Baron and Travel Air focuses on the unique systems, piloting techniques, maintenance and ownership considerations for the Beechcraft twins. We encourage ABS members to submit your articles about flying, owning and maintaining Beechcraft Barons and Travel Airs to info@bonanza.org.

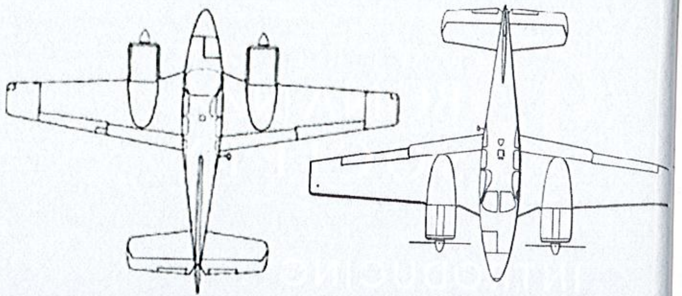


Figure 1: The T-42A flight line at Cairns Army Airfield in 1968

Single-Engine Stalls and Flat Spins: Cause and Mitigation

by George Brown

For the past 40-plus years, it has been widely publicized that Barons, and to a lesser degree Travel Airs, are prone to developing usually fatal flat spins during a failed attempt at the V_{MC} demonstration. This maneuver is required by the FAA as part of its Airman Certification Standards (ACS) for the Private and Commercial multiengine rating and can also be performed (depending on the instructional syllabus or objectives) during recurrent multiengine training and as part of the FAA-required flight review. Unfortunately, a number of fatal flat-spin V_{MC} accidents still occur, especially during initial or recurring multiengine training.

Before I go any further, I need to note that neither the Baron nor the Travel Air were spin tested for certification, nor were spins and spin recovery required by their certification standards.

That stated, let's look at the difference between a normal and a flat spin in a single or multiengine airplane. A normal spin exhibits an aggressive nose-down pitch initially with one wing aerodynamically stalled and the other still flying, possibly progressing to both wings stalled with one deeper than the other. The airplane autorotates around the roll (longitudinal) axis spiraling downward in a helix at a relatively low airspeed but with a high sink rate. The tail surfaces remain aerodynamically effective so with the proper piloting procedure and sufficient altitude, recovery from a normal spin is successful.

However, in a flat spin the airplane's pitch is more-or-less level, the airplane rotates violently around the yaw (vertical) axis in a vertical descent. Forward speed is very low, well below flying speed with both wings and horizontal and vertical tail surfaces aerodynamically stalled—all control surfaces are ineffective with the relative wind flowing vertically from underneath the airplane, not horizontally from in front of it. The airplane literally falls out of the sky, with recovery from the fully developed flat spin impossible. At impact with the ground, it is in a flat attitude and at a vertical speed that is almost always not survivable.

To illustrate the vertical characteristic of a flat spin, an Army Flat Iron rescue and medical evacuation helicopter pilot at Fort Rucker, Alabama, in the mid-1960s wrote the following observation. As background, this was when the U.S. Army initiated multiengine and instrument training in its new fleet T-42A trainers (**Figure 1**). These trainers were the military version of the B55 Baron: the B55B.

> T-42 accidents were flat spins. There were times when we had a terrible time finding the aircraft after an accident because they went straight down in a very tight rotation. When going into a forested area, the aircraft didn't break any trees because its descent was so vertical.

During that time, engine-out full stalls were a required maneuver in the Army's training syllabus. However, after Army aviation command learned that engine-out stalls were the cause of the repeated fatal flat-spin accidents and removed those type of stalls from the training syllabus, flat spin accidents no longer occurred during multiengine training in the T-42A.

