Stall Warning/Low Speed Warning/AOA Systems to consider for Europa Classic Tri-gear N12AY

Description of type of warning, operation, and equipment.

There are three basic types of AOA and stall warning systems.

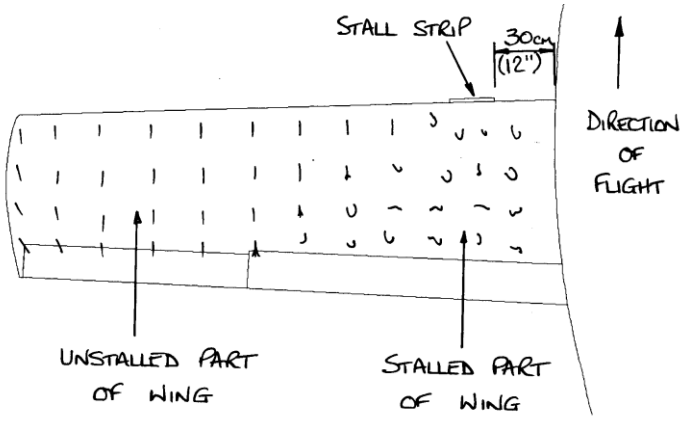
1. Aerodynamic airframe warning;
2. Angle of Attack (AOA) vanes or probes which give true airstream angle to the chord line of the wing providing angles specific to that aircraft and wing;
3. Stall warning indicators which trip or activate at a pre-stall setting for audible or visual warning;
4. Low Airspeed warning devices which alert the pilot to deviations 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.

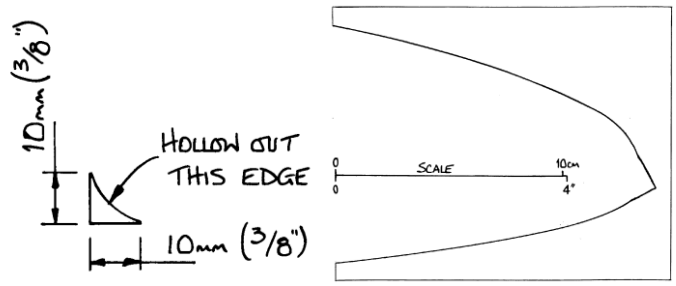
Aerodynamic airframe warning devices.

Stall Strips attached to the leading edge.

Europa Aircraft requires a stall strip be added to the leading edge and through successive flights, move the stall strip up or down to increase the buffet warning without increasing the stall speed or cruise speed. As positioned with the supplied template they increase stall speed slightly and provide heavy rumble prior to the stall. Experience shows that stall strips slightly lower than the template tend to work well. As positioned, the strips tend to produce an incomplete flare or as Europa called it, a heavy landing, as in ground affect, the rumble of the stall strip was shrouded from the feel by ground affect to the point where the aircraft stalled about 5 knots early surprising the pilot. A piece of 3/8 to ½ inch aluminum angle strip works fairly well as a quick test stall strip between 9 and 12 inches from the fuselage side, placed slightly below the template line reduces the warning to about 3-5 knots above the stall. It also tends to resist the break of the stall and as the stall is approached the plane's nose bobbles up and down in moderate buffet and will resist a hard break in the clean configuration. With flaps fully down, the stall warning is still only 3-5 knots prior and the actual brake tends to break cleanly with little wing drop unless the ball is well out of center. Properly positioned through flight test, in the flare there is no difference in flare out float or speed bleed-off, and the aircraft settles very nicely without any unannounced stall even if the pilot is in a slight balloon or high flare. This type of warning strip requires multiple attempts to get right but requires no aircraft electrical power or internal panel or cockpit modification. However, in all cases I have tested to date, landing speeds are a bit higher by about 3 knots.



