Always Leave Yourself An Out

While single-engine aircraft may not be safer, twins can be more dangerous

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Despite heated scoldings from flight instructors and grim warnings from the National Transportation Safety Board, many pilots still seem to believe that implied in the fact that an aircraft has two engines is a promise that it will perform with only one of those engines operative. And the light-twin stall/spin accident rate further indicates that many multiengine pilots have not come to grips with the facts that 1. Significantly more than half the climb performance disappears when one engine signs out, and 2. Exploration of the Vmc regime close to the ground is a sure way to kill yourself.

A while back, the NTSB reported that light multi-engine aircraft are involved in fewer engine-failure-related accidents than single-engine aircraft. However the same report observed that an engine-failure-related accident in a twin is four times more likely to cause serious or fatal injuries. An analysis of that report appeared in the June issue of B/CA (Cause and Circumstance).

This article is not intended to debate the relative merits of twins versus singles. The twin offers obvious safety advantages over the single, especially in the enroute phase, and if, only if, the pilot fully understands the real options offered by that second engine in the takeoff and approach phases as well.

Takeoff is the most critical time for a light-twin pilot, but if something goes wrong he may have the option of continued flight, an option denied his single-engine counterpart. More often than not that second engine will provide only a little more time to pick a soft spot. (This assumes that the engine is lost before the aircraft reaches maneuvering altitude of 300 to 500 feet.) But even those few extra seconds, representing a few hundred extra yards, can give the twin pilot a hell of a safety advantage over his single-engine counterpart. But I must stress again, this safety advantage exists only if the multi-engine pilot fully understands his machine.

In this article we're going to explore some of the design concepts and certification procedures applicable to current-production light twins and then take a look at light-twin performance tables and attempt to find ways of getting more realistic information out of them. Along the way, we'll establish five rules for technique. We use these rules at B/CA, pilots at the FAA Academy use them, and we're sure many readers are aware of them, but we'll throw them in anyway in hopes of picking up a few more converts.

Let's look first at the implied promise that a general-aviation twin will perform with one engine inoperative. Part 23 sets standards for the certification of light aircraft weighing 12,500 pounds or less. Multi-engine aircraft are further divided by Part 23 into two weight classes, split at 6,000 pounds with the group that weighs 6,000 pounds or less, subdivided into two, depending on Vso (stall speed in the landing configuration). The break comes at 61 knots CAS.

Only those twins that weigh more than 6,000 pounds or have a Vso higher than 61 knots need to demonstrate any single-engine climb performance at all for certification. And the requirement is pretty meager. Basically, the regulation says that these aircraft must demonstrate a single-engine climb capability at 5,000 feet (ISA) with the inoperative engine feathered and the aircraft in a clean configuration. The amount of climb performance required is determined by the formula ROC=0.027 Vsol. The Rockwell Commander 500S (Shrike), for example, weighs over 6,000 pounds and therefore must meet this climb requirement. Vso for the Shrike is 63 knots, thus its minimum single-engine climb performance at 5,000 feet is 0.027 x 631 or 107.16 fpm. The Shrike's actual single-engine climb at 5,000 feet is 129 fpm, so the manufacturer bettered the Part 23 requirement, but not by much.

The Cessna 310 weighs less than 6,000 pounds, but stalls at 63.9 knots, so it too must meet the enroute single-engine climb standards. Plugging 63.9 knots into the 0.027 VS02 equation produces a requirement of 110.2 fpm. The 310's actual single-engine climb under Part 23 conditions is 119 fpm.

The Aztec, like the 310, weighs less than 6,000 pounds, but it slips under the Vso wire with a stall speed if 60.8 knots. The only requirement that an airplane in this group must meet is that its single-engine climb performance at 5,000 feet (positive or negative) be determined. The Aztec climbs at 50 fpm on one engine at that altitude, but the regulation doesn't require that it climb at all at that or any other altitude.

We can see then that where an enroute single-engine climb is required, it's minimal. Consider a hypothetical aircraft with an outrageous Vso of 100 knots CAS. The FAA requires only that such an aircraft demonstrate a paltry climb of 270 fpm on one engine at 5,000 feet.

There's another point to consider here. The FAA does not require continued single-engine takeoff capability for any light aircraft other than those designed for air-taxi work and capable of hauling 10 or more passengers. Stated another way, there is no reason to assume that an aircraft will exhibit positive single-engine performance in the takeoff configuration at sea level just because it had to meet a single-engine climb-performance requirement at 5,000 clean.

