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Angle of attack indicator was one of the few instruments installed on the Wright brothers' first airplane. The Wrights certainly must have thought the AOA instrument provided important flight management information for the pilot and so does Raoul Castro. He has it installed on the current Marcor flagship, the Falcon 20, and will be aboard the recently acquired Gulfstream II which is now undergoing outfitting at Page-Gulfstream at SAT.

WHEN the first commercial jets were put in operation some years ago, a gray beard airline captain was to be rated on a 707. As part of the oral, the FAA inspector asked the captain to tell him the wing span and length of the fuselage. The captain retorted: "I don't want to build a box for that airplane, I just want to fly it."

During the energy debacle, there was a multitude of articles on how to fly the bird and save fuel, most of them rather erudite. In reading the articles, I felt something like the airline captain. I don't want to design an airplane, I just want to fly one as efficiently as possible. Angle of attack and L/D max play a very important part in obtaining the best performance from an airplane and every jet pilot should have an insight into angle of attack and lift/drag ratio. But, how to go about this in everyday life without your Hewlett-Packard HP-45 calculator?

While flying DC-3s and Twin Beeches, I felt that there should be something better than the airspeed indicator to fly an airplane. So at that time, we installed a Safe Flight angle of attack indicator. Although the range of this early instrument was limited,

we learned that it was ideal for operating into short fields and it gave some required indications in event of engine out flight.

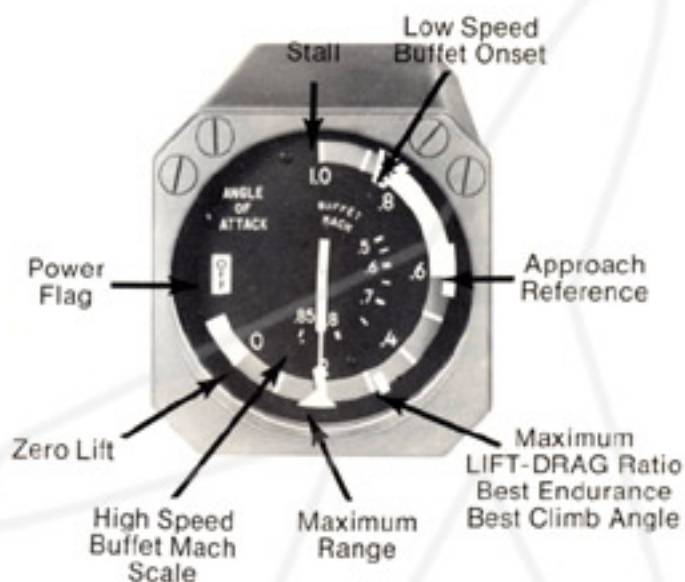
As we entered the jet age, I hunted for an angle of attack system that could be used as a tool to translate engineering information, as practically as possible, on a display mode to be used by flight crews to obtain maximum performance from the aircraft within usable approximations.

Understanding Angle of Attack Information

Many aerodynamic conditions exist at various angles of attack in an airplane. The conditions of stall, low speed buffet onset, landing approach, takeoff, max range, max endurance, etc., occur at specific values of lift coefficient and consequently at specific angles of attack. Thus, an instrument to indicate angle of attack becomes an invaluable aid to the pilot. At high angles of attack accurate airspeed indications are difficult due to position errors. An angle of attack indicator can be a great aid at high angles of attack. Of great advantage is the



Teledyne Avionics indicator references angle of attack through entire flight envelope for all aircraft in any configuration. Complete system costs about \$4000 uninstalled. Falcon system shown.



fact that the AOA is not affected by gross weight, bank angle, load factor, speed or density altitude. CL max occurs at a precise angle of attack. A stall warning device should be predicated on the function of this critical angle of attack. Airplane stalls happen at various airspeeds depending on load factor, gross weight, etc., but for a particular configuration always at the same angle of attack. Landing speeds are usually specified at 1.3 above stall speed, approach to landing will be made at specific values of lift coefficient and therefore, at particular angles of attack. The proper approach speed will be assured by maintaining the proper angle of attack.

I hope that by now I have made my point that the angle of attack indicator should be a flight instrument to be installed and used next to the airspeed indicator because after all, the airspeed indicator is useful in determining VR and to let you know when to put gear and flaps down, also to maintain controller requested speeds and indications of VMO and MMO. With modifications an angle of attack system should be able to determine VR speeds.



Transmitter/probe is primary sensing unit of AOA system.



Indexer mounts atop glare shield for heads-up display during transition from approach to landing, using lighted vee and doughnut indications.

Panel Planning the AOA System

Original electronic specifications on our Falcon seven years ago included an angle of attack system. Since then we have had an opportunity to evaluate and develop methods of how to apply the angle of attack indications for better aircraft performance. Although the system cannot offer V_r indication it can be used to obtain best single engine performance, best angle of climb, max endurance, max range, reference speed. As can be seen as the article progresses, the AOA indicator is a safety instrument. With flap compensation the system presents indications in all configurations.