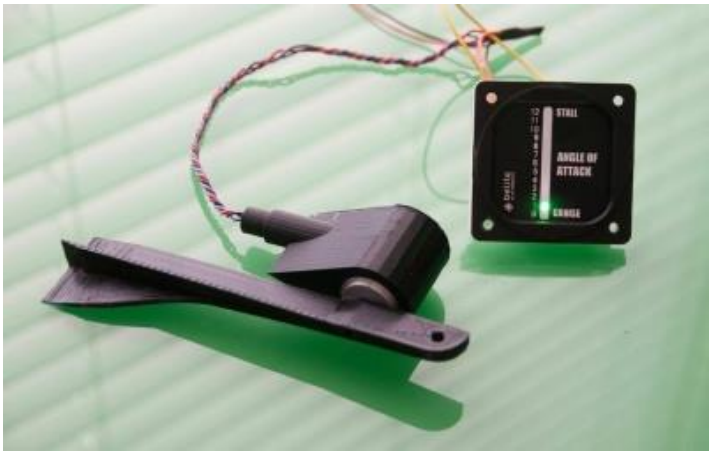
All that is necessary is a template and a bit of fabrication.



AOA Vanes, probes or airfoils.

Typically probes are not used on tractor propeller aircraft due to propeller wash and although very accurate, are normally used on jet or pusher aircraft where the air is undisturbed over the forward fuselage. These are not suitable for the Europa 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 Europa.

Belite Vane:



F-4 Phantom Type Probe

Heavy high speed probes are very accurate but not suitable for light aircraft.

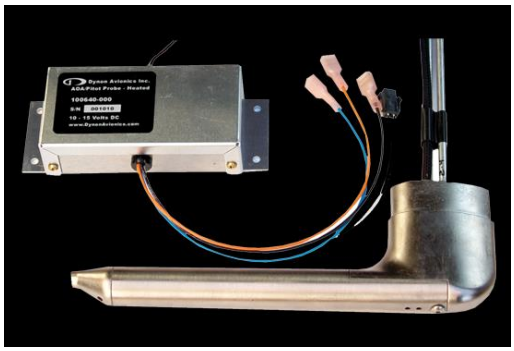
Pitot tube or rectangular probe style systems that are primarily airspeed differential gauges that approximate ideal approach, L/D max, and slow speed warning:

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 <u>are not</u> AOA indicators but represent the lift curve slope speed/angle relationship for display, through computer programing and sensors it gives a graphical display 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 reference or slow speed warning limit device. Two manufacturers are listed below:

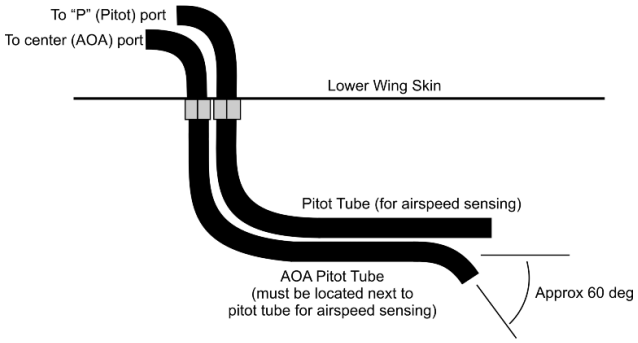
ALPHA SYSTEMS ANGLE OF ATTACH INDICATOR
This is a frequently used system on Piper type aircraft. Located well aft (about 60% chord) on the lower surface works quite well. $2000+

LIFT 2-1/4 AOA MONITOR SYSTEM FAA APPROVED.
A less expensive system and not as robustly built it works well as an add on warning system. Panel Mount or Glareshield Mount gauge and can cost typically $389.00

Similar in concept, but using a pitot type tube with an additional port at 45 to 60 degrees is the now considered a common “AOA”. This is not a true AOA but is close enough if positioned properly. This must be installed very close to the wing leading edge or on a probe beyond the leading edge for good accuracy. If positioned very near the leading edge, it is fairly accurate at the stall, however, if installed farther aft, under the wing, the two ports work as the above probe systems to approximate the lift curve slope and warn when approaching the area of the stall as in the probe style above