FAA Academy flight instructors are fully aware of this situation and believe it's important to stress it with the agency's GAIDO inspectors. An in-house white paper on light twins used at training courses for FAA pilots puts it this way:

"There is nothing in the FAR governing the certification of light multi-engine aircraft which says they must fly (maintain altitude) while in the takeoff configuration and with an engine inoperative. In fact, many of the light twins are not required to do this with one engine inoperative in any configuration, even at sea level…. With regard to performance (but not controllability) in the takeoff or landing configuration, the light multi-engine aircraft is, in concept, merely *a single-engine aircraft with its power divided into two or more individual packages.*" (Emphasis ours.)

While this concept of not putting all your eggs in one basket leads to certain advantages, it also leads to disadvantages should the eggs in one basket get broken.

You'll remember from your multi-engine transition training that the flight instructor and check pilot repeatedly insisted that when you lose one engine on a twin, performance is not halved, but actually reduced by 80 percent or more.

That 80-percent performance-loss figure is not just a number pulled out of the air for emphasis. It's easy to figure for any aircraft. Consider the Beech Baron B55 which has an all-engine climb rate (sea level, standard conditions, max gross weight) of 1,670 fpm and a single-engine climb rate under the same conditions of 318 fpm. The loss of climb performance in this case is

100-(318/1,670 x 100)

or 80.96 percent. The climb performance remaining after the loss of one engine on the B55 is 19.04 percent.

Performance loss for the cabin twins, turboprops and business jets is similar. The Rockwell Commander 685, for example, loses 83.42 percent of its climb performance when one engine quits; the Swearingen Merlin III loses 75.49 and the Learjet 25C 71.07. The Lockheed JetStar loses 43.48 percent if its climb performance with the loss of one engine, but remember, it has four engines. The loss of one quarter of its thrust results in a loss of almost half its climb performance and if it were to lose half its thrust, climb performance would be cut by more than 75 percent. (The table on this page shows similar performance changes for other aircraft.)

Some turboprops and all turbojets demonstrate a continued takeoff capability with one engine inoperative. The turbojets do so because of the tougher certification requirements of FAR Part 25. Although loss of power in terms of percentage reduction is similar in all categories of business aircraft, the turbojets and some turboprops have much better single-engine performance because they're starting with higher numbers. While the Learjet 25C, for example, loses more than 71 percent of its climb performance when one engine is shut down, it begins with an all-engine rate of climb of 6,050 fpm. When this is reduced by 71 percent, It still climbs at 1,750, which Is much better performance than you get out of many light-piston twins with both engines running.

Why the performance loss is greater than 50 percent with the failure of one engine needs a bit of explanation. Climb performance is a function of thrust horsepower (or simply thrust in turbojets) which is in excess of that required for straight and level flight. You can convince yourself that this is the case by trimming your aircraft for straight and level at its best all-engine rate-of-climb speed and checking the power setting. If you ease the stick back at this point, the airplane will not settle into a sustained climb. After a momentary climb it may, in fact, begin to descend. However, if you go back to straight and level flight at the best-rate-of-climb speed and slowly feed in power as you maintain airspeed, a climb will be indicated, and the rate of climb will depend on the power you add-which is power in excess of that required for straight and level.

Now trim for straight and level (in the clean configuration at about 1,500 feet) at the best single-engine rate-of-climb speed, adjust one engine to its zero-thrust setting (about 10 inches to simulate feather). You'll notice that the "good" engine, now carrying the full burden, is producing 75-percent power or more. If you increase the power on the good engine, your aircraft will begin a climb, but at a very modest rate. This is so because you've got much less "excess" horsepower available. If you are interested in the math behind this, an approximate formula for rate of climb is:

R/C = ehp x 33,000/weight(ehp is thrust horsepower In excess of that required for straight and level.) To determine ehp, rearrange the formula to read:

ehp = R/C x weight/33,000

Using the Seneca as an example, with its maximum gross weight of 4,200 pounds and all-engine and single-engine climb rates of 1,860 and 190 fpm respectively, we find that this aircraft has about 236 thrust horsepower available for climb with both powerplants operating and only 24 excess thrust horsepower for climb on one engine. If you refer to the climb-performance-loss formula, you'll see that the Seneca loses about 89.78 percent of its climb performance when an engine stops:

100 - 190/1,860 x 100 = 89.78

If you examine the two figures above for excess horsepower and state them in terms of percentages, you'll see that an engine loss in the Seneca represents a loss of 89.83 percent of thrust horsepower available for climb.

