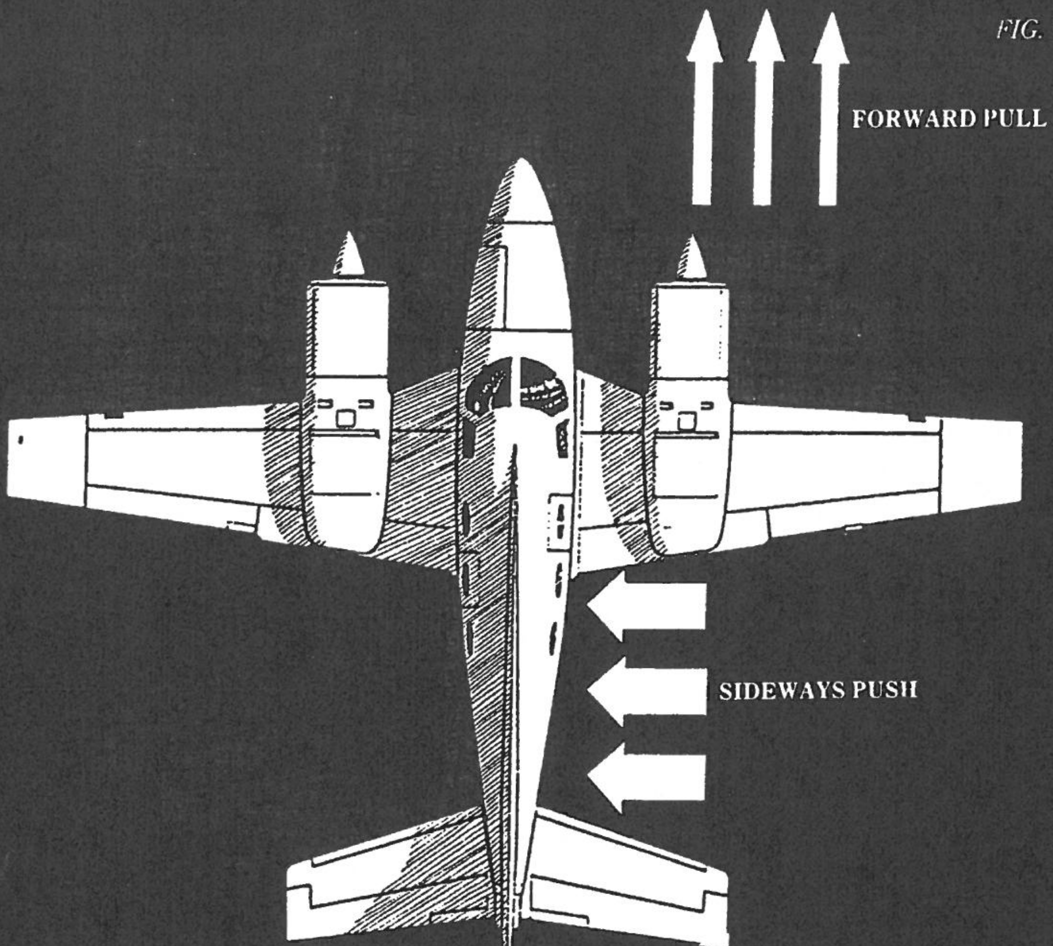
FIG. 1



MULTI-ENGINE ADVICE TO BANK ON

WHAT REALLY HAPPENS TO A TWIN WHEN AN ENGINE FAILS?

BY BARRY SCHIFF

PILOTS OF multi-engine aircraft who suddenly experience an engine failure recognize the urgent need to maintain directional control. But many do not realize that, if the wings are held level and the slip/skid ball is centred during certain critical phases of engine-out flight, they unwittingly contribute to the loss of directional control. This may seem incongruous to those trained to maintain a wings-level attitude following engine failure. Nevertheless, it is true.

Various publications do point out that a wings-level attitude erodes engine-out performance and controllability because is causes the airplane to slip sideways through the air. Although this is accurate, no explanation is offered to help pilots understand why this occurs. Some pilots even refuse to accept the possibility. But a little imagination can help to resolve this perplexing concept.

Imagine that a light twin is parked on an extremely slippery sheet of ice. Two men wearing spiked shoes, one at each wing tip, are pulling the airplane forward. Suddenly, the man tugging on the left wing has a cardiac arrest and falls down on the job. Since the man at the right wing tip is still working, the airplane veers (or yaws) left, simulating a failed left engine. The remaining worker yells for help, and a third man appears. But instead of replacing the ailing man on the left, the newcomer arrests the left turn by pushing against the right side of the tail (simulating right-rudder application). As shown in *Fig. 1*, this causes the airplane to move forward at a constant heading (zero yaw).

