Stall Warning and Prevention Measures for Experimental Aircraft

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Custom Flight Creations, Inc.

https://www.youtube.com/watch?v=_L7o_JlPg5w

Stall Warning and Prevention Measures for Experimental Aircraft
Why this topic?

- Stall/Spin accidents are still occurring far to often in GA and the EAB community.
- Much has been written over the years to name a few:
  - Stall/Spin Safety (aopa.org and eaa.org)
  - By Tony Bingelis (originally published in EAA Sport Aviation, April 1981)
  - Stall/ Spin Accidents, Understanding - Prevention – Causes www.experimentalaircraft.info › stall-spin-accident
- The emphasis in the past was on what I call “Avoidance Training”

Stall Warning and Prevention Measures for Experimental Aircraft

- Is stalling an airplane a maneuver or an emergency?
- How did you learn to stall an airplane?
  - Level Flight
  - Slow approach to the stall at 1-2 knots/second
  - Listen/feel for the stall warnings such as buffet or warning horn
  - At the break:
  - Release back pressure.
  - Add full power and level the wings.
  - Once the altimeter is stopped and the VVI is reversing
  - Exercise Complete!

How did you learn to stall an airplane cont'd:

- Accelerated Stalls.
  - 45 degrees of bank,
  - Clean configuration
  - Level turn
  - Allow speed to bleed off holding coordinated turn
  - Once the horn/burble begins,
  - Relax back pressure
  - Roll wings level
  - Add power
  - Exercise complete

How are pilots getting killed then? Some emergency Scenarios:

- Overshooting final at Oshkosh or Sun ‘n Fun
  - Increasing bank
  - Using additional rudder to skid
  - Increasing back pressure
  - Increasing power (possibly)
- Result
  - Additional rudder causes increased bank
  - Inside wing slows in rotation
  - Top aileron added causing inside turn aileron to increase AOA
  - Abrupt inside wing stall and aircraft rolls inverted.

How are pilots getting killed then cont’d?

Perhaps we don’t train and practice properly. Maybe we should do more scenario training!   Here is a scenario to consider:

- Abrupt Go Around or Collision Avoidance (Oshkosh/SnF scenario)
  - On final approach
  - Rapid loaded roll (causes adverse yaw)
  - Abrupt pull up at the same time
  - Power abruptly increased (perhaps engine hesitates)
  - Little or no rudder used to combat torque.
- Result
  - Down aileron wing stalls.
  - Aircraft rolls rapidly opposite to the stick input
  - Insufficient altitude to recover.

How are pilots that practice stalls in their biannually flight test getting killed then? Another Example:

- Engine difficulties on takeoff or in the pattern departure.
  - Pilot fails to maintain what power is available and achieve level flight attitude.
  - Aircraft continues to bleed airspeed below L/D max.
  - Pilot continues to try to fly the aircraft and attempts to maintain altitude
  - Half hearted attempt to turn to field
  - Loaded roll made to turn toward safe area or runway.
  - Speed bleeds off more.
  - Pilot attempts to maintain flight and a low power or power off stall occurs.
  - Lack of coordination causes one wing to drop.
- Result

  Aircraft rolls off and there is insufficient altitude to recover.

How are pilots getting killed then cont'd.

There is an old military saying:

"Train like you fight and you will fight like you were trained."

Hence military training attempts to train in very demanding ways requiring many check rides and exercises that many would consider dangerous, putting equipment and lives at risk.

In the civilian pilot world, you may say:

Train like you fly and you will fly like you were trained.

If one avoids stalls, one can never find himself in a dangerous situation right!

But then aircraft may need to be made more tame!

Or: The pilot needs to be fully trained and confident in his specific aircraft.

How are pilots that practice stalls in their biannually flight test still getting killed in their new experimental aircraft?

- Are skills and scenario training ever practiced in the biannual?
- Is the aircraft stall characteristics and warning systems really understood?
- Is the aircraft flight characteristics just above the stall practiced (aka Slow Flight Maneuvering)?
- Is turning performance practiced at low speed and low power, i.e. the demonstration/practice should show altitude loss and airspeed management when operating below L/D max on the fringe of the stall.
- These are somewhat trained in “Upset Training” syllabi. But how many have ever had this training.
- We have an issue in the EAA with our new builders and second hand buyers who:

“I fly a C172, it’s a pussy cat. What could go wrong. Now I’m building/buying a homebuilt for fun.”

Why worry about stalling my homebuilt, I practiced in a 172 and I will avoid the stall!

- Consider the new homebuilt aircraft:
  - Instruments are new and uncalibrated.
  - Engine has never been stressed to full power.
  - Fuel System untested or is modified.
  - Airframe, has it been verified square, true, rigged properly and CG calculated.
- Amateur Test Pilot:
  - Zero time in this model.
  - No advanced slow speed handling or training in model.
  - No test procedure or flight plan for test that has been practiced.
- Builder/Test Pilot:
  - His first consideration is not to damage or loose his aircraft, so he may maneuver to try to make a landing when a forced landing is more appropriate.
  - If he isn’t the test pilot, can he translate the pilots debrief or understand what the aircraft is doing to take proper corrective action post flight.
  - Has the builder the energy to do extensive modifications if necessary or will he just attempt to avoid the problem.

How are pilots getting killed then cont’d?

- It is beyond the scope of this briefing to look at how to train to recognize a situation where a stall spin accident will occur, but we can:
- If we are a smart builders, we will get time in similar kit aircraft to ours.
- We will get instruction and ensure we are current and capable before attempting test flying the new homebuilt.
- We will practice to determine the indications of a stall or poor slow speed characteristics in that aircraft before we test the newly built aircraft.
- Finally, the builder won’t allow the plane fly until he has done everything to ensure the aircraft is as airworthy as it can be.
- My rule:

“The plane is ready for its first flight when you are prepared to knock on the door of the test pilots house and explain to his wife that he is dead and there was nothing you could have done to make the aircraft safer to fly.”

Now that the aircraft is finished, ground tested and is airworthy we find we have stall, trim and rig issues.

What do we do?

Stall Warning and Prevention Measures for Experimental Aircraft
What do we do to correct problems?