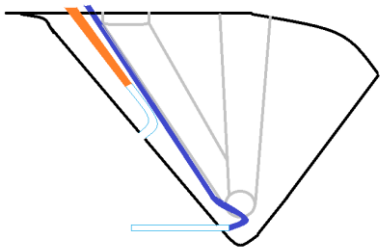
This type probe can be made with simple tubing just like the Europa Pitot/Static tube. I made one myself in a day.



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

This type of sensor can actually be built into the flap hinge covers of a speed kit which makes it very unobtrusive, yet install is somewhat finicky getting the tubes fitted in the wing.

GRT AOA (Slow speed warning) built Europa flap cover.



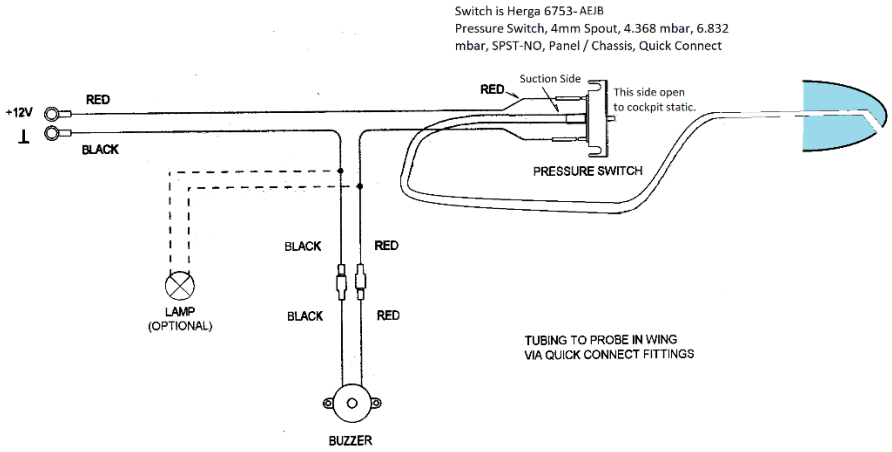
Stall indicators based on leading edge suction.

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.

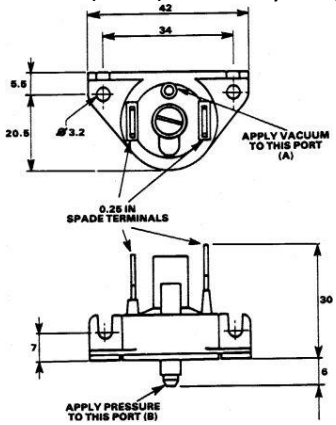
The Europa Mod 61 is not bad as a pre stall margin warning.

Available from Europa as a retrofit or new build at a reasonable price. 150BP or $180USD

Europa Mod 61a/b installation



Europa supplies RS 317-443 0.5amp 250volt (4231) switch by Herga



Alternate switch Honeywell C6065A1135:2 or Herga 6753 AEJB or A is $45

Complete components alone are $100 retail.

Stall warning using tab type indications.

Many certified aircraft use a simple tab device located on the leading edge. At the warning angle of attack, the tab is lifted, closes a micro switch and a light/horn sounds in the cockpit. To install, normally it is riveted or screwed into the leading edge on the inside.

Normally we see these tabs fitted to certified aircraft in one or more positions. One is positioned for clean configuration and the second is the fitted and powered when the flaps are lowered.