V_{MC} Calculation

For review, V_{MC} is the lowest indicated airspeed at which the airplane has the control authority to maintain directional control in flight under the worst-case conditions listed below as defined in 14 CFR 23.149 and published in the POH:

- Maximum takeoff weight
- Aft limit of center of gravity (c.g.)
- Landing gear retracted
- Flaps up
- Cowl flaps open
- Critical (left) engine total failure with windmilling propeller (not feathered)
- Operating (right) engine at maximum sea-level power (full throttle/high rpm)
- Maximum rudder deflection against the yaw
- Maximum 5° of bank

Here I note that while there are actually two loss of control airspeeds for light twins, V_{MCG} for operation on the ground (when nosewheel contact provides friction that resists yaw) and V_{MCA} in

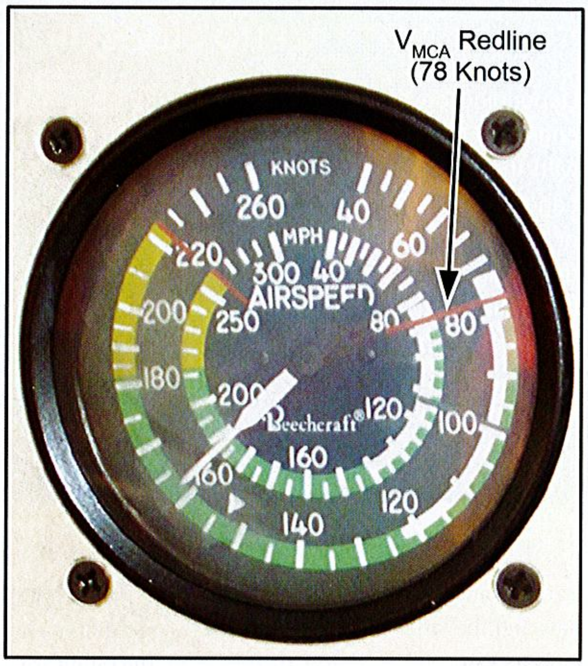


Figure 2: Red V_{MC} radial on a B55 airspeed indicator

ZERO SIDESLIP

Depending on aircraft weight, zero sideslip can be achieved at a bank angle of 1 to 5 degrees toward the good engine, typically about 2 degrees, with the turn coordinator ball somewhere between 1/4 to 1/2 out of the cage, also toward the good engine. With a one- to two-foot length of string or yarn taped to the bottom of the windshield, zero sideslip exists when the string points straight up the windshield. By recording the bank angle and ball position, you can fly those numbers again for any future V_{MC} demonstrations.

the air, the former is not mentioned in Beech manuals and the latter is usually referred to simply as V_{MC}.

For any multiengine aircraft including Barons or E95 Travel Airs, V_{MC} is a calculated speed at the ICAO standard temperature of 59 degrees Fahrenheit and sea-level pressure of 29.92 inches of mercury. Calculated V_{MC} is different for each model Baron and Travel Air as listed in its respective flight manual. For example, the *Pilot's Operating Handbook* (POH) for the B55 serial number TC-2003 and after lists V_{MC} at 78 knots indicated; the red line on the example airspeed indicator in **Figure 2**. For the Baron 58 serial number TH-1472 and after, V_{MC} is 84 knots indicated. The E95 *Owner's Manual* lists the single-engine minimum control speed at 80 miles per hour (70 knots) indicated. By the way, none of the manuals for the earlier Travel Airs, models 95 through D95A, cite the single-engine minimum control speed.

FAA V_{MC} Demonstration

Multiengine pilots and those pursuing the rating are familiar with the procedures and pilot's performance requirements of FAA's V_{MC} demonstration. According to the FAA Airman Certification Standards, the objective for this maneuver is, "To determine that the applicant exhibits satisfactory knowledge, risk management, and skills associated with a V_{MC} demonstration." Unfortunately, exploring the V_{MC} regime puts the airplane and its occupants in an extremely dangerous corner of its flight envelope, one where the airplane can suddenly enter a single-engine asymmetric stall that can quickly progress into a flat spin.