But, this example also demonstrates that the airplane moves sideways (or is sideslipping) toward the left, a result of the two applied forces. Notice that this happens even though the wings are level and the slip/skid ball on the instrument panel remains centred.

Sideslipping occurs in flight for the same reason. The side force created by a properly deflected rudder moves the airplane toward the dead engine, even though the wings are level, and the airplane is forced to maintain a constant heading. It is one of those phenomena that must be accepted on faith because it normally cannot be detected from inside the cockpit.

Such a sideslip can be observed, however, by taping a yaw string to the outside of the windshield or on top of the nose. It must be located in an area of undisturbed airflow where reliable sideslip indications can be obtained and where it is visible from the cockpit. In non-slipping flight, the yaw string—little more than a piece of yarn—is blown straight back by the relative wind; but during a sideslip to the left, for example, the yaw string moves right.

Another way to observe an engine-out sideslip is to fly precisely along a runway centreline on a calm day with one engine shut down and the wings level. To be safe at such a low altitude, powerplant failure should be simulated by allowing the "failed" engine to develop only enough power to overcome its own drag (zero thrust). To maintain track along the centreline, the pilot must crab toward the operating engine. Otherwise, the airplane will sideslip (or drift) toward the dead engine.

Allowing a twin with asymmetric power to sideslip results in two negative effects. The first is an obvious rise in drag resulting from moving sideways through the air. Slips, after all, sometimes are used intentionally to create additional drag, a procedure that enables a pilot to descend rapidly without gaining airspeed when on an excessively high final approach. But, when a twin is flown on one engine, performance may be so anemic that the additional drag created by an unintentional and unnoticeable sideslip cannot be tolerated. This can make the difference between being able to climb and sinking helplessly.

The other disadvantage is not so obvious. *Fig. 2* shows a light twin in a wings-level sideslip toward the dead engine. Notice that some of the relative wind, which approaches the airplane from the left, pushes against the left side of the vertical stabilizer. This force compounds the problem of directional control because it adds to the effect of asymmetric thrust; both forces try to yaw the airplane toward the dead engine. Consequently, the rudder must work harder to keep the airplane pointed straight ahead.

At a time when additional yaw control is required, however, the amount of available rudder power actually erodes. This is because the vertical stabilizer prevents some of the relative wind from reaching the rudder, obviously decreasing control effectiveness. Finally, the airflow that does reach the rudder during a sideslip brushes by the control surface at a relatively small angle, further reducing rudder effectiveness.

Since sideslipping dramatically reduces rudder power, it is necessary to increase airflow across the rudder if the airplane is to be prevented from yawing toward the dead engine. One way to do this is to maintain a faster airspeed, one that might be 10 or 20 knots above the published V_{MC} (minimum single-engine control speed). This could even require an airspeed in excess of V_{YSE} (best single-engine rate-of-climb speed).

Such a high V_{MC} can place a pilot between a rock and a hard place. If, just after take-off, an engine fails and air-speed is below the *actual* V_{MC}, but faster than the *published* V_{MC}, a pilot will believe that directional control is possible at a time when it is not. Failing to understand this, he becomes astonished when full rudder application fails to arrest the persistent yaw. Seemingly with a will of its own, the airplane continues its deathly spiral toward the dead engine.

The pilot's only recourse is to retard both throttles and accept the consequences of a possible forced landing (even though airspeed exceeds the published V_{MC}).

If sufficient airspeed is available to maintain directional control, the power of one engine may be insufficient to hold altitude because of the excess drag created by a sideslipping airplane. Most light twins—especially when heavy or at a high density altitude—then are destined for a downhill slide.

The only alternative is to fly the crippled twin properly. This demands eliminating most or all of the negative effects caused by wings-level sideslipping. Since a sideslip is an undesirable consequence of rudder deflection, the cause cannot be eliminated without centering the rudder and sacrificing directional control. But the force that produces a sideslip can be neutralized by creating an approximately equal force in the opposite direction. As shown in *Fig. 3*, this is accomplished by banking the airplane toward the operating engine and tilting the direction of wing lift. The resultant horizontal component of lift acts opposite to the sideslipping force produced by the rudder.

When the airplane is prevented from sideslipping, rudder effectiveness improves substantially, because the yaw force created by the relative wind striking the vertical stabilizer is eliminated. Also, a greater amount of airflow contacts the rudder at a larger angle. The bottom line is that increased rudder power allows directional control to be maintained at the slower, published V_{MC}.

Performance improves, too. This is because the airplane can be flown at a slower, possibly more efficient airspee (at V_{YSE} instead of above it). Also, the drag created by moving an airplane sideways through the air is eliminated. With less power required to maintain altitude, more excess power is available for climb (or reducing sink rate).