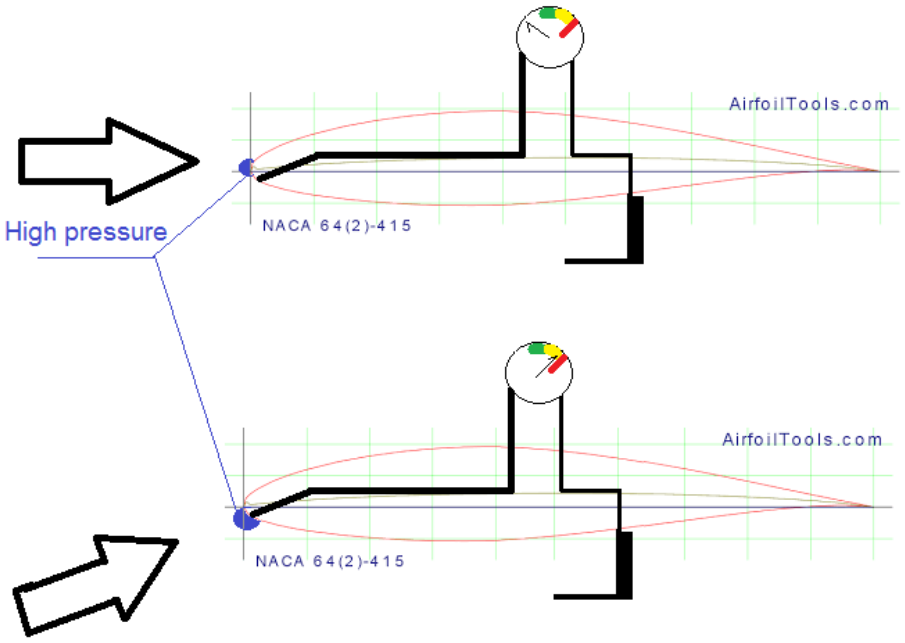
THE REDDISH STALL WARNER from $89.95 to $94.95
Rather large and clunky on a small wing. Hard to install without access from inside the wing.

Pre stall warning systems using airfoil pressure distribution.

This type system can be used as a stall warning and as a true AOA system depending on readout and pressure port location.

Some years ago I fabricated a simple probe and pitot pressure differential system. Unfortunately, it was very close to some patents and not producible for the masses or for my clients. I did make one for personal use and now find it has been less than ideal because it is a better stall warning device rather than a true AOA detector due to my stubborn use of analogue sensors rather than digital. I used a simple differential pressure switch used in a furnace (HVAC) system of 0.5 to 3 inches H2O. It combined leading edge pitot and cockpit static.

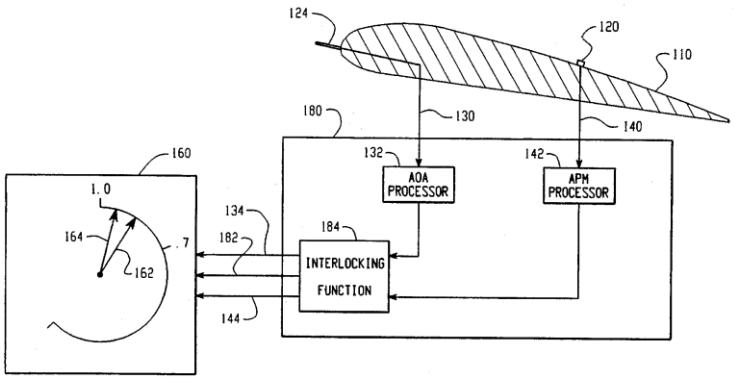
These pressure port systems for measuring pressure distribution around the airfoil and simple analogue pressure sensors have been around since the 1950's. Some use a pressure tap on the top and bottom of the wing and others near the leading and trailing edge. Below is my original stall warning using a differential between leading edge pressure and pitot pressure.



This works for flapped or clean as the pressure or stagnation point moves aft with flap extension, but the stagnation point pressure is still in the vicinity of the leading edge tube. When the pressure point is measured with a differential pressure device hooked to the static system or a point after the maximum thickness point it can be even more accurate as an AOA than using simple pitot reference pressure.

BF Goodrich Patented Leading edge pressure to trailing edge separation point differential.