With a few exceptions, any change in aircraft weight, c.g. location, and flight altitude results in V_{MC} occurring at an airspeed lower than what is listed in the flight manuals. However, the stall speed, actually the wing's critical angle of attack, is constant. For all practical purposes during a V_{MC} demonstration, the aircraft will be lighter than its gross weight if for no other reason than fuel burn-off for takeoff and climb to altitude. The demonstration flight's altitude will naturally be higher than sea level with the Baron POH recommending at least 5,000 feet AGL. The ACS altitude requirement is a minimum 3,000 feet AGL. With normally two or even possibly three on board, the aircraft's c.g. location will likely be somewhere forward of the aft limit.

Additionally, at altitude normally aspirated engines produce less than their maximum rated sea-level power. For example, at 6,500 feet MSL (5,500 feet AGL in my area) the normally aspirated IO-470L engines in my B55 can produce a maximum of slightly over 75 percent power. Given these differences in aircraft configuration for the actual demonstration, in the vast majority of flight conditions where the pilot increases pitch to slow the aircraft into the V_{MC} effect, the wing with the idling engine will reach its critical angle of attack and stall before the loss of directional control occurs, thus leading to a single-engine asymmetric stall.

Unfortunately, the Baron POH does not give us any numbers for V_{MC}/V_{S1} relationships for anything other than the worst-case conditions. Even worse, the Travel Air Owners Manuals do not provide any V_{MC}/V_{S1} information at all. But all is not lost. *Section 10, Safety Information*, in the Baron POH has some tips on avoiding single-engine stalls, which I'll delve into later under the "Mitigating Flat Spins" heading in this article.

As to the few exceptions I mentioned earlier, the FAA's *Airplane Flying Handbook* states V_{MC} "may increase as much as three knots for every degree of bank angle less than 5°." And, if the airplane is overweight and/or exceeding its aft c.g. limit, V_{MC} will also increase.

As an example of what was very likely a V_{MC} demonstration that developed into a stall/flat spin, and which was quite possibly aggravated by airframe icing and turbulence aloft, let's look at this Accident Investigation *Preliminary* Report of a flat spin crash that occurred during a multiengine training flight in a B55 in January of this year (NTSB Accident Number ERA24FA088):

On January 14, 2024, at 1125 eastern standard time, a Beechcraft 95-B-55 airplane, N7345R, was substantially damaged when it impacted terrain near Leyden, Massachusetts. The flight instructor, commercial pilot, and the passenger were fatally injured. The airplane was operated as a Title 14 Code of Federal Regulations Part 91 instructional flight.

A preliminary review of Automatic Dependent Surveillance–Broadcast (ADS-B) radar data revealed that the airplane departed runway 20 at Westfield-Barnes Regional Airport (BAF), Westfield/Springfield, Massachusetts, about 1106. After departure, the airplane made a 180- degree left turn toward the north-northeast. The airplane then climbed to about 3,000 to 3,300 ft mean sea level (msl) and made four alternating 360-degree turns while continuing to fly northbound. After the fourth 360-degree turn, the airplane began to climb, reaching an altitude of about 4,000 ft msl. The airplane then entered a rapid descent until data ended at 1125.

The airplane was not receiving any air traffic control services during the flight and there were no recorded radio communications.

The airplane impacted terrain located in the Leyden Wildlife Management Area. The wreckage came to rest in a clearing on a hill facing a magnetic heading of about 260 degrees. All major components of the airplane were located at the accident site and there was no postimpact fire. The disposition of the wreckage was consistent with the airplane landing in a relatively flat position with little forward movement. Both wings, along with their respective engines and propeller systems, remained attached to the fuselage. The right wing impacted a tree about mid-span. The tail section was partially separated from the empennage but remained attached via control cables. The fuselage was compressed and crushed downward. Airframe icing was observed on the leading edge of both wings and horizontal stabilizers, both engine nacelles, and the leading edge of the rudder. Ice was also observed on the front face of one of the left engine's propeller blades, and on the nav antenna located on the vertical stabilizer.

Weather reported at Orange Municipal Airport (ORE), Orange, Massachusetts, about 12 miles east of the accident site, at 1152, was reported as wind from 220 degrees at 11 knots gusting to 23 knots, visibility 10 miles, broken clouds at 4,600 ft, a temperature of 2 degrees C, a dewpoint of -7 C, and a barometric pressure setting of 29.68.