As mentioned earlier, the type of sideslip resulting from flying wings-level with an inoperative engine cannot be detected with a slip/skid ball; it remains centred. But when the sideslip is arrested by banking toward the operative engine, the ball will slide toward the lowered wing. This false indication of a slip can be ignored.

Many multi-engine aircraft pilots do not realize that the value of V_{MC} determined by the airframe manufacturers is obtained by flying the airplane is a zero-sideslip condition. In other words, the factory test pilot is allowed to bank the airplane up to 5° toward the good engine. This reduces V_{MC} to the slowest possible airspeed. When the wings are level and the airplane is sideslipping, V_{MC} rises unacceptably.

To maintain directional control following engine failure, it is imperative that a pilot similarly bank toward the operative engine. Otherwise, the red radial on the airspeed indicator that represents V_{MC} (a determined during certification flight testing) has little more than decorative value.

It is possible, of course, to have too much of a good thing. An excessive angle of bank erodes climb performance and must be avoided when there is a critical need to gain altitude. For this and other

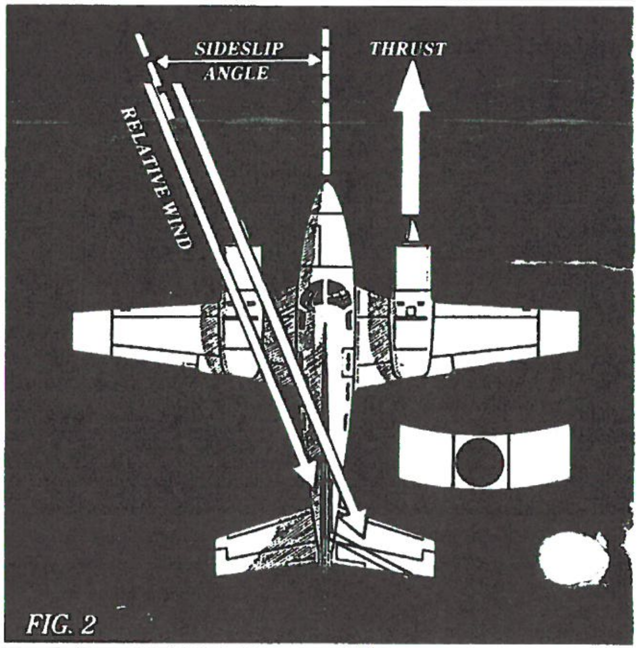


FIG. 2

reasons, the certification authorities allow airframe manufacturers to obtain and publish the V_{MC} resulting from *no more* than 5° of bank.

Such a shallow bank may not seem par- ilarly significant, especially when a pi- is fighting to keep the airplane upright. But even though 5° of bank is barely noticeable on the attitude indicator, it has a profound effect.

Consider, for example, the 5,000-pound airplane in *Fig. 3.* The amount of lift developed by the wings also is about 5,000 pounds. When the airplane is banked 5° to the right, the horizontal component of lift represents a sizeable 436-pound force that usually is enough to offset the rudder force causing the sideslip in the first place.

The vertical component of lift is barely affected by the slight angle of bank. It amounts to 4,981 pounds, which represents a mere 19-pound loss.

The importance of banking toward the operative engine cannot be overstressed. Failing to heed this requirement results in an excessively fast V_{MC} and potentially inadequate performance. Some pilots have trouble remembering which way to bank. (A bank in the wrong direction is worse than none at all). Although mnemonics are not satisfactory for everyone, the following may be helpful to some. After all, "dead foot, dead engine" probably has saved more than a few lives. Consider, "leaning on the good engine for support" or "raise the dead (engine) to stay alive."

A DECREASE IN GROSS WEIGHT AUSES AN UNWANTED INCREASE IN Vmc

Pilots are quick to recognize that lightly-loaded airplanes perform better than heavy ones. But there is an exception to this generalization: A decrease in gross weight causes an undesirable increase in V_{MC}. Simply stated, this occurs because the wings of a lightly-loaded airplane (in stabilized flight) do not produce as much lift as when the airplane is heavier. Consequently, the horizontal component of lift created during a 5° bank is proportionately less. In other words, the horizontal component of lift, being weaker, loses some ability to offset sideslip during flight with an inoperative engine. As a result, V_{MC} rises somewhat. The slowest V_{MC}, therefore, occurs at the heaviest gross weight (for a given airplane).

Moving the centre of gravity aft also causes V_{MC} to rise. This is because an airplane yaws (and rolls and pitches) about the centre of gravity. The rudder (and other control surfaces) becomes increasingly less effective, therefore, as the distance (or lever arm) between it and the centre of gravity decreases.