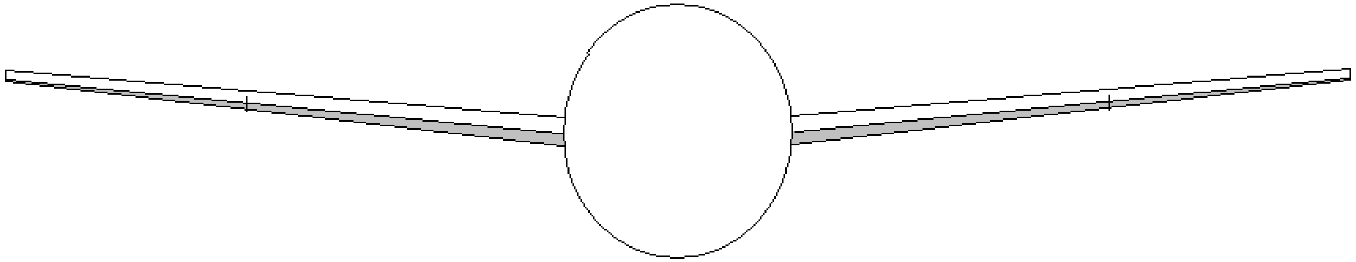
What a builder can do to correct or improve the stall warning and characteristics of the experimental aircraft.

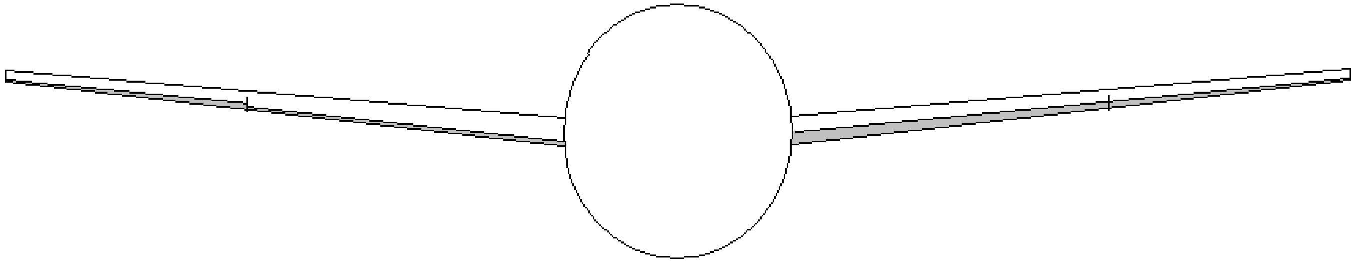
Stall Warning and Prevention Measures for Experimental Aircraft

- What can you do as the builder to ensure the aircraft will fly as the designer intended:
- Build the aircraft square and balanced.
  - The manual should give main wing incidence angles and be properly set.
  - Flaps should be dead even and retract and extend evenly.
  - Ailerons should be even, have no binding, or loose hinges.
  - All controls should deflect within the allowances of the build manual.
  - The weight and balance should be set to the middle of the range per the manuals first flight recommendation.

Trimming the Aircraft.

- How to ensure it is square.
  - Use your “Mark One Eyeball”

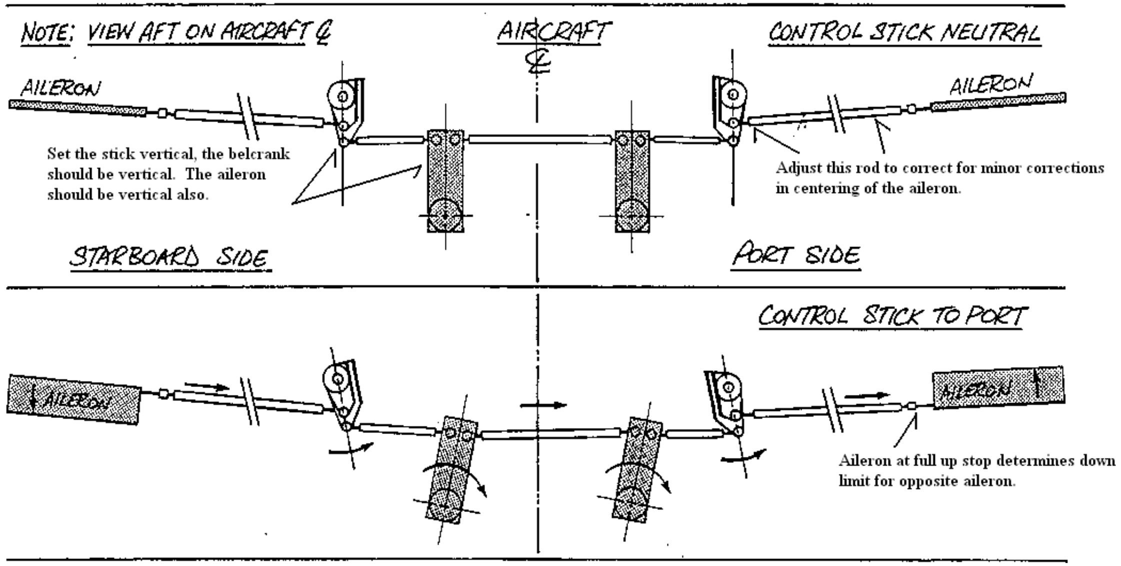




Ref Trimming 101, CFC

Trimming the aircraft.

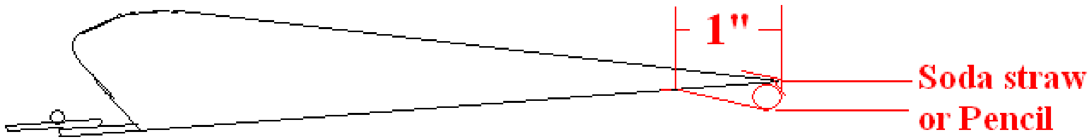
- Check the engine offset per the manual as many aircraft with right turning engines offset the thrust line to the right.
- Check the fin is set per the manual if the engine is not offset.
- Ensure the ailerons work together, are not binding, and the deflections up and down are per the manual, and differential is properly set.



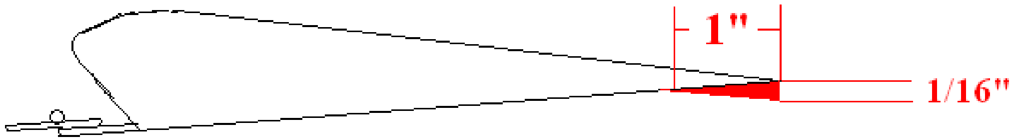
Ref: Europa Aircraft

Trimming the Heavy Aileron.