The accident occurred during a training flight with the flight school owner as the third occupant in one of the aft seats.

However, not all single-engine stall/flat spin accidents occurred during training for a V_{MC} demonstration. When flying at a very low airspeed, such as during a takeoff or even in the landing approach, failure or shutdown of one engine can be enough to initiate a stall

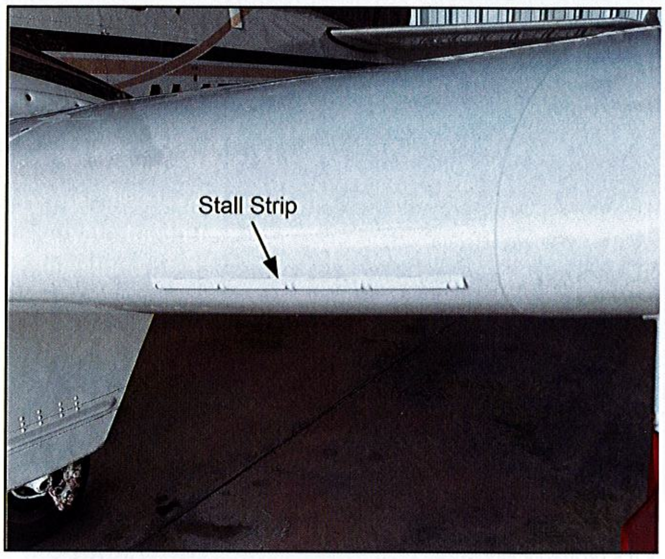


Figure 3: Baron stall strip on left wing

of the associated wing resulting a V_{MC} rollover, a flat spin if enough altitude exists, and a crash. The fatal results of an engine failure and V_{MC} rollover during takeoff have been and continue to be widely documented. As an example of a V_{MC} flat spin that occurred in flight, I cite the following excerpts from the Accident Investigation Final Report of a Baron 58 flat spin crash in April 2019 (NTSB Accident Number CEN19FA124):

> The pilot was conducting an instrument flight rules (IFR) flight in a twin-engine airplane with five passengers. During a GPS approach to the destination airport, both engines lost total power within 10 seconds of each other; the left engine regained near full power about 40 seconds later, which it maintained until the end of recorded data. As the pilot continued the approach, he did not ensure the flaps were up or feather the propeller of the inoperative right engine, which was contrary to the airplane manufacturer's emergency procedures guidance.
>
> As the airplane descended with the right engine inoperative below the cloud ceiling to about 500 ft agl, its flightpath leveled and airspeed decreased below the minimum controllable airspeed (V_{MC}). The airplane's continued flight profile below V_{MC} with the unfeathered propeller of the inoperative right engine, the left engine near full power, and the airplane's aft center of gravity resulted in a right-turning [upright or flat] spin and ground impact.
>
> In summary, multiple errors before takeoff led to a loss of engine power due to fuel exhaustion. The pilot did not accurately record the amount of fuel added after fueling, the pilot did not verify the amount of fuel onboard the airplane, the fuel quantity transmitters did not accurately indicate the amount of fuel onboard, and the pilot decided to take off with inadequate fuel to conduct the IFR flight in an overweight airplane. Lastly, during the flight, once the right engine lost power, the pilot failed to properly configure the airplane per the manufacturer's emergency procedures guidance and allowed the airspeed to drop below the point at which the airplane could maintain flight.

Single-Engine Stall and Flat Spin Entry

To quote the U.S. Army's 1974 report on its investigation of the T-42A single-engine performance and stall,

> The stall characteristics with single-engine power-on are considerably more severe than those for symmetrical power conditions. Single-engine power-on stall is characterized by a rapid roll toward the inoperative (dead) engine. If not immediately arrested, this roll progresses rapidly into a wing-over or split-S entry into an upright spin. Vigorous and immediate recovery action is required.