Part 23 defines Vmc as "the minimum calibrated airspeed at which, when any engine is suddenly made inoperative, it is possible to recover control of the airplane with that engine still inoperative, and maintain straight flight, either with zero yaw, or, at the option of the manufacturer, with an angle of bank of not more than five degrees." Vmc may not be higher than 1.2 times the stall speed with flaps in takeoff position and the gear retracted. In flight-test work, Vmc is determined with takeoff or METO power on each engine, the rearmost allowable center of gravity, flaps in takeoff position, landing gear retracted and the propeller of the inoperative engine 1/ Windmilling with the propeller set in the takeoff range, or 2/ Feathered, if the airplane has an automatic feathering device. During recovery, the airplane may not assume any dangerous attitude or require exceptional piloting skill, alertness, or strength to prevent a heading change of more than 20 degrees.

Vmc is not at all mysterious. It's simply that speed at which airflow past the rudder is reduced to such an extent that rudder forces cannot overcome the asymmetrical forces caused by takeoff power on one side and a windmilling prop on the other.

When that speed is reached and the nose starts to swing toward the inoperative engine, the only hope of regaining control is to reduce thrust on the good engine (or increase speed). An increase in airspeed requires a change in momentum and thus a certain period of time to become effective. Thus, for practical purposes, the *only* method of regaining control is to reduce power on the operating engine quickly.

Performance Loss of Representative Twins with One Engine Out

Pistons			
	All engine climb (fpm)	**S.E. climb (fpm)**	**Percent loss**
Beech Baron 58	1,694	382	80.70
Beech Duke	1,601	307	80.82
Beech Queen Air	1,275	210	83.53
Cessna 310	1,495	327	78.13
Cessna 340	1,500	250	83.33
Cessna 402B	1,610	225	86.02
Cessna 421B	1,850	305	83.51
Piper Aztec	1,490	240	83.89
Piper Navajo Chieftain	1,390	230	83.45
Piper Pressurized Navajo	1,740	240	86.21
Piper Seneca	1,860	190	89.78
Turboprops			

	All engine climb (fpm)	S.E. climb (fpm)	Percent loss
Beech King Air 90	1,870	470	74.87
Mitsubishi MU2-J	2,690	845	68.59
Rockwell Commander 690A	2,849	893	68.66
Swearingen Merlin III	2,530	620	75.49

Business Jets

	All engine climb (fpm)	S.E. climb (fpm)	Percent loss
Cessna Citation	3,100	800	74.19
Falcon F	3,300	800	75.76
Falcon 10	6,000	1,500	75.00
Gates Learjet 24D	6,800	2,100	69.12
Grumman Gulfstream II	4,350	1,525	64.94
Hawker Siddeley HS 125-600	3,550	663	81.32
IAI 1123 Westwind	4,040	1,100	72.77
Rockwell Sabre 75A	4,300	1,100	74.42

Vmc is not a static number like flap-operating speed or the never-exceed speed. It changes with conditions. The Part 23 test described above cites the worst conditions. Aft cg, for example, reduces the force of the rudder because it shortens the arm and thus the turning moment. Vmc will be lower with forward cg and all other factors being equal. Conversely if the aircraft is loaded slightly out of rear cg, Vmc will be higher. In normally aspirated aircraft Vmc decreases with an increase in density altitude primarily because the output of the operating engine decreases, thus the asymmetrical power situation decreases.

At first glance, this situation seems to be a good one. The hotter and higher the airport, the lower Vmc. But actually nothing about Vmc is good and there's a hell of a catch in it. As Vmc decreases (with a decrease in good-engine performance) it approaches the stall speed. This is especially bad news for flight instructors who must purposely explore the Vmc regime with their students. If Vmc and stall are reached simultaneously, a spin is almost inevitable and Part 23 twins are often impossible to get out of a spin. (One northeast flight school lost two aircraft in one summer because of this problem.)

Landing-gear extension seems to reduce Vmc for most light twins and this, like the density altitude situation, can be both good and bad.