- Ensure trim tabs are set neutral and if you have no trim tabs have a plan on how to trim during flight test.



To test, place 10 inch pencil or straw on trailing edge and tape it in place making a ramp about 1-1.5 inches long. If the tab is 10 inches long that corrects a pound of stick force and will require a filler strip of 1/16 inch for nearly the length of the aileron.



Filler added like a ramp or flap

The filler strip is to hide the fact you needed a trim tab. It is called contouring the aileron.

Ref: Triming 101, CFC

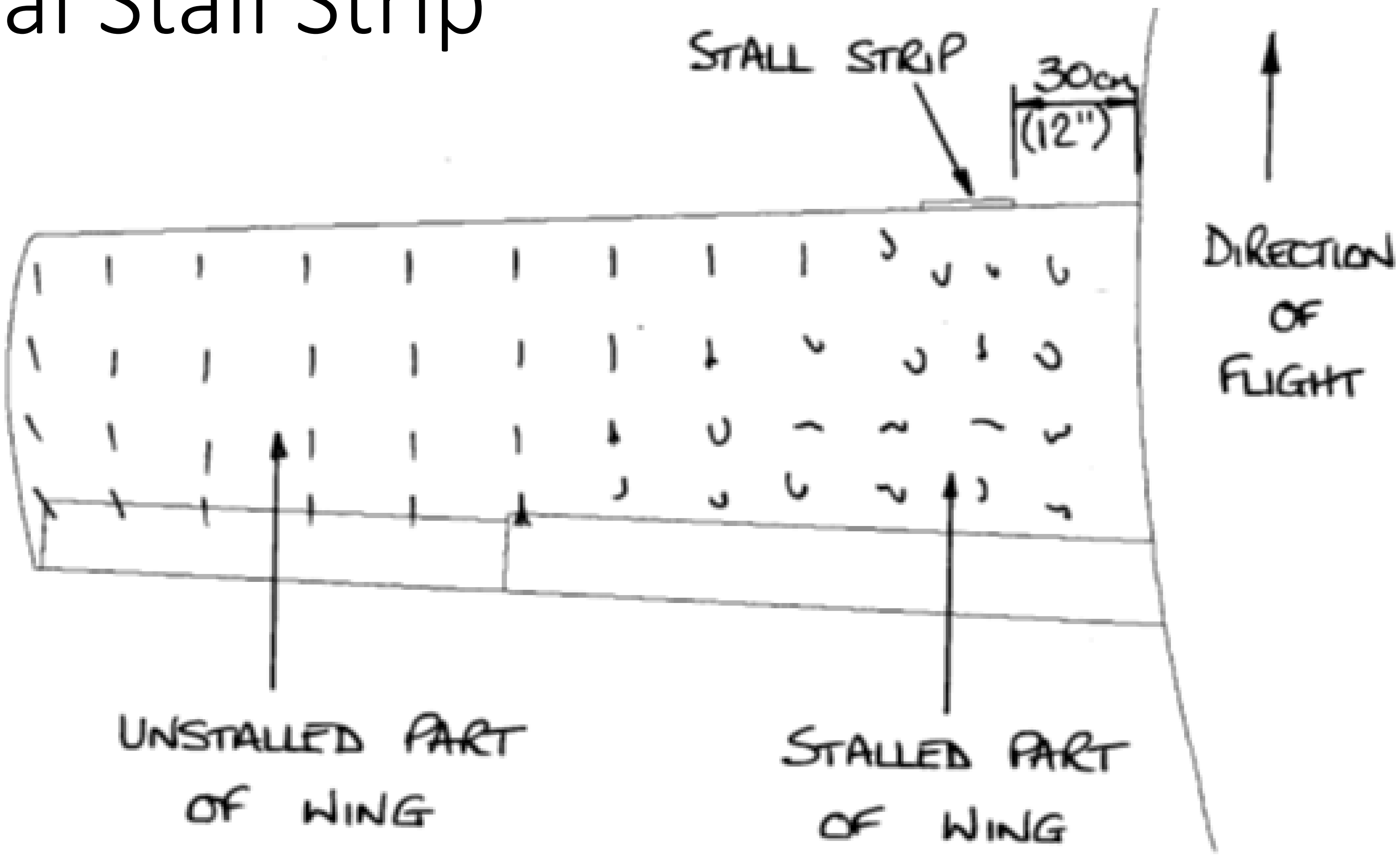
What can be done to improve the stall warning of your experimental kit aircraft?

There are four basic types of AOA or stall warning systems.

1. Aerodynamic airframe warning (Buffeting); aka wing design/stall strips.
2. Angle of Attack (AOA) vanes or probes which give true airstream angle relative to the chord line of the wing, and the angle is provided to pilot via a readout or aural tone;
3. Stall warning devices that trip or activate at a pre-stall setting for audible or visual warning of approach to the stall;
4. Low Airspeed warning devices which alert the pilot to deviations from preset speeds.

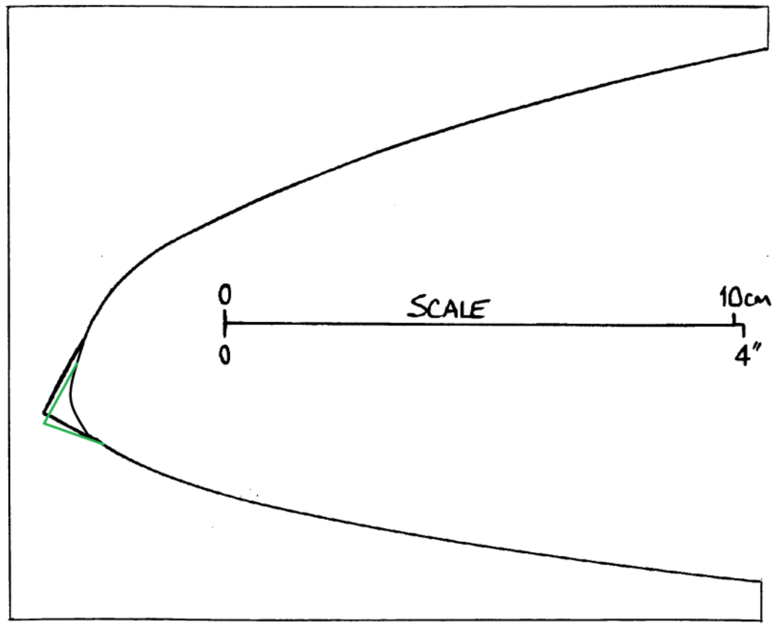
- All these systems require proper installation, setup and flight test. Often times requiring multiple flights before the AOA or pre-stall warning is acceptable as a pilot warning device.