On the other hand, as an airplane with normally aspirated engines (no turbocharging) gains altitude, V_{MC} decreases, because the severity of asymmetric thrust diminishes as the operative engine loses power while gaining altitude.

For those bored by aerodynamic explanations, it is important only to recognize that the published V_{MC} occurs in the practical world of flight only when the propeller of the inoperative engine is windmilling, the operative engine is developing rated horsepower, flaps are in the take-off position, the landing gear is retracted, the centre of gravity is at the aft limit, gross weight is at a maximum (usually), and the airplane is banked 5° toward the operative engine.

V_{MC} increases when the angle of bank is less than 5° or the aircraft is below gross weight.

V_{MC} decreases when the propeller is feathered, when power on the operative engine is reduced, or when the CG is forward of the aft limit.

Considering the variables involved, it is clear that the precise value of V_{MC} at any given time is largely guesswork. The published airspeed applies only during a specific set of circumstances and otherwise is only a crude guide.

Since failure to bank into the operative engine is most responsible for increasing V_{MC}, pilots must be particularly alert to this during initial climb. This is when indicated airspeed may be above the published V_{MC} and yet below the actual, faster V_{MC} that would result from keeping the wings level following an engine failure. To maintain directional control and have a shot at climbing, the pilot must be prepared to bank into the operating engine as quickly as rudder is applied to arrest the yaw.

The need to develop and maintain the proficiency required to cope with an engine failure properly suggests that multi-engine pilots refresh themselves with periodic dual instruction. But this can present another kind of problem.

V_{MC} is reduced significantly below the published value when the operating engine produces less than maximum rated horsepower. Unfortunately, this occurs routinely during multi-engine training at altitude. The operating, normally aspirated engine cannot produce more than 82% power at 6,000 feet, for example, so V_{MC} may be dangerously close to stall. An attempt to demonstrate directional control at V_{MC} (required of applicants for a multi-engine endorsement) can result in an asymmetrically powered spin—a frightening, sudden maneuver that has claimed numerous lives.

(A knowledgeable multi-engine instructor widens the gap between actual V_{MC} and stall speed either by extending flaps partially, which decreases stall speed, or by sticking the toe of one foot behind the depressed rudder pedal to limit rudder travel, which artificially raises V_{MC} to a faster speed).

This demonstrates clearly that training for proficiency can be as hazardous as the lack of it, a case of the cure being worse than the ailment. Such is the nature of multi-engine airplanes.

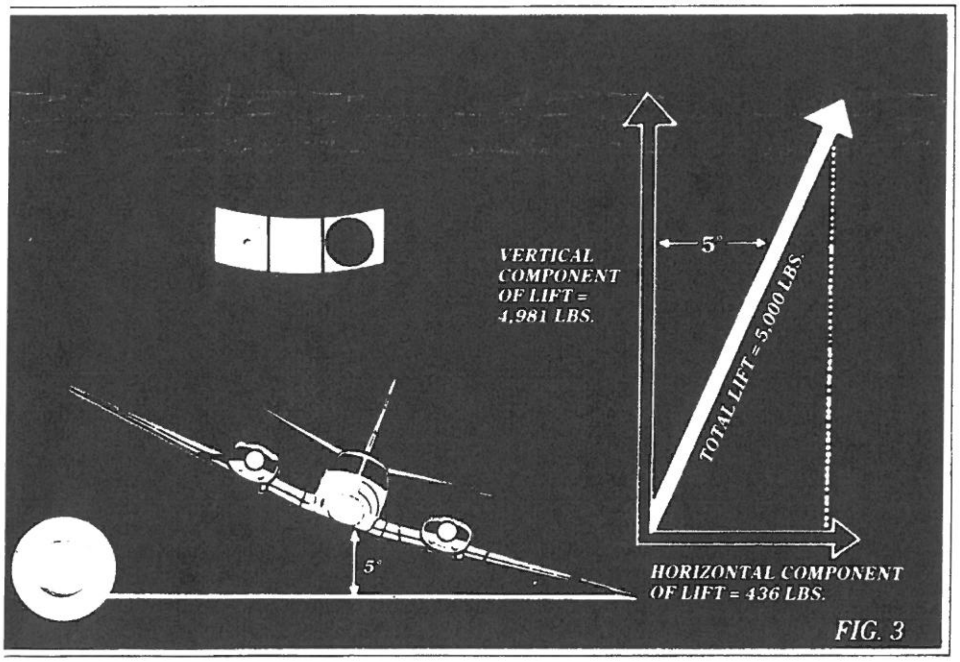


FIG. 3