Suppose a pilot gets himself in the unhappy situation of being 50 feet in the air, gear down, with one engine out, full power on the good side and full rudder to keep the nose from swinging. He doesn't like the look of the trees in front of him so he decides to make a go for it. He reaches down and retracts the gear to get rid of its drag, hoping that will enable the aircraft to accelerate to a climb speed. Suddenly he's looking at the trees through the top of the windshield. Why? Because he was on the edge of Vmc and sucked up the gear, which increased Vmc costing him control of the aircraft.

The prudent light-twin pilot, of course, would never find himself in that situation because he would know beforehand that his hopes of accelerating without altitude loss from Vmc to Vxse or Vyse are practically nil.

If your aircraft is relatively new, Vmc, as determined by the Part 23 certification test, is marked by a red line on the airspeed-indicator face. Indicated Vmc will never be higher than this line, so the slash can be used as a guide to keep you out of trouble. This does not mean that the airplane will spin out as soon as the line is reached. Under the circumstances described above (such as high density altitude) controlled flight with full power on the operative engine is possible when the indicated airspeed falls below the red line, but it certainly isn't advisable. Exploring this part of the flight envelope in an actual emergency can (and probably will) kill you. So let's establish our first rule for multi-engine flying.

Rule #1 — Never allow the airspeed to drop below *published Vmc* except during the last few yards of the landing flare, and then only if the field If extremely short.

Some aircraft have an all-engine best-angle-of-climb speed (Vx) below Vmc. Using that climb speed under any circumstances can be extremely dangerous. The instructors at the FAA Academy have this to say about the use of Vx near the ground: "Trying to gain height too fast after takeoff can be dangerous because of control problems. If the airplane is in the air below Vmc when an engine fails, the pilot might avoid a crash by rapidly retarding the throttles, although *the odds are not in favor of the pilot.*" Thus we have another rule:

Rule #2 — A best all-engine angle-of-climb speed that is lower than Vmc is an *emergency* speed and should be used near the ground only if you're willing to bet your life that one engine won't quit during the climb.

Manufacturers differ on the proper takeoff speed for a light twin. Piper, for example, recommends that most of its twins be rotated at Vmc. Cessna, on the other hand, suggests liftoff at a speed much higher than Vmc and very close to best single-engine angle-of-climb speed. In the case of the Cessna 310, Vmc is 75 knots, recommended rotation speed is 91 knots and best single-engine angle-of-climb speed is 94.

It's important to note that manufacturers who recommended liftoff at or near Vmc do not, as a rule, show figures for continued takeoff in event of an engine failure at the liftoff speed. The reason is simple. Most Part 23 twins cannot accelerate in the takeoff configuration from Vmc to best single-engine rate-of-climb speed while maintaining a positive climb rule. Conversely it is possible to accelerate them (under near sea-level conditions) from best single-engine angle-of-climb speed to best single-engine rate-of-climb speed while maintaining a positive, though meager, climb. Manufacturers who recommended liftoff well above Vmc usually show continued single-engine takeoff performance in their owners or flight manuals.

Engine-Out Angle of Climb

(degrees, at best-rate speed)

	ISA	ISA + 20
Piper Seneca	1.2	0.6
Cessna Skymaster	1.7	1.3
Piper Turbo Aztec	1.6	1.5
Cessna 402B	1.2	0.6
Piper Navajo	1.5	1.1
Cessna 340	1.4	0.8
Cessna 421	1.6	1.0
Rockwell International 685	1.2	0.7
Piper Navajo P	1.2	1.0
Mitsubishi MU2-K	4.2	2.4
King Air A100	2.1	1.0

NOTE: For comparison purposes, the average two engine rate of climb for the above aircraft is 8 degrees.

We have to recommend against lifting off at Vmc for the same reason most flight instructors recommend against "stalling" a single-engine aircraft off the ground. In the latter case, the single will fly to the edge of ground effect but could reach that point behind the power curve. An engine failure at that point could result in a stall and pitch over. In the case of the twin, an engine failure at liftoff at Vmc could produce such a rapid turning moment that control would be lost immediately. The FAA says, "Experience has shown that an unexpected engine failure surprises the pilot so that he will act as though he is swimming in glue." If a pilot rotates at Vmc, loses an engine and begins the "swimming in glue" routine, his odds of survival are minimal.

