "P" (pressure) opening in the airspeed indicator.

The other tube (static) of the pitot head assembly must have its end sealed (pinch, weld, insert a screw or otherwise close the opening in the tube). In addition, it will have at least four small holes (use a #60 drill bit) equally spaced, around its circumference to provide the ambient (static) air pressure needed by the airspeed indicator, altimeter and the rate of climb. This static source will also be connected to each of the VFR flight instruments with 1/4" plastic tubing. See Figure 1 for a few ideas and typical hook-ups.



PITOT TUBE INSTALLATION WITH REMOTED STATIC PORTS (VENTS) (Schematic)

FIGURE 1.

Before completing the connections at the instruments, blow out the tubing to assure yourself that none of the lines are plugged. Do not, however, blow into any of the instruments as that may cause internal damage.

Aircraft used in instrument flying should have an alternate source for static pressure in case the primary static source becomes inoperative. This alternate source can consist of a single valve that opens the line to the cabin atmosphere – an unreliable source at best but better than inoperative instruments.

A few builders of uncomplicated aircraft often don't bother with a static source and simply leave the "S" ports of the instruments open behind the instrument panel.

This is a poor installation if for no other reason than the abuse the instruments will be subjected to from ingested dust and dirt floating around in the unfiltered air. Another drawback to using the cabin atmosphere as a static source is the wild fluctuation induced in the instrument readings every time the cabin ventilation vents are opened or closed.

Ever hear of adjusting your airspeed by modifying the static tube in a pitot-static installation? Well suh, the story goes like this.

If your airspeed reading is slow, it is because the static port is in a slight high pressure zone. This can be corrected by slipping a small "O" ring over the end of the static tube ahead of the tiny drilled holes (vents, that is).

Moving the "O" ring aft on the tube (in very small increments) will increase the airspeed - on the gauge (not for the airplane, amigo . . . sorry). Conversely, moving the "O" ring forward, away from the ports, will decrease the indicated airspeed in much the same manner. Very small changes in the "O" ring position make a noticeable difference in the indications.

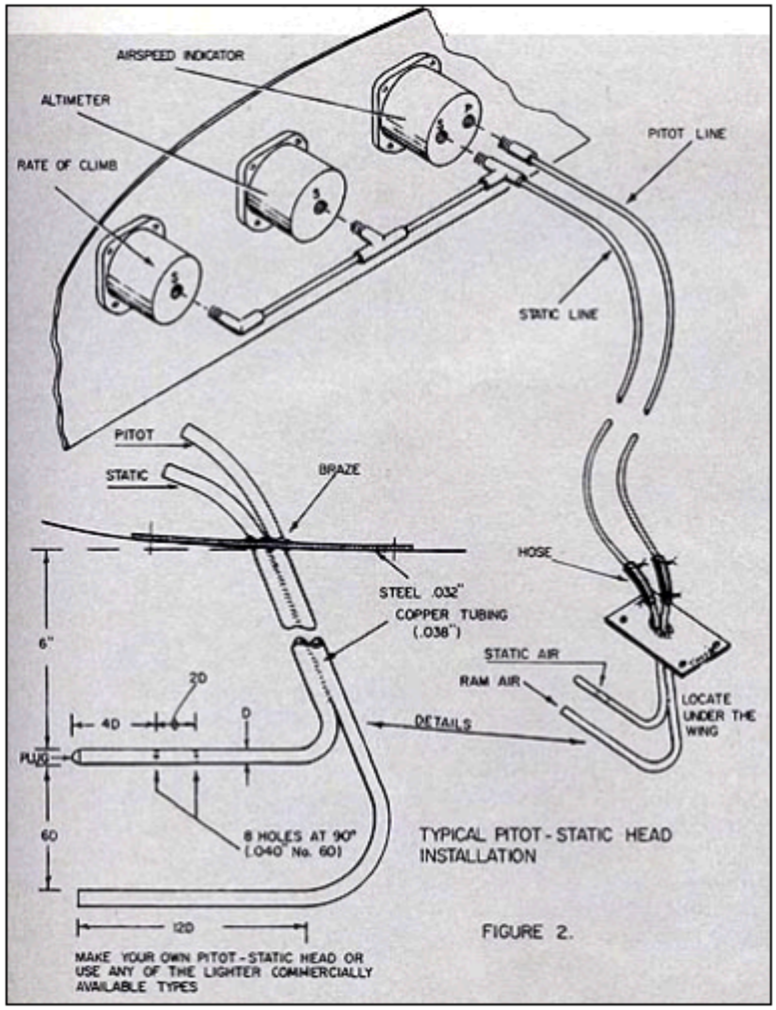
What happens is that you are attempting to lower the static pressure "felt" by the static ports with the "O" ring interrupting the airflow, thereby causing a slight lowering in air pressure behind (downstream) the ring.

The closer the ring is to the ports, the lower the induced pressure.

If on the other hand the static-tube port happens to be located in an area of low pressure, moving the ring to a position behind the ports should provide a slight increase in the pressure felt by the static ports with results opposite to that described above.

Because a rubber "O" ring will deteriorate, it should be replaced with a metal ring having identical dimensions after the proper location is determined. A dab of paint or epoxy should hold it in place. One gent who does some wild gyrations in his modified Starduster has a big ol' set'screw securing his "scientifically" located ring.

There you have it – much more than you wanted to know about pitot-static systems. And thanks to my Technical Advisor for this month, Frank Luft of Central Point, Oregon.



TYPICAL PITOT-STATIC HEAD INSTALLATION

FIGURE 2.