Typical Stall Strip

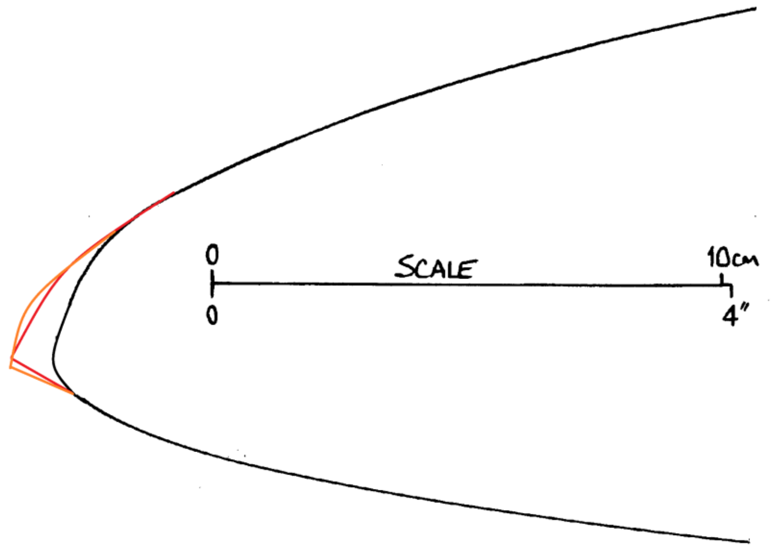


N12AY leading edge stall strip experiment in reshaping the inboard leading edge from the root to about 9 to 12 inches out from the root rather than an angle centered 12 inches out from the root.

Note that a classic 90 degree angle makes the leading edge a flat plate to the relative wind at cruise.

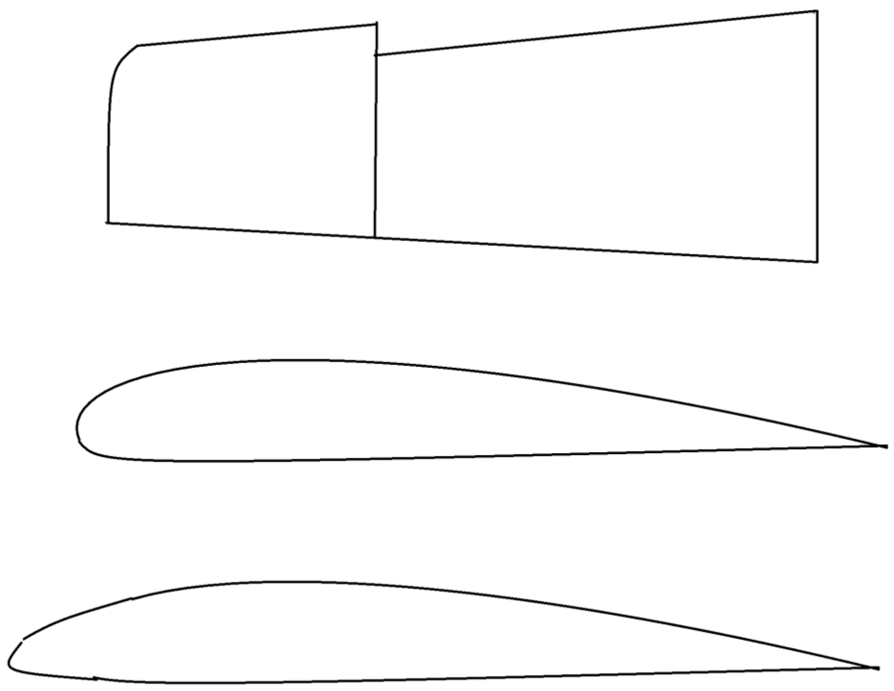


By reshaping the leading edge allows for a smoother flow of air at cruise, yet still provide a clear separation at angles of attack that approach the stall.



Wing Planform Design Changes done by Manufacturers

The Stepped Wing
Necessary to improve tip stall

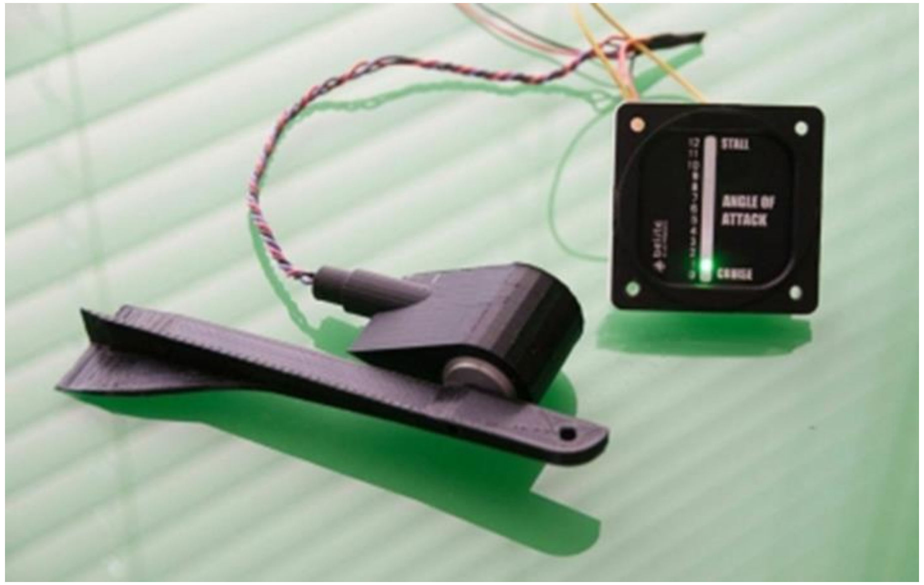


Warning Devices
Probes, AOA Vanes, pressure probes.

Typically probes are very accurate, but they tend to be costly and are normally used on jet or high speed aircraft. They are installed in an undisturbed portion of the forward fuselage or on a probe sticking well out in front of the wing or fuselage. These are not suitable for the single engine tractor aircraft. A vane type installation is ideally installed on the forward fuselage or nose in clean air, then calibrated. Although extremely effective, I see no use of these on the average experimental unless it is a pusher aircraft without a canard.

