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In an airworthy airplane, therefore, a stall is a perfectly safe maneuver if done high enough above the ground. *But inadvertent stalls near the ground account for about half of civil aviation's fatalities.*

ATTITUDE AND ANGLE OF ATTACK

Returning to normal flight, it is evident that straight and level flight can be performed with any angle of attack between the stalling angle and the small negative angle found at top speed. This range of angles is almost 20° , with

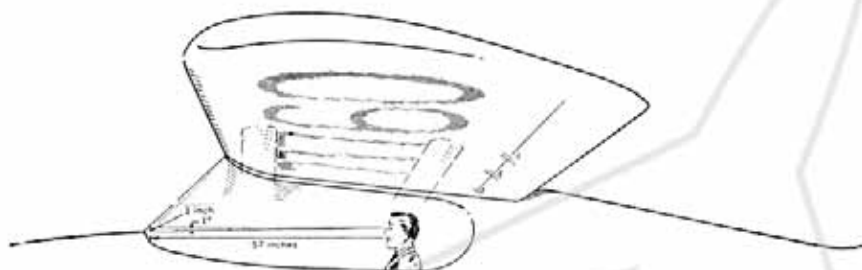


Figure 7.—At 57 inches, each inch means 1° .

any ordinary wing section. Most flying is done fast enough to stay within about the lowest 5° or 10° . Even 5° , however, is enough to make quite a range of heights of the nose as seen from a rear seat. In fact, if an airplane was so designed that the front window was just 57 inches from the pilot's eyes, each inch of vertical height on that window would mean almost exactly 1° , as in figure 7. (In many light airplanes with tandem seating the window is between 40 and 50 inches from the pilot's eyes, if he is in the rear seat, so each

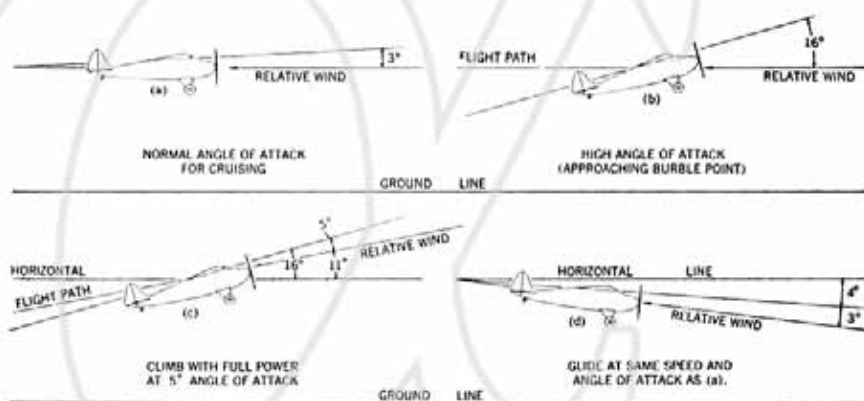


Figure 8.—Angles of attack under various conditions.

vertical inch means about 1.2 to 1.4° .) So, in level flight, the horizon may be seen through any point over a range of several inches on such a window, the exact location depending on the speed. *In other words, there is no one line in the airplane always pointing in the direction of its motion.*

Not all flying is confined to attitudes within this range, however. Landing involves letting the airplane lose speed until it stalls just before the wheels touch the ground. Just before it stalls, the line of flight is level. So the

upper range of angles of attack and of level-flight attitudes is used in landing. The difference between this and an ordinary level-flight attitude is illustrated in the upper pair of diagrams in figure 8.

The same attitude as in landing, but with a higher speed and lower angles of attack, makes the upward flight path shown in the third picture in figure 8. This flight path is far too steep for an ordinary light airplane, but not for a very powerful ship.

In gliding, the attitude is more nose down, but any given speed again gives practically the same angle of attack as in level flight, as shown in the fourth picture in figure 8.

SPEED AND ANGLE OF ATTACK

The accuracy of this rule about the same angle of attack for any given speed, either in level flight or climbs or glides, might be questioned on two grounds.

One of these is the very common misconception discussed on page 6, the belief that climbing requires the lift to exceed the weight and that gliding requires the reverse. As explained there, what does require the lift to exceed the weight is not steady, straight climbing, but starting from level flight into a climb.

A better ground for question is the fact that in a climb or a glide the lift is not vertical, but perpendicular to the line of flight, and there are also other forces to help support the weight. In the climb, the *thrust*, or pull of the propeller, has to exceed the drag, and it is inclined upward, practically along the line of flight. In the glide, the direction, upward along the line of flight, is backward, which is again the direction of the drag, but there is no thrust. Thrust in a climb, and drag in a glide, do indeed help support the weight. In practically all civilian flying, however, climb and glide angles are small. Therefore these forces are relatively weak, in comparison to the lift; and since they are only slightly inclined, their upward components, or lifting effects, are doubly weak.

Practically, therefore, in any straight flight, whether level or at any ordinary angle of climb or glide, LIFT EQUALS WEIGHT.

This fact makes the relation of the angle of attack to speed, for any given airplane, practically the same for all kinds of straight flight in still air. This relation, for a typical modern light airplane, is shown in figure 9.

This graph does not fit any one light airplane exactly, but is a compromise between data from several sources. It illustrates several important points, most of them summarizing what has been explained above, as follows:

(1) *There is no such thing as straight flight in still air with any speed less than the stalling speed V_s .*

(2) *For any speed in a very short range above stalling speed, straight flight is possible at either of two angles, the smaller angle giving normal flight and the larger one stalled.*

(3) *As the speed increases, the angle of attack for normal flight always decreases.*

(4) *At first this decrease is very rapid, but it becomes slower and slower, so that over a very wide range of the higher speeds the angle of attack changes*

but little, and all high speeds give angles of attack within very few degrees above or below zero.

GROUND SPEED, WIND AND AIR SPEED

The restriction to still air, in the laws just stated, raises the question, how to allow for the wind.

The fundamental law about an airplane flying straight in a wind is this: Suppose the wind is perfectly steady and perfectly uniform in strength and

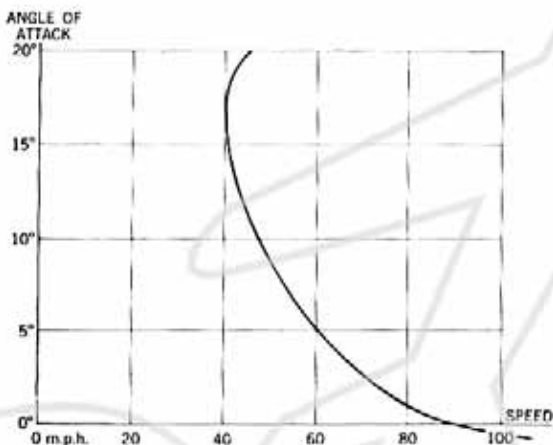


Figure 9.—Relation of angle of attack to speed for a typical light airplane, with $V_2=40$ m. p. h.

direction everywhere, and suppose you have inside the airplane a small balloon, so weighted that when it is released it will neither rise nor sink; then, if you release this balloon while you are flying straight, and you continue to fly straight, with exactly the same attitude and throttle setting, *the balloon will always be exactly behind you, and you will get exactly as far from it in any*



Figure 10.—Airplane and balloon in a wind. ♣

given time as you would with the same attitude and throttle setting if there were no wind at all.

Your relation to the balloon at various times is therefore as shown in figure 10.

This law is a direct consequence of Newton's First Law of Motion, that in any straight, steady motion all forces must balance exactly. For direct aeronautical evidence, however, perhaps the best reason for believing it, is that