The alternative, of course, is to hold the aircraft on the ground a little longer. Most multi-engine instructors believe that Vmc-plus-five knots is a good compromise for use in those aircraft with a- recommended liftoff at Vmc. Why not hold it down until almost reaching best single-engine angle-of-climb speed like the Cessna folks recommend? The reason again is controllability. Cessna light twins and most cabin twins of all manufacturers are designed to stay on the ground well beyond Vmc. But some of the light twins simply are not. For example, we've tried holding the Seneca and Aztec on the runway beyond Vmc-plus-five knots and have discovered that both aircraft begin to wheelbarrow. (Tests were at maximum gross weight, zero flaps.) High-speed wheelbarrowing can be just as dangerous as liftoff too close to Vmc, especially when we're talking about selecting an appropriate speed for every takeoff. Remember too that the takeoff-performance figures in the aircraft-owners or flight manual are invalid as soon as we use techniques different from those specified in the table footnotes. (More on this later.) Anyway, we've got a third rule now for light-twin operation:

Rule #3 — Use the manufacturer's recommended liftoff speed or Vmc plus five knots whichever is greater.

Now that we're in the air, the first priority is to accelerate the aircraft to best single-engine angle-of-climb speed (if we're not already there), then best single-engine rate-of-climb speed and finally best all-engine rate-of-climb speed. Each of these speeds is a milestone in the takeoff and the realization of each reduces the decisions to be made in the event of an engine failure.

Many instructors recommended that best single-engine rate-of-climb speed (the blue line if it's marked on your airspeed indicator) be used for the initial climb to a safe maneuvering altitude. B/CA's pilots recommended the best all-engine rate-of-climb speed, when it is faster (it normally is), for two reasons. First, the swimming-in-glue syndrome is going to translate into speed lost. So if an engine does quit while you're holding best all-engine rate-of-climb speed, the deceleration while you're getting things straightened out will probably put you pretty close to best single-engine rate-of-climb speed which is where you want to be anyway. Second, the best all-engine rate speed will get you to maneuvering altitude and out of immediate danger.

One caution here is important. Avoid climbing to maneuvering altitude at a speed greater than best all-engine rate of climb-to do so is sloppy and inefficient. Here's why:

As we have seen, climb is a function of thrust horsepower in excess of that required for straight and level flight and drag increases as the square of the speed. At the same time, power required to maintain a velocity increases as the cube of the velocity.

The Cessna 421 has a best all-engine rate-of-climb speed of 110 knots, which produces a climb of 1,850 fpm at sea level. If the aircraft is climbing at 122 knots, drag would increase by 1.2 times and the power required to maintain that velocity would increase 1.4 times with a resulting decrease of excess thrust horsepower available for climb. In this example the climb rate decreases to about 1,261 fpm; thus a 10-percent increase in speed over the best-rate speed produces a 32-percent decrease in climb performance. These exercises produce another rule:

Rule #4 — After leaving the ground above Vmc, climb not slower than single-engine best rate-of-climb speed and not faster than best all-engine rate of speed. The latter speed is preferable if obstacles are not a consideration.

You may have gotten the impression by now that we're picking on Cessna and Piper in our examples. Piper twins and the Rockwell Commander 500S have shown up in our examples here because the Ziff-Davis Aviation Division operates (or operated in the case of the Shrike) these aircraft and our observations concerning them were gained from extensive first-hand knowledge. The Cessna twins are used as examples because Cessna, in our opinion, produces the best owners manuals in the industry. This is not to say that the Cessna manuals can't be improved-they are merely the best of a very poor lot. But in any event Cessna manuals provide most of the information a pilot needs to plan for emergencies. At this writing, a special committee of the General Aviation Manufacturer's Association is working on standardization and improvement of light-aircraft flight manuals. But until such time as the GAMA committee and the FAA improve the situation, we're stuck with the paper work that comes with the airplane. Here comes rule five:

Rule #5 — Be a skeptic when reading the performance tables in your Part 23 aircraft-owners manual and be doubly sure you read the fine print. Add plenty of fudge factors.

You'll notice first when you look at light-twin takeoff-performance tables (in anybody's manual) that the takeoff is initiated after power has been run to maximum with the brakes locked and the mixtures adjusted to optimum settings. We've attempted to measure the difference in the takeoff roll for brakes held versus a normal throttles-up-smooth start and have come up with figures ranging from an extra 200 to 400 feet. Remember that these figures will increase in density altitude.

If the book figures for continued single-engine takeoff and accelerate/stop distances, you've really got it made, because now, by adding a few hundred feet here and there to compensate for real-time situations, you can get a good handle on what's going to happen if one quits-and what you're going to do about it.