Probe or Vane AOAs

Belite Vane AOA



F-4 and Airline Probes

My plane has vortex generators or slots/slats so I can’t stall.

- Although the pilot feels like he has full control, these devices allow very low speed control, but are insidious in that the allow complacency and good roll control at low speed. In the event of low speed high descent approach or maneuvering they result in the aircraft high sink rates where power alone will not recover. Bud Yerly Quote from a flight test of a slotted winged aircraft:

“Failure to vigilantly monitor the airspeed in the pattern can lead to very high sink rates in low power turns to final. Aileron control is fine but the aircraft tail volume is insufficient to bring the nose up to arrest the descent and power may not be sufficient either. You are literally “falling with style”.


Zenith 750 STOL Engine failed. Speed allowed to dissipate too low. Tail unable to raise the nose to arrest the descent. No major injuries. Just because a plane can glide at 30 does not prove it can be flared at 30! Highlander Super STOL and other slat equipped aircraft are similar.

Airspeed Probe Type Systems

These devices are pitot tube or rectangular probe style systems that are primarily airspeed differential gauges that approximate ideal approach, L/D max, and slow speed warning:

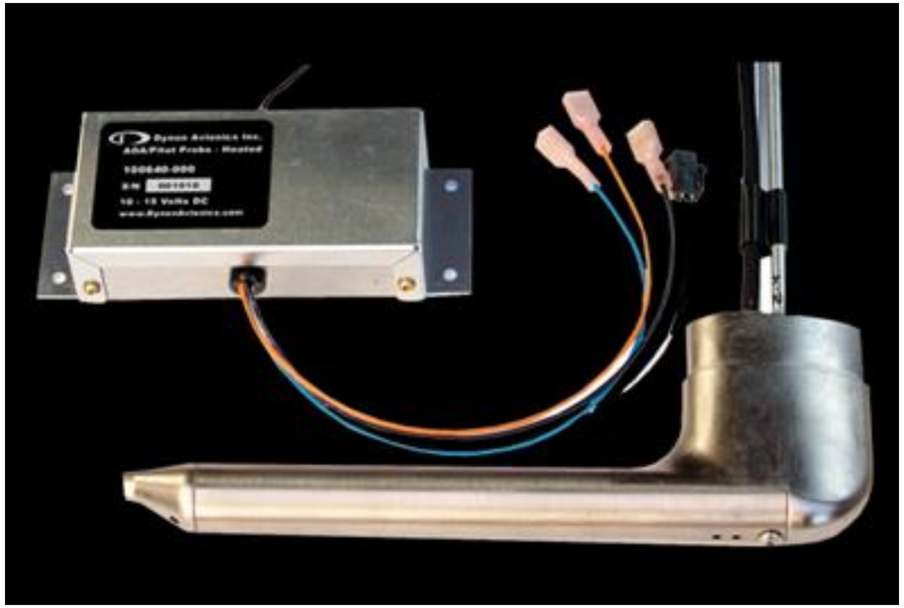
This type of probe has been around for some time and has many different advocates. In 2015 the FAA looked into this in the following paper: **DOT/FAA/TC-14/38 Low Cost Accurate Angle of Attack System (see reference 1).** This paper clearly explains the aerodynamics, design, and electronics necessary to build this unit and is very well respected. This system has been copied by various manufactures and of course is FAA approved. These probes are not AOA indicators but represent the lift curve slope speed/angle relationship for display, through computer programing and sensors it gives a graphical display which is acceptable as a low speed warning device, or a pre-stall warning device. Properly calibrated it will display L/D max, best range if calibrated, optimum final approach angle and a reasonable reference or slow speed warning limit device. Two manufacturers are listed below:

ALPHA SYSTEMS ANGLE OF ATTACK INDICATOR

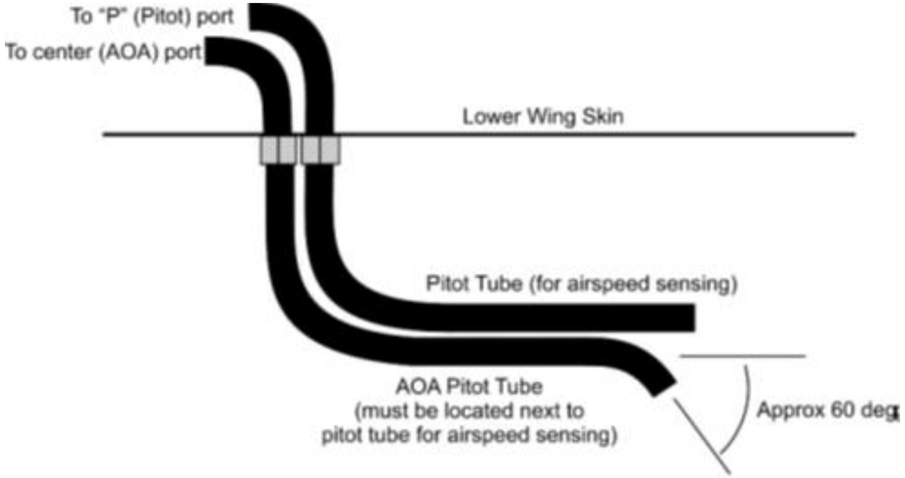
LIFT, 2-1/4 AOA MONITOR SYSTEM FAA APPROVED.

Some probes look like pitot tubes but their placement is very important.

Shown is a typical Dynon or Garmin tube. This tube must be very near the leading edge of the wing to be accurate.