The system we chose, manufactured by Teledyne Avionics, consists of a probe, indicator and indexer—these items the pilot becomes familiar with. Interface unit provides computation for normalizing flap compensation and output to drive flight director FAST/SLOW pointer.

Probe is installed at the proper aerodynamic position on the side of the fuselage. AOA indicator should be installed adjacent to the airspeed indicator as the two instruments are related.

Indexer is best positioned at the vertex of an isosceles triangle with the end points of its base being the center of the airspeed indicator and the center of the flight director. The indexer is the heads-up display and should be very carefully placed so as to be seen when concentrating on the instrument panel T.

AOA Flight Procedures

Here are some pointers on flying AOA. First meaningful indication received after takeoff is the max lift/drag position (shown in Figure 2) at the beginning of the second segment climb. This is the best climb angle and also will be the best position in the event of engine failure since it will produce the maximum glide ratio.

On the Falcon it is best to accelerate to the max range position for the climb until unable to maintain that position because engine thrust curve starts to flatten. At this point, power ratio dictates going back to max L/D ratio indication. If ratio indication cannot be maintained the first step of the climb has been reached and it is best to level out. When the pointer indicates slightly beyond max range with the thrust as specified in the flight manual for that altitude and temperature, the second step of the climb can be initiated and so on until the preferred altitude has been reached. To obtain best range keep adjusting power to stay in the max range position.

$$\text{Specific Range} = \frac{\text{Naut. Mi./Hr.}}{\text{Lbs. of Fuel/Hr.}}$$

Continuing our hypothetical flight, let us assume that as the destination is neared ATC requests a hold. The pilot very simply adjusts the power levers to place the AOA on the max endurance position starting the hold.

AOA INDICATOR



INDEXER



FLIGHT-DIRECTOR FAST-SLOW



Approach very slow, AOA very high, large correction necessary.

Approach slow, AOA high, small correction necessary.

Best approach speed, AOA optimum, V_{REF} no correction necessary.

Approach fast. AOA low, small correction necessary.

Approach very fast, AOA very low, large correction necessary.



MAXIMUM LIFT/DRAG RATIO

This reference, usable in the clean configuration, places the aircraft at its best endurance point as well as the best climb angle and best glide angle.

$$\text{Specific Endurance} = \frac{\text{Flight Hrs./Hr.}}{\text{Lbs. of Fuel/Hr.}}$$

As the 180° turn is made it is noticed that the pointer falls below the max endurance position and the green doughnut appears on the indexer indicating that optimum hold speed is being maintained. As the second 180° turn is made the red chevron appears indicating that a correction is necessary and some thrust has to be applied to maintain the optimum angle. Should the engines decide to flame out at this time the minimum angle of descent would be obtained at the L/D max position providing the max glide distance. Engines back in operation the flight is resumed as planned but ATC requests to pass a certain point at a low altitude to intercept the ILS, the air brakes have to be deployed and 15° flaps used to reduce speed and comply with the altitude request. Because of the sudden increase in cockpit work load there is no time to compute the minimum airspeed for the present configuration and gross weight but by looking at the indexer it is found that the red chevron is visible indicating a slow condition. As the air brakes are stowed the green doughnut appears. I am illustrating that the indexer readily becomes a very valuable heads-up display that can keep the pilot out of trouble.



LOW SPEED BUFFET ONSET

Low speed buffet will occur at this reference. Provides visual stall warning.

Localizer is intercepted and the AOA pointer is at max lift/drag position. Glide-slope becomes alive and full flaps and landing gear are requested for landing configuration. Pointer on the AOA indicator is brought back to the approach reference, amber chevron appears and then the green doughnut indicating proper VREF speed is displayed. As visual contact is made the proper ref speed is maintained with the indexer. As we pass the threshold and a slight flare is made the red chevron will appear, but as the aircraft enters ground effect the green doughnut prevails and the landing is made. In turbulence it is advisable to maintain the green doughnut and the amber chevron showing until in ground effect. This requires some concentration but it can be done.



STALL 1.0

This indication on the dial is stall and is defined by the aircraft flight manual. This point is valid for all flap configurations. 100% of the available lift has been used.

The small jets appear to run out of fuel before takeoff, but as the flight progresses and the power levers are pulled back to maintain the max range indication, it seems that fuel is being produced.



MAXIMUM RANGE

This reference provides the pilot with an approximate point where he can obtain the maximum distance per pound of fuel.

I really became interested in the angle of attack indicator when I read a letter in the advice to the lovelorn column. The letter went something like this:

"Dear Doctor C: I was flying over my house and saw the milkman go inside. I kept circling but he did not come out. I tightened my turns so that I finally spun in. Fortunately I was not seriously hurt. What shall I do, Doctor? Signed Spun In."

Reply was: "Dear Spun In: Get an angle of attack indicator. Signed, Doctor C." *ztc*