This system is quite accurate for straight wing aircraft and would be popular if it wasn't so hard to set up. The position of pressure point 120 is located in the turbulent flow section of an airfoil and is very close to static pressure. This makes the probe (124) to upper wing port 120 to be able to work over a large range of flight conditions. However, an upper surface hole tends to fill with water making draining a necessity, so retrofit to an existing aircraft is difficult.



Airspeed 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.

SmartASS-3 Air Speed Speaker 195 BP or about $250USD

System is an airspeed sensor with accelerometers to assist in rate of speed change anticipation. This is a very simple kit to install consisting of: SmartASS-3 device (includes micro SD card) Combined volume control and push switch + cable 1 metre 6mm OD tubing + 2 Tee connectors, Printed manual, USB Micro SD card reader, instrument panel label.

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. The airspeed can be reported in Knots, MPH or KPH. It also provides a 'speed director' mode that informs the pilot when the airspeed deviates from a target airspeed (perfect for nailing that approach speed). *The SmartASS-3 is not a stall warning system and it does not provide a stall warning function.* A built-in accelerometer speed director mode takes into account wing loading due to gusts or a pilot pulling 'Gs'. It acts as a 'stall margin preserver' to help the pilot maintain a safe margin above stall the speed. Its uses are also handy for: Undercarriage down audible alert on approach if undercarriage is not down and locked. It also can provide audible alert triggered from external events such as a wind shift. Videos are available. This is a rather-easy system to install with many options only requiring panel/electrical work for power, intercom input, microswitches on the gear and flaps, etc.

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

Today's EFIS manufacturers make many different AOA or low speed warning alerts for the pilot. Garmin, Dynon and Grand Rapids can use one another's angled pitot tubes which connects to a dual pitot/AOA black box as discussed above. However, GRT is one avionics manufacturer that only requires the pitot connection to the unit. The unit EFIS pitch, speed, rate accelerometers, and attitude sensors are used to approximate the approach angle (not AOA) from pitot/static, pitch and accelerometers and can provide visual display of the ideal final approach speed and warnings on the Primary Flight Display (PFD) for flying too fast or too slow. Some systems also have audible inputs for the intercom for an aural warning.

Again, like the Smart Ass and the probe type pressure sensors, this is not a true AoA or even aerodynamic stall warning. The pilot can still enter into an accelerated stall through maneuvering, or from violent up or down drafts as in heavy convective weather. Talk to your EFIS manufacturer if this is right for you. In-flight setup of the approach aid on the Mini or HX is accomplished quite easily. Slow to a near stall and set the pitch bar and save settings. It is very effective for normal flight operations.

Displayed below is the Grand Rapids Mini which now comes with the software to display approach to stall or final approach speed:

GRT Mini/HX

No installation of special probes is required, as the angle of attack is computed from the AHRS airspeed, pitch attitude/rate, and vertical speed. Note again that this method, although not requiring any sensors or additional pressure connections is not a true AOA. Also, in my opinion it is not acceptable for soaring as its performance degrades in accuracy while in vertical rising or falling air such as thermal sailing.
It is acceptable as a final approach slow speed warning even if flaps are lowered and for maneuvering in normal flight conditions. System is installed in the EFIS so there is no installation or additional equipment cost. Testing has proven it to be quite good as a reference during instrument approaches as well as for final turn and final control. I have not flow with this system hooked into the intercom or a buzzer for audible warning.

References and acknowledgements:

1. DOT/FAA/TC-14/38 Low Cost Accurate Angle of Attack System, 2015
2. NACA TECHNICAL NOTE 2676, SUMMARY OF STALL-WARNING DEVICES' By John A. Zalovcik
3. CFD Study of a NACA 63-415 Aerofoil, Fitted with Stall Strips, Frederik Zahle, Niels N. S0rensen, Jeppe Johansen, 2002
4. Flightlab Ground School, Two-Dimensional Aerodynamics, Copyright Flight Emergency & Advanced Maneuvers Training, Inc. dba Flightlab, 2009. All rights reserved.