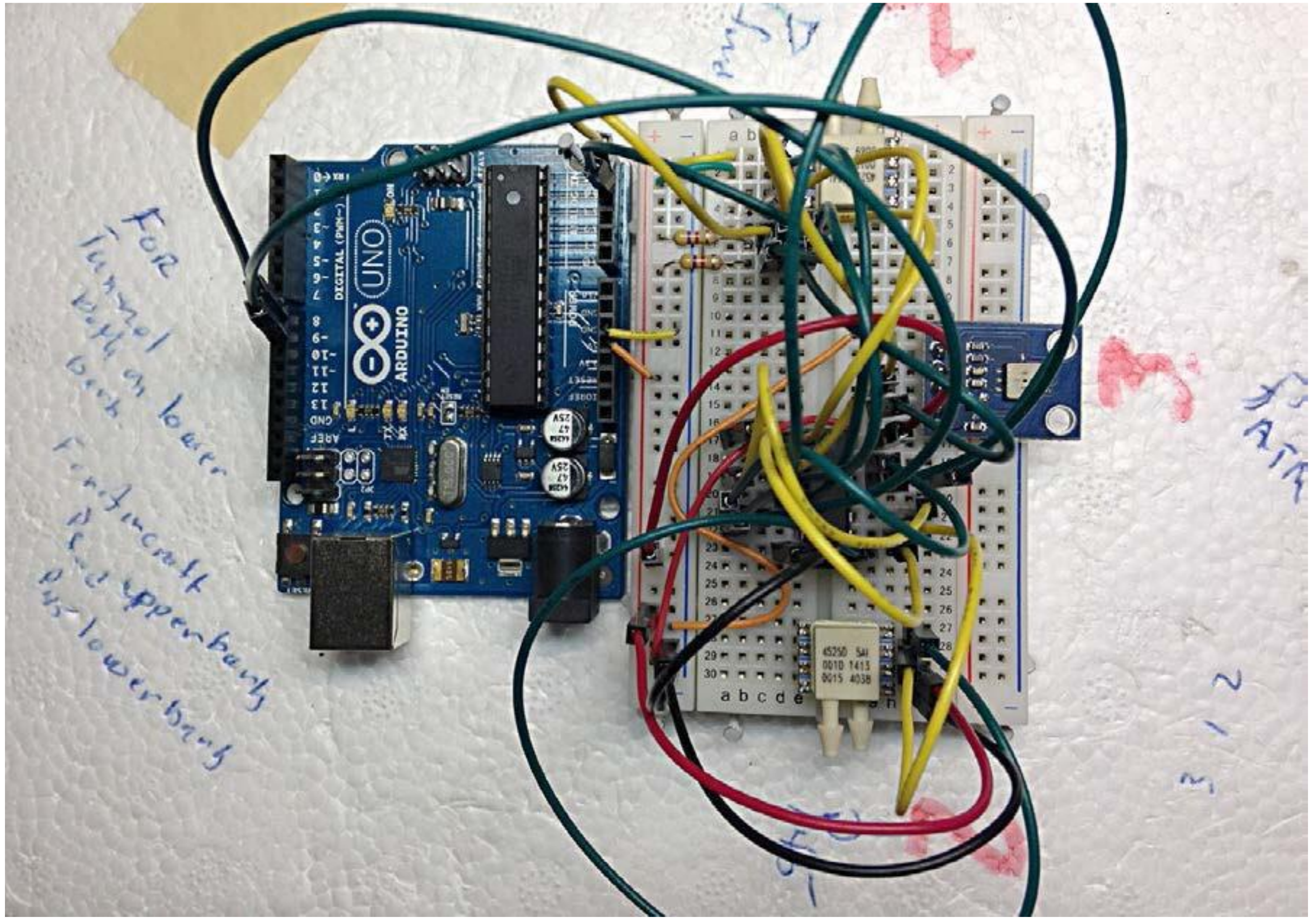


GRT is more open in the design. Can be as far aft as 60% chord.



Fabricating a dual port pitot tube for airspeed and angle of attack sensing.

These probes can actually be home made. Below is a typical Arduino Test kit with pressure sensor for home made unit.



It is clear in the test data that the correlation between an actual calibrated AOA vane probe and the Alpha probe is quite accurate from just below the stall and down to zero angle of attack.

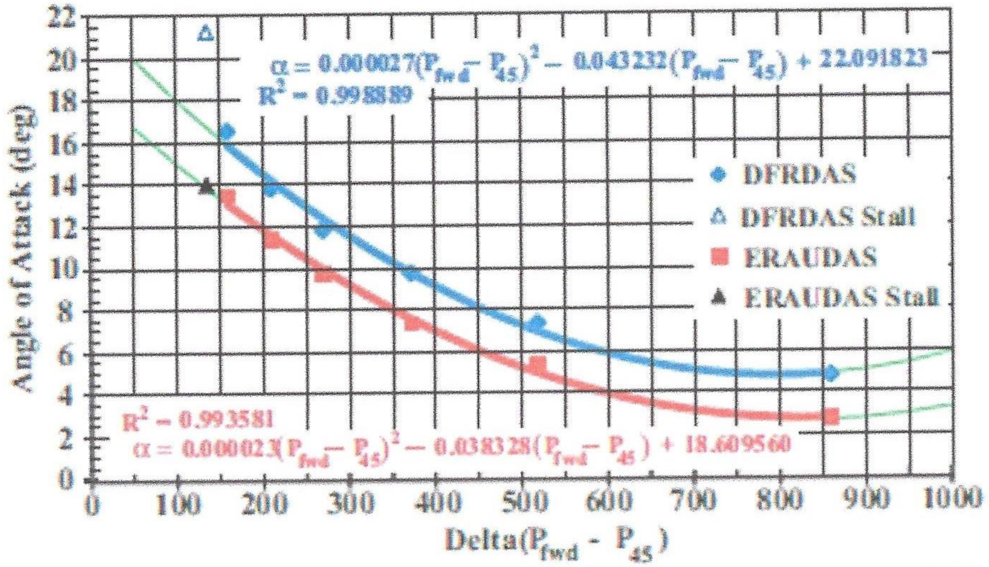
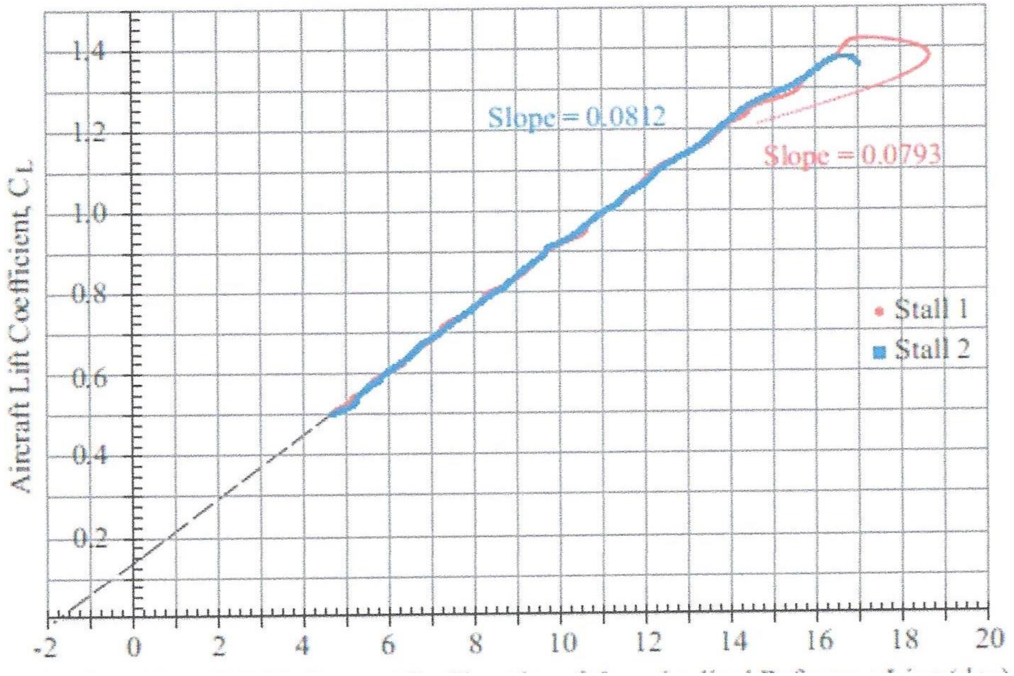