Before I get into the Baron's and Travel Air's behavior in a single-engine stall, the B95A through E95 Travel Air Owner's Manuals lists the both-engines power-on and power off stall speeds. For example, the D95A stalls power-on at 53 knots (61 miles per hour) and power-off at 73.3 Knots (85 miles per hour—a 20-knot difference). Although the weight and power of the later Barons are higher than the E95, the wingspan and airfoil are the same (except for longer flap chord length on the later Travel Airs and early Barons) giving a similar spread in stall speeds. It's easy to see a situation approaching the critical angle of attack with asymmetric-power, the wing with the dead engine is going to stall much sooner than the wing with the power-producing engine.

I note here that the Baron and Travel Air wings have a spanwise twist or washout that puts the tip at a lower angle of incidence than the root. This means that at the critical angle of attack, the area of the wing near the tip will still generate lift while a portion of the wing towards the root stalls. However, the aerodynamic nature of a tapered wing is unfriendly stall propagation. At the onset of a stall, initial boundary layer separation occurs at the wing's trailing edge more or less mid-way between the fuselage and the tip and as the stall deepens, propagates in both directions along the wingspan as well as forward. Making matters worse for a single-engine stall with a failed left engine, Barons have a stall strip midway out on the left wing, outside of the propeller arc (**Figure 3**). When approaching a normal stall with *symmetric power* (both engines at the same power setting), this stall strip induces a narrow boundary layer separation mid-wing at less than the critical angle of attack for a more predictable and controllable stall maneuver.

Now let's take a look at the aerodynamics of the single-engine stall in Barons. **Figure 4** shows the airflows and force vectors at the wings' critical angle of attack with zero sideslip. (See the Zero Sideslip sidebar.) For this discussion, the airplane is assumed to be at a safe altitude with the airplane's forward airspeed as the relative wind velocity. The right engine is producing its maximum available thrust with the left engine's propeller windmilling.

The high-airspeed propeller blast from the right engine is along the wing's chord line at what is essentially a zero angle of attack. Given the tip washout and the much higher relative wind flowing over wing root, the right wing provides normal lift. But on the left wing, its relative wind velocity over the wing root is much lower at the airplane's current airspeed and its pitch is at the critical angle of attack with the stall-aggravating aileron deflection employed to maintain up to 5 degrees of bank angle. Boundary layer separation occurs with the resultant loss of lift and the wing falls, dramatically increasing the angle of attack to where the wing becomes fully stalled.

With the full available thrust and lift on the right wing and neither on the left wing, the airplane violently rolls and yaws toward the dead engine (left in this case) engine, rapidly going inverted with the nose down. Given the weight and center of mass consisting of the engines, propellers, and fuel on each wing that are well outside of the center of the fuselage, the angular momentum (also called the rotational momentum) around the airplane's c.g. almost instantly comes into play with the airplane's resultant horizontal rotation impossible to overcome. An aft c.g. increases the rotational momentum.

The Army's recovery action in its report of 1974 best explains the dynamics of an asymmetric stall and V_{MC} rollover along with the necessary recovery actions to avoid a flat spin:

> **Instantaneous Recovery Action.** When recovery was initiated immediately at stall, a rapid forward movement of the elevator control normally arrested the roll rate and regained control of the aircraft. Full rudder control opposite to the direction of roll was normally already applied since stall occurs below V_{MC}. If full rudder had not been previously initiated, it was applied concurrently with the forward elevator control. If these combined actions did not arrest the roll rate, power was reduced on the operative (good) engine. Recovery was normally from a large bank angle (approaching 90 degrees), nose-down attitude, which results in a steep, diving pullout. Rapidly increasing airspeed during the pullout exceeded the airframe limits for the landing gear and flaps requiring these items to be retracted. Extreme care was necessary during the pullout to avoid a high-speed, accelerated stall.
>
> **Delay Recovery Action (one second delay).** When any delay in recovery action was allowed at full stall, the roll rate increased rapidly. Virtually full forward movement of the elevator control and complete power reduction on the operative engine was required for recovery. Recovery following a slight delay (1/4 to 1/2 second) was from a split-S or complete wing-over maneuver. With slightly longer delays (approximately one second) the wing-over progresses immediately into an upright spin. The considerations discussed above concerning rapidly building airspeed and avoidance of a high-speed, accelerated stall likewise apply for the delayed recovery.