Evaluation of stall strips on Euorpa N12AY

By Bud Yerly
Custom Flight Creations, Inc.
12/01/2010

The stall strips described in the Pilots Operating Handbook (POH) for the Europa Classic and XS aircraft is a very fine description of installation and setup of this stall warning device for this aircraft.

This paper is for info only.

The Europa Kit Aircraft has been designed around the Dykins modified laminar flow wing. The laminar flow wing (when clean) is very efficient in its drag bucket area.

However, the airfoil stall break is rather sharp even with the leading edge modification. If a very slow onset of stall is approached (at a speed of 1 knot per second or less) and precise pitch control is maintained the following happens in the stall:

The Europa is equipped with a powerful stabilator in line with the trailing edge downwash of the wing allowing buffet from the root stalled area to impact the stabilator. As the nose is commanded to rise to the critical angle of attack, the root of the wing stalls decreasing the downwash over the stabilator, which drops the nose (lowers the angle of attack) breaks the stall, which allows the wing downwash to be reinstated and causes the nose to rise again. The aircraft will repeat this motion of "nose bobble" if the aircraft is kept perfectly coordinated (ball centered is not accurate enough, the pilot must maintain alignment to the relative wing or said another way, look over the nose and concentrate on the heading to a fixed point like a cloud). If the stabilator is commanded aft to maintain the peak pitch of the bobble, a sudden stall can be expected. Should the pilot allow the nose to slice or yaw due to rudder input, or P factor, at or near the peak of the bobble, the aircraft can break into a very rapid roll as one wing stalls. During this bobble there is a very mild, but noticeable pre-stall buffet, burble or vibration in the airframe.

If the stall is commanded to rise at a high rate of increasing angle of attack, or rapid speed decrease or AoA increase in level or accelerated flight, the mild burble is often times masked. The same is true during operations in ground affect. Leaving the pilot with little or no pre-stall warning. This is common behaviour in all aircraft and not exclusive to the Europa.

Flap extension in the Europa is limited to 27 degrees which helps the abrupt stall break somewhat in the landing configuration, but the pre-stall modest buffet is masked by the flap turbulence leading to little pre-stall warning with the flaps down in or out of ground effect.

The stall characteristics above leads to two areas of concern:

1. Spirited flying at low speeds and high angles of attack can cause the stall to come on quite abruptly with little warning. In maneuvers such as a pitch to a slice for quickest tightest turn, at the peak of the nose high or low speed transitioning from a nose high to a 90 degree knife edge turn, it is very easy with the powerful stabilator to rapidly enter a stall and wing break without warning. A simple unload of the stick to neutral rapidly breaks the stall and rotation without fail, but insufficient altitude may be available for recovery.

2. The stall margin in low speed abrupt maneuvering and lack of pilot feel is a concern with flaps down in the landing patter. In a situation where the pilot is maneuvering to land and must make a rapid emergency go around while failing to keep the ball centered and monitoring the stall speed, the aircraft can be flown out of control due to lack of pre-stall warning. Whether full down flaps or half flaps are used, the flap down stall is more abrupt.

Clean stall in flight evaluation:

To alleviate this lack of pre-stall warning stall strips were included in the POH. The explanation could be enhanced a bit but is very accurate.

Note: In ground effect, the burble or pre-stall indication is virtually non-existent with a rapid onset of stall. It is imperative that the test of the stall strips be made both clean and in the landing configuration at a safe and reasonable altitude of at least 3000 feet AGL. Then landings should be made over a long and smooth runway where the approach and round out can be made with slight power on to allow a slow flight very close to the runway.

Test procedure considerations:

Tuft testing is not feasible in the flare to the test pilot as his attention is to the landing area, so a camera system helps determine the stall characteristic much more safely and is better for post flight analysis.