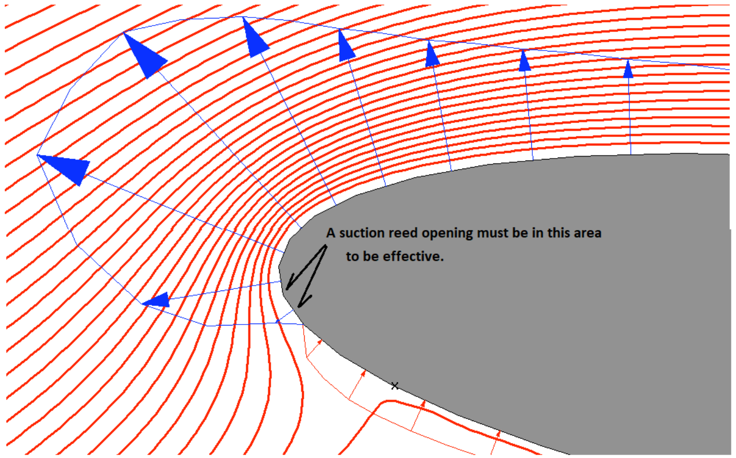
Figure 24. Alpha vs Pfwd- P45 results for the right wing DFRDAS-2 for the 22 April 2015 flight test.



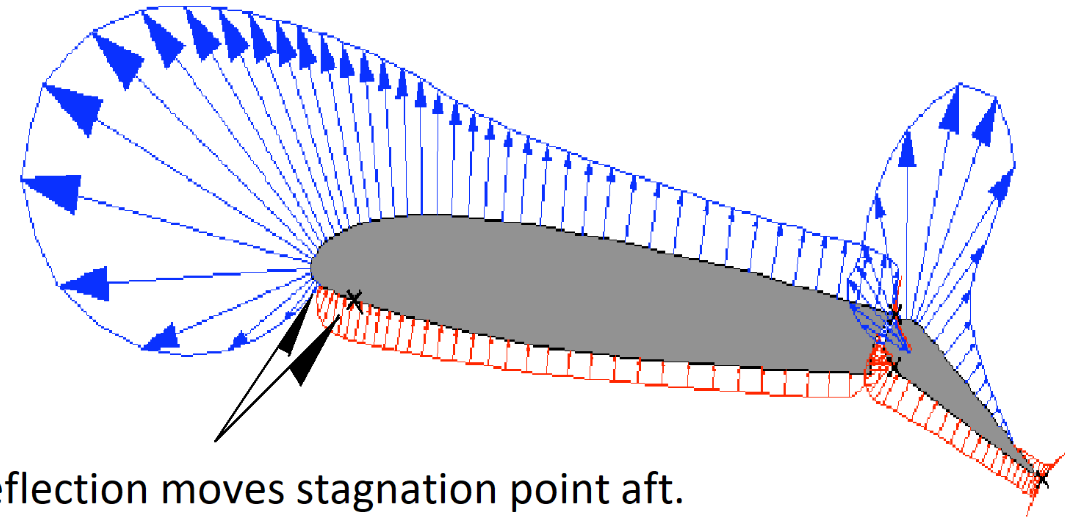
Stall indicators based on leading edge suction.

- Suction stall warning reed or switched type indicators are used in many training aircraft such as Cessna 150/172. The leading edge suction at high angles of attack can produce sufficient suction (about 1”WC) to activate a switch or vibrate a reed (like a woodwind instrument) alerting the pilot of a near stall condition. Due to stagnation point movement aft with flap extension, the suction pressure changes with speed and many of these suction systems have a far too low stall warning margin with full flap extensions. That said, although rather finicky to adjust precisely, they are acceptable. The sensor is best installed in the fuselage for ease of adjustment and a reasonable static pressure differential (I prefer the center tunnel on a trigear). If installed in the wing, multiple flights are needed for adjustment. I find the placement of the suction point to be rather finicky as well as a very deft touch in adjusting the vacuum pressure switch.