We'll use a Cessna 421 for this exercise and remind you again that we're not picking on the 421. It's just that Cessna is honest enough to try to tell it like it is in its owners manuals.

On a standard day at 7,450 pounds, a 421 needs 2,500 feet to get off and over a 50-foot obstacle. This assumes a rotate speed of 106 knots, well above Vmc. If an engine is lost at rotation and the pilot elects to go anyway, he'll need a total of 5,000 feet to clear the obstacle. The ground run in both cases is about 2,000 feet. In the case of both engines operating, the climb from rotation to 50 feet requires a horizontal distance of only 500 feet; but in the case of the single-engine takeoff, the climb to 50 feet requires a horizontal distance of 3,000 feet, a six-fold increase. And keep in mind that we're still only 50 feet above ground and that to get this far we've made split-second decisions all along the way.

Let's get some real-life factors into the single-engine takeoff equation. Suppose, as is usually the case, we begin the takeoff roll about 75 feet from the approach end of the runway and do so without holding the brakes. This could add 475 feet to the handbook figure. Next, suppose we lose the engine at rotation, but it takes us three seconds to recognize the situation and react. (This, by the way, is a very conservative figure.) The reaction time will cost us about 537 feet. Now the total horizontal distance from the beginning of the runway to a point at which the aircraft is 50 feet above the surface (assuming engine loss at rotation) is 6,012 feet, an increase of 20 percent. The 421's sea-level, single-engine climb rate is about 305 fpm. Assuming that we want to get at least 500 feet under us before trying anything fancy like returning for a landing, we must continue more or less straight ahead for one minute and 28 seconds. This climb will cover a horizontal distance of some 16,485 feet bringing the total distance covered from the rotation point to 19,485 feet, or *3.7 miles.*

If all this happens at a sea-level airport on a hot day (ISA plus 20 degrees C.), we will not reach the 50-foot level until the aircraft has covered a horizontal distance of 7,040 feet from the point of rotation and engine failure. Assuming calm air the aircraft will reach 500 feet some *5.9 miles* from the rotation point or *6.6 miles* from the runway beginning. If the hot condition brought convective turbulence with it, the effective climb rate would be reduced by 100 fpm. Under these conditions, the aircraft would reach 500 feet some *9.9 miles* from the rotation point and *10.6 miles* from the runway beginning.

I've been stating these horizontal distances in terms of miles to stress a point. If your flight manual gives figures for continued single-engine takeoff, make sure you look at the climb performance beyond the 50-foot altitude to be certain that continued takeoff is a viable alternative if an engine quits. You might be able to live with that 10.6-mile hot-day figure on a departure from JFK where you could head out over the Atlantic, but the same departure from Teterboro would make collision with obstacles almost a certainty. In the case of the Teterboro departure, a rejected takeoff within the boundaries of the airport or stuffing it into the first available parking lot might be your only survivable alternative. You certainly aren't going to survive if you run into something, or fall out of the air trying to get performance from the aircraft that the manufacturer never built into it.

So, on the subject of rejected takeoffs, check the accelerate/stop tables and the landing-distance charts before each takeoff. Remember to add 500 feet or so to the accelerate/stop distance to compensate for the runway left behind you when you moved into position and the rolling (rather than brakes-held) ground run; add another 500 feet or so for your reaction time and then another 200 feet for "technique." Part 23 sets no standards for the determination of accelerate/ stop distances in light twins. The stopping distances are often determined by a 10,000-hour test pilot who does everything short of retracting the gear to stop the aircraft. Even in an emergency situation, you're probably not going to get the same stopping performance he does. (Remember to get the flaps up to increase the weight on the wheels.)

If you're lucky enough to have normal takeoff, single-engine takeoff and accelerate/stop tables in your airplane manual, another check you should make before takeoff is the total distance (adding our real-life factors, of course) for takeoff with both engines operating, climb to 50 feet, then to land from that 50-foot altitude and bring the aircraft to a complete stop. This figure for the 421 (adding all our fudge factors) comes to 5,689 feet. This is less than the distance required (6,012 feet) to climb to 50 feet assuming an engine loss at rotation under the same conditions.

Knowing this number gives you another alternative. If you have 5,700 feet of runway and overrun, you might decide to put the aircraft back on the runway even if the engine failure occurs well after takeoff as you're going through 50 feet. Even if you don't have the full 5,700 feet, you may have enough runway to get the wheels back on the hard surface and begin some serious braking before you run off the end of the runway. B/CA's philosophy, which was copied from that of the flight department of a major manufacturer of light twins, is that it's always better to go through the fence at 50 knots than to hit the trees at 120.