Figure 4: Airflow at the onset of the V_{MC} demonstration stall

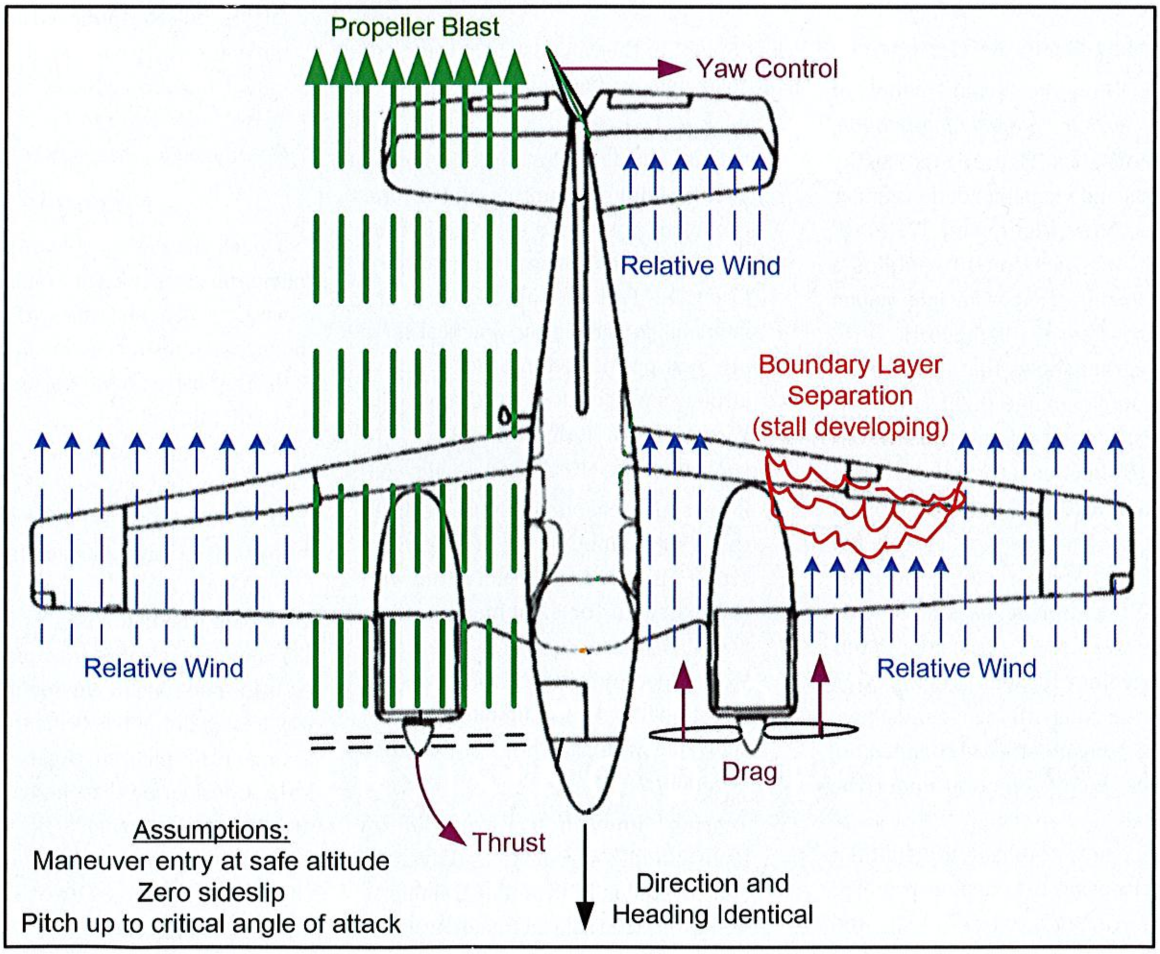
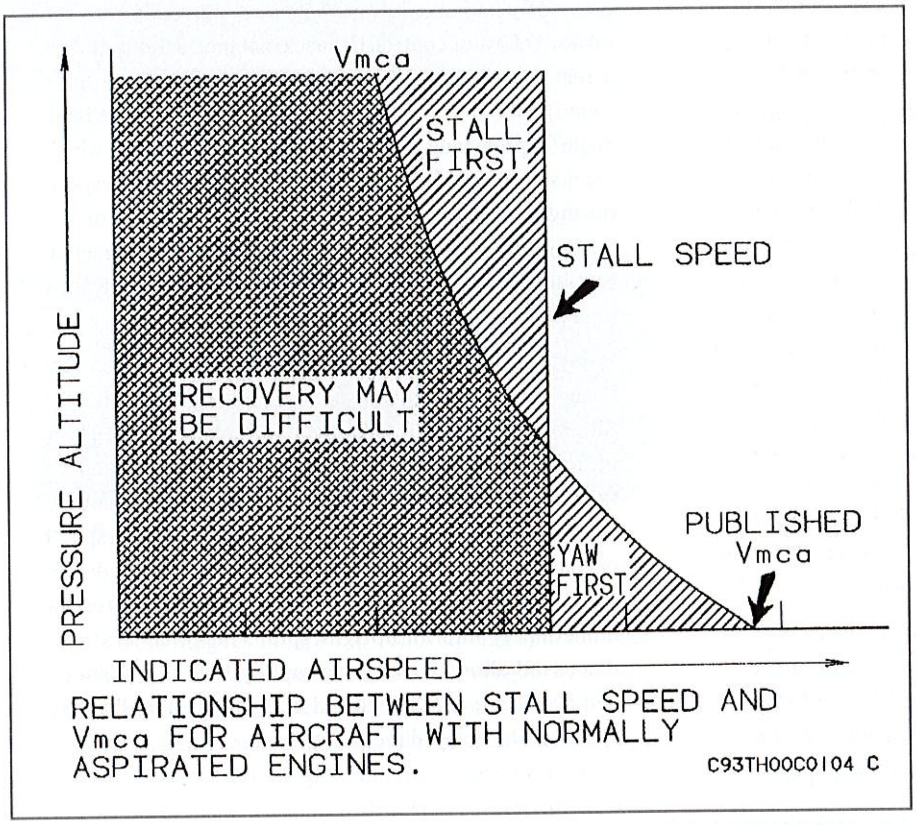