Typical Suction Stall Warning Concept

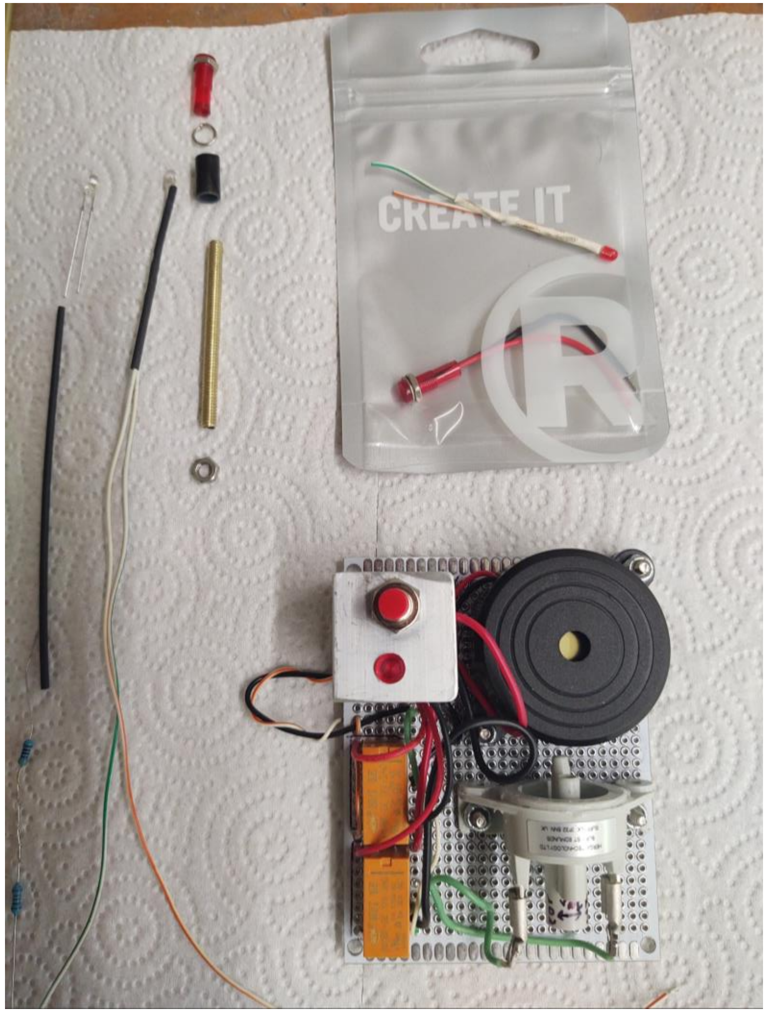


Suction Stall Warning must be placed near the leading edge radius to act with enough suction to activate a pressure switch or reed type "horn"

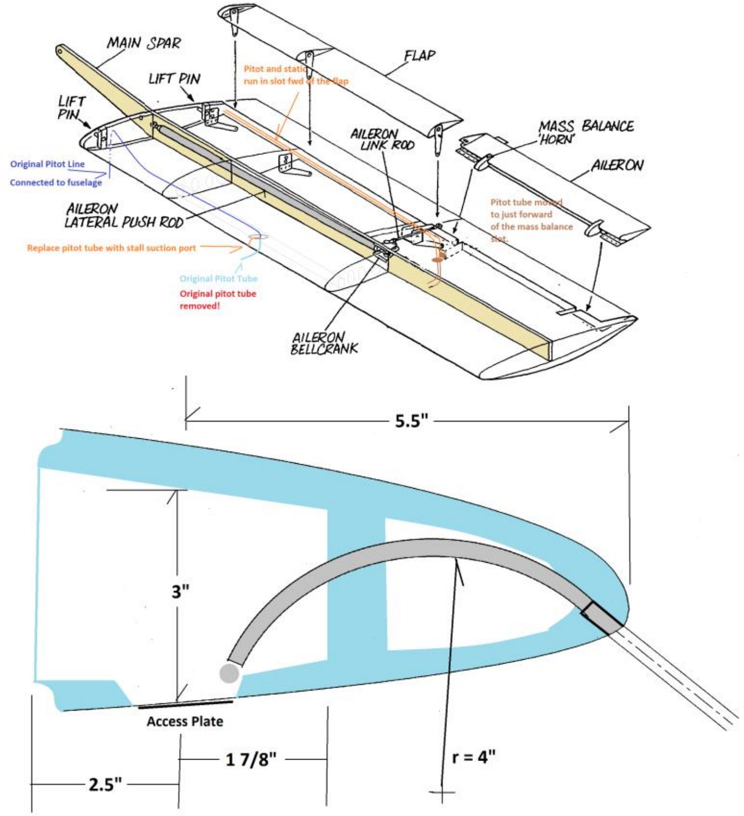


Flap deflection moves stagnation point aft.

Suction stall warning can be either activated by a reed or a pressure switch with light and horn.



Port Wing Stall Warning and Pitot Static install.



A simple tab on the leading edge device is simple, can be heated for all weather use and is easily adjusted. It is a somewhat difficult retrofit due to the leading edge of many aircraft are closed so access to install this is limited.

Airspeed Alert Warning Systems:

This type airspeed warning system has pre-sets and micro switch inputs from gear and flap to alert the pilot to deviation from set airspeeds or approaching a speed limit such as the stall, final approach, L/D max, etc. It uses pitot and static from the aircraft and is easy to set up.

The SmartASS-3 is an Air Speed Speaker, or a talking Airspeed Indicator. This is excellent for the inattentive or rusty pilot. This system uses the auxiliary audio input of the radio/intercom system, the SmartASS-3 works from airspeeds between 25 and 250 Knots.

New EFIS Systems have an electronic type of pre-stall final approach speed warning pre-programmed into the software of their EFIS equipment:

GRT Horizon HX Shown:

Summary:

- The experimental aircraft are generally not built with pre-stall warning systems. The addition of a pre-stall warning system is left to the builder. I highly recommend installing one.
- There are many types of devices which can be installed by the builder to assure an audible or sensory warning prior to the stall.
- The stall warning system should work at low speed on final, get the pilots attention, and should be effective even when the stall is rapidly induced, or is immanent due to low speed maneuvering.
- Finally, the pilot should be well practiced in recognizing potential stall situations, and be completely knowledgeable of his planes stall avoidance, characteristics and recovery and be well practiced.

How much warning do you need?

- Typically, I set stall warning systems to activate at 5 knots above the stall. This can be irritating in the flare to a passenger but is a good safety reminder for the pilot.
- The stall warning device must work for both clean and fully flapped configurations.

Caution

If an aerodynamic device such as stall strips are tested, USE CAUTION as they work marvelous at altitude but in the landing pattern just prior to touchdown the root may stall and the loss of this lift will make for a dropped in landing.

Can you actually hear your warning device?

- Many times when practicing stalls with other pilots or instructors I find the other pilot cannot hear the cockpit aural tone device (reed squeaker as in a 172 or electronic horn or beeper as in some Pipers.
- The advent of ANR headsets has caused this issue as the horn or squeaker is literally cancelled out as noise by the ANR headset.
- In this case if the plane has an electronic stall warning, the warning should be plumbed into the intercom.
- For training it is proper to have a silence button on the intercom aural input and have it adjusted for enough volume to overtop the inter-cockpit voice (or screams).

References and Acknowlegements

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