To the best of my knowledge, a takeoff to 50 feet followed by an immediate landing is not taught in twins, although a similar maneuver is taught in single-engine aircraft. It should be, but before you go out and try it, take your aircraft to altitude and practice the transition from climbing flight to gliding flight until you can make the transition without significant loss of airspeed. And it might be a good idea to take an instructor along. If you decide to try it on a runway allow a good 8,000 to 10,000 feet for the first few attempts-and take your time.

If your aircraft-owners manual does not show performance figures for continued single-

engine takeoff, chances are that the airplane simply is not capable of accelerating from liftoff speed to a reasonable climb speed in the takeoff configuration. In this case, your decisions are pretty limited. You really don't have a go-situation until the aircraft is cleaned up and has reached at least best single-engine angle-of-climb speed. An engine failure before that time (on the ground or in the air) dictates an immediate *controlled* descent to a landing. The surviving engine, in this case, can be used to help maneuver to a suitable (nearby) landing place if all of the runway is gone.

You can calculate your own accelerate/stop distances by running the aircraft up to takeoff speed and then bringing it to a stop. (Make sure you start these tests on a good long runway). Do this several times at max gross weight counting runway lights (the airport operator can tell you the distance between lights) and you'll get a good ball-park figure for accelerate/stop. Then use that figure in your future takeoff planning.

To sum it up, we've seen that:

- The loss of an engine on a Part 23 twin will decrease sea-level climb performance by at least 80 percent and can decrease it by as much as 90 percent.
- There is no requirement for continued single-engine takeoff capability for Part 23 twins, nor, in fact, is there a requirement for any positive single-engine climb at all for twins which weigh less than 6,000 pounds and have a stall speed of 61 knots or less in the landing configuration.
- It is vital to know all you can about your aircraft's performance in normal and emergency situations *before* the takeoff is attempted. To arrive at reasonable performance predictions you must adjust the information provided by the manufacturer to take into account real-life factors such as reaction time, runway condition and obstacles, including obstacles five or more miles beyond the airport boundary.
- A well-executed Part 23-twin takeoff is one in which the aircraft leaves the ground at least at Vmc-plus-five knots and climbs at a speed of at least Vxse and not more than Vy.

One final comment should be made on the single-engine takeoff. Your personal IFR takeoff minimums should include factors for an engine failure. Certainly your go-no go decision with an engine failure immediately after rotation or in the initial climb segment is strongly affected by weather. Consider the case of the 421 we discussed above which, in the event of engine failure at rotation, requires about 10.6 miles on a hot day from the start of the runway to a point where maneuvering altitude (500 feet) is reached. Poor visibility and low ceilings could make that situation almost hopeless in any but the most sparsely built-up areas.

Single-engine landings, as you'll remember from your check rides, are not difficult at all. Single-engine go-arounds in Part 23 twins are, on the other hand, damn near impossible unless they are begun from an altitude several hundred feet above the terrain and at an airspeed at or slightly above the best single-engine rate-of-climb speed. The situation is doubly bad if you start a go-around and *then* lose an engine. If you want proof, go to altitude and set up a 500 fpm rate of descent at a speed 10 percent below the best single-engine rate-of-climb speed. Continue the descent until you are within 200 feet of a cardinal altitude, then simulate a single-engine go-around. Attempt to clean up the airplane, and accelerate to best single-engine climb speed without sinking through the cardinal altitude. It can't be done with Part 23 twins-we've tried it in just about everything from the Seneca to the King Air A100. At or above single-engine climb speed it can be done if you're sharp. But don't bank on being sharp after a long flight involving an engine shutdown somewhere along the way.

So establish a single-engine I'll-land-come-hell-or-high-water attitude (agl) and minimum-airspeed combination for your aircraft and stick to it. If you find yourself below that speed or altitude and a truck shows up on the runway, pick a soft spot to hit on the airport. Because it's much better to wipe out the gear by landing off the runway than to wipe out the whole airplane by spinning into the middle of it.

Summing it up-stay proficient (an annual check is a good idea), stay constantly aware of your airplane's performance by analyzing the flight-manual information under realistic conditions, and have a plan of action before things start to come unglued. The key philosophy of that plan of action is easy to remember and may save your bottom — *always leave yourself an out*.