As depicted, the stall strips with a 10 mm triangle gives ample pre-stall warning but in my opinion is too high up the leading edge and leads to a very abrupt stall when in ground effect. At altitude, the pre-stall buffet is quite pronounced. In landing, the pilot notices nothing until rounding out for the flare. If the flare is accomplished early (high) and the aircraft is a foot or two off the ground, as the pilot brings the nose up to bleed energy and slow, the stall comes on very suddenly and the aircraft drops quickly due to the root stalled condition. Although a wings level straight ahead stall is achieved, it is abrupt and alarming as the aircraft literally quits flying. When alerted to this, the aircraft was flared inches above the pavement and touchdown speeds of 50 knots were common so it was deduced landing speeds would be higher.

Lowering the stall strip 1-1.5 mm from the POH position prevents this aggravated unannounced stall in the flare. It also lowers the pre-stall margin very slightly also. Positioned at this point, the stall warning buffet is still present even in the landing (full flap) condition. There was no evidence of an abrupt stall in the flare. Touchdowns of 45 knots were possible but routinely higher at a bout 47 with the strips. Stall warning is in the 3-5 knot range depending on the speed of onset. In flight the well announce pre-stall buffet was still evident with no wing drop even with mild out of trim conditions.

If the stall strip is increased in size to 12.5 mm (1/2 inch is a convenient size for US builders) the stall margin at this position is maintained but the lower position does affect the cruise speed slightly as it is evident at this position it can blunt the leading edge profile.

A smaller 7mm strip was tried and was just as successful as the 10mm. No attempt was made to shorten the strip length to try to keep the stall localized to the root section only. Also, the angle of the strip (nose up/nose down) was not attempted due to time/funding. Fences to prevent the stall progressing to the outer wing were not tried, but would be effective to prevent the wing from “unzipping” or rapid stall progression from root to tip along the wing.

Observations:

1. I find clients do not want to add, touchup or modify their aircraft once built. Flying an aircraft in the raw is not advisable either. I find prebuilding and painting the stall strip to be handy. Then it is just attached when the desired angle is set based on flight testing. This can be done prior to after painting with little or no difficulty by making the angle stock, positioning it on the leading edge with release tape protecting the wing and filling the void with flox. Allow to cure and peel off. Reattach can be done with silicone if the edge of the angle is thin and the ends were tapered nice and neat.

2. The Europa Stall warning Mod 61 can and should be used in conjunction with the stall strip. A visual and audible warning system may be more effective for some pilots than airframe buffet or feel alone. Inexperience or inattentive pilots will benefit the most from this. There are also after-market angle of attack systems that can be added to the wing to give a visual reference on how close the pilot is to the stall. However, this may be distracting or require additional construction cost due to wing or panel modifications.

3. I find making my stall strips detachable for training new pilots is quite effective as a teaching aid for newly transitioning pilots for the demonstrator aircraft. I use small barrel nut inserts drilled into the leading edge to hold the strip in place. The strip is painted and kept for training purposes in Europa handling demonstrations.

Note:

For testing it is best to use a thin 2 inch glider tape on the leading edge. Position the angle stock and make a line on the leading edge of the tape with a fine tip marker. Then reference all moves from that line. Two inch glider tape works very well when lapped over the angle stock for repositioning the angle stock between tests and does not pull off the marker line used on the tape for reference.

My thanks to Gary Leiberger who allowed me to fit the ½ inch stall strips during testing of his aircraft to verify this larger angle stock and evaluate the effect.

References:

Europa POH
NACA TECHNICAL NOTE 2676, SUMMARY OF STALL-WARNING DEVICES' By John A. Zalovcik,1952
CFD Study of a NACA 63-415 Aerofoil, Fitted with Stall Strips, Frederik Zahle, Niels N. S0rensen, Jeppe Johansen, 2002