Short final, full flap,
a good descent, needle on the barberpole . . .
forget about the airspeed
if you have an

Angle-of-Attack Indicator

by Peter Garrison

THE AIRSPEED INDICATOR tells airspeed and nothing else; but when we use it in slow-speed flight, we are using it as a device to measure lift coefficient—a purpose to which it is adequately, but not excellently, suited.

Lift coefficient is a figure of merit used in describing behavior of wings; it relates lift to speed in such a way that for the lift to remain constant, the lift coefficient must change in inverse proportion to the square of the airspeed. In other words, if you double your speed, your lift coefficient goes down by a factor of four. The practical range of lift coefficients for normal wings is from zero to around 1.6 with no flap or perhaps 2.5 with a slotted flap fully deflected.

Lift coefficient is of no practical interest to the pilot, except in that it has an upper limit that limits the lowest speed at which an airplane can be flown. It happens also that besides the stalling speed, several other important speeds—best angle and rate of climb, best glide, best endurance, approach and slow-approach speeds, best range and turbulence-penetration speed—can be mapped on a scale of lift coefficients. By relating them to lift coefficient, they are made independent of airplane weight, and therefore more relevant to actual flying conditions. For example, the book best-rate-of-climb speed applies only at gross weight; at light weight, the best rate of climb is to be had at a lower speed. Usually, the handbook does not give a range of reference speeds for different weights, and the pilot is left to apply as well as he can the rule of thumb that all the reference speeds go down with a decrease in weight.

If airspeed is not directly related to lift coefficient, we must find something that is in order to have a true measure of the conditions under which our wing is operating. At first glance, angle of attack would seem to be it. Angle of attack is, for all practical purposes, the angle between the fuselage reference line and the direction of flight (more strictly, the proper reference line is the chord line of the wing, but the fuselage reference line is easier to visualize and keeps us out of a confusing thicket when we get to deflected flaps). Seemingly, in order to measure it we have only to put a vane out in undisturbed air somewhere, let the vane pivot and drive a potentiometer, and read the output of the potentiometer on the panel as a measure of degrees of vane deflection. Indeed, this will work fine, and it will produce the gratifying result that the airplane will always stall at the same indicated angle of attack, whether it is

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moving fast or slowly, is light or heavy, or is pulling G or no G, banked or level. There's only one hitch: As soon as we deflect the flap, we have equipped the airplane with a new wing, which, in effect, is attached to the fuselage at a different angle of incidence than the old wing. We now find that the stalling angle of attack has changed—although as long as we stay in this configuration the airplane will always stall at the new angle of attack.

Since the airplane may have any number of possible flap settings, as well as a couple of gear positions that also may affect stalling attitude, interpreting our vane has now become a rather complicated matter. Perhaps we could install an electronic network between the vane and the panel meter that would shift the meter reading around in such a way as to compensate for different flap settings. This is what is done in systems found on some Learjets, where the vane is mounted on one side of the nose, close to the fuselage skin. (Since the meter can be calibrated to make up for position error in the sending unit, it is not actually necessary to locate the vane in undisturbed air; any position where flow direction varies consistently with angle of attack will do.)

Another type of sensor bypasses the vane and the angle of attack of the airplane completely and measures pressure patterns at the leading edge of the wing. This type is identical in outward appearance to the small, square stall-warning sensor on the leading edges of most general-aviation airplanes; but rather than containing an on/off switch, it contains a potentiometer and a spring-balance arrangement that lets the sensor blade (which, confusingly, is also called a vane) move forward or aft in reaction to pressures around the leading edge. Again, the potentiometer operates a panel meter, and the meter is calibrated in terms of certain standard reference speeds. The leading-edge vane acts just like an idealized lift-coefficient sensor; in most cases, it is self-compensating for flap movement and is unaffected by gear and power settings.

The only device of this type now on the market is made by the Safe Flight Instrument Corporation, the same company that makes all the leading-edge stall-warning sensors found on lightplanes. Lift sensors have been in use on sophisticated airplanes for years, but though Safe Flight offers models for light aircraft at under $500, it is rare to see one. We have a heated Safe Flight 200 installed on a FLYING Beech Sierra, however, and it has proved to be phenomenally useful.

The panel meter, which is mounted on top of the glare shield, has an edgewise display about half an inch high and two and a half inches wide. As the meter was supplied to us, it was to be mounted flat, with the slow end of the band to the left, represented by a red zone, and with a yellow arrow giving the reading. I probably did not give myself enough time to get used to this display, but at first I found it a little difficult to interpret rapidly: Does "left" mean "up" or "down?" Accordingly, I had the meter reinstalled vertically, with the stall zone at the top. The people at Safe Flight thought this arrangement backward; they do supply some instruments for vertical mounting, but they put the stall at the bottom. The difference is in the assumption made about the pilot's interpretation of the display. I saw it as an artificial horizon, with a bug—the moving arrow—that represented the airplane; "up" meant "nose up," as it does on the attitude gyro. Safe Flight's customers, however, regarded the arrow as a flight-director bug; a down movement of the bug meant "fly down," which would have the effect of decreasing the lift coefficient and bringing the bug back upward.

I think that for light-aircraft applications, the artificial-horizon analogy is better. Most of us are not in the habit of following a flight-director bug, and though we do have the habit of following a glide-slope needle in which a low needle means "fly down," there is no analogy between the lift-sensor arrow and the glide-slope needle; the needle represents a reference point in space toward which you are flying, while the arrow represents a condition of the aircraft which you are directly affecting by your control inputs.

The display, then, consists of a small vertical rectangle with the red stall zone at the top, marked by the word "slow" (which happens to be written sideways, since the Sierra's meter was meant to lie flat). At the bottom is the word "fast", and across the middle is a cross-hatched line called the "barber pole" for no obvious reason. At about the one-quarter- and three-quarter-scale points are two diamonds; the upper one is called the slow diamond and the lower one the fast diamond.

Getting this thing adjusted properly with the help of Safe Flight's opaque instruction manual is quite a trick; ours is still not right after several hours of trying, but it is close enough to be useful. We had one on a previous airplane—a Lark Commander—which we never managed to adjust at all, and finally returned to the factory. That was an older version of the instrument, however, and the present one represents a quantum improvement in serviceability.

Once working, it virtually replaces the airspeed indicator except for measuring cruising speed. You test its stall-warning function before takeoff with a button on the meter. (The audible stall-warning device is now incorporated in the lift-coefficient meter.) After takeoff, if you want best-angle-of-climb speed you put the arrow on the slow diamond; for best rate of climb, it goes on the barber pole. The fast diamond gives a good cruise-climb speed. The sensor compensates by itself for your flap setting, if any. During cruise, you forget it; but at the other end of the flight, you slow down to the fast-diamond speed, once on the ILS or as you are about to enter the traffic pattern; this is your maximum flap-operating speed. When you lower the landing gear or are starting your pattern proper, you slow down to the barber-pole speed. In the Sierra, this is around 81 knots—the best-rate-of-climb speed. Then a little miracle happens; as you add flap, the IAS corresponding to the barber-pole position drops until, with full flap, it is the recommended approach speed—74 knots in the Sierra. No trim change is needed throughout the approach, either. What is happening here is that lift coefficient is changing, since you are slowing down as you add flap, but the percent of maximum lift coefficient is remaining about the same. Why the trim remains the same all the time I don't know; that may not happen with all airplanes.

For the final phase of the landing, the lift indicator is ignored, although if you feel like it you can follow it throughout the flare, because it is so narrow that when you focus your eyes on the runway, the two images of the meter do not overlap; they are therefore both transparent but readable (though a little blurred).

A short-field approach is flown in the same way, but with the arrow on the slow diamond throughout the approach.

Naturally, this system compensates for weight. Whether you are alone in the airplane or you've brought your family and friends, you fly in exactly the same manner. You can see the weights reflected in the IAS: at the barber-pole best rate of climb, the Sierra indicates around 77 knots when very light, and 81 at gross.

That a few little marks on a dial manage to stand for every characteristic speed of the airplane is mainly a matter of luck; the speeds do, in reality, cluster around a few points, and some of them, such as approach speed, have no strict definition, so they can be defined in terms of a more specific speed, such as best-rate-of-climb speed. The meter defines approach speed, for instance, as the indicated speed with gear and flaps down when the meter indication is the same as that for the best rate of climb with the airplane cleaned up. On the Sierra, all these speeds come out remarkably well; even the maximum flap-operating speed, which is an FAA specification rather than an aerodynamic one, coincides exactly with the fast diamond. If one or another of the speeds did not line up perfectly, however, you would only have to make a mental note of the discrepancy and fly accordingly; for instance, you might prefer to make your slow approach with the arrow one diamond-width to the fast side of the slow diamond.

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If this device were nothing more than a glorified airspeed indicator, it would be of little value. What makes it tremendously helpful is its independence of every sort of disturbance and the high natural stability of the information it delivers. I found a striking improvement in my approach performance as soon as I began using the Safe Flight; I used to chase the airspeed indicator and fly the approach with one hand on the trim wheel. With the Safe Flight, to a degree exceeding anything I would have imagined, I find myself cruising down the glide path like a car down a turnpike. Practically no flying is necessary. I simply ignore the airspeed indicator, except to notice its surprises—for instance, that you really have to drop the nose and pick up speed on your turns to keep a constant margin above stall. Apparently because of the greatly increased precision of the approach, the final flare and landing are better, too: smoother and more accurate, even on the Sierra's rocky rubber-doughnut landing gear.

Climb performance is also enhanced. I used to consider the Sierra a doggy climber; with the Safe Flight, it delivered 500 fpm at gross weight at 9,000 feet on a recent trip to Colorado, hands off, with the arrow locked onto the barber pole.

The essential trick, I suppose, is the lift indicator's giving you real-time angle-of-attack information. The airspeed indicator is always lagging, because the angle of attack must first decrease (for instance), and the plane then accelerate to a new trim speed before you become aware of a change. By the time you correct, it is too late. With the lift indicator, you pick your angle of attack and let the speed catch up on its own time. You always fly at the most efficient angle of attack for the phase of flight you're in.

I'm sure that any pilot, even one with a high level of proficiency, would find a lift-coefficient indicator an invaluable help in getting the most out of his airplane. I also think that students would find the whole approach and landing process substantially easier if they had a real-time display to work from rather than the airspeed indicator. I would like to see the results of exposing students to this kind of instrument; it could be that the ease with which I can fly the airplane by it is really the result of years of experience hidden in the back of my unconscious and that a student pilot would find the "a-of-a" indicator just as hard to master as the airspeed; but I doubt it.

For everything except cruising, this is *the* pitch-control reference. It also has an advantage over the conventional audible stall warning in that it gives a progressive display of approach and entry into the stall region, as well as audible warning of the coming stall break. The supplementary detail in stall warning is a help; however, it should not be used by manufacturers, as the simpler tab-type stall warner has been, as an excuse to overlook good aerodynamic stall warning in their airplanes. ✈