Figure 5: Stall and V_{MC} relationship



"...in actual or simulated single-engine flight, a narrow range of airspeed and altitude combinations exists where directional control with up to full rudder deflection is possible."

Stall/Flat Spin Mitigation

In the POH for the various models of the Baron, *Section 10, Safety Information*, includes the diagram (**Figure 5**) and lengthy explanations and recommendations under the "Stalls, Slow flight, and Training" heading. In fact, Section 10 contains a surprising amount of important information published nowhere else in the POH.

This diagram shows that in actual or simulated single-engine flight, a narrow range of airspeed and altitude combinations exists where directional control with up to full rudder deflection is possible. In most combinations of airspeed and altitude the wing will reach its critical angle of attack and stall before the airplane loses directional control. For an excellent explanation of this diagram, see Tom Turner's article "V_{MCA} vs. V_S" in the June 2014 issue, available on the ABS website at *www.bonanza.org* in the Issue Archive section under the Magazine tab.

So, how can we mitigate the stall/flat spin danger during V_{MC} demonstrations? From Tom Turner's article "V_{MC} and Flat Spins" in the January 2020 issue are the following recommendations:

1. Recognize that the V_{MC} maneuver, though vital to the understanding and training of multiengine pilots, cannot be conducted safely in Barons and Travel Airs using the standard Practical Test techniques. Primary multiengine training and Practical Tests are best performed in other types of airplanes with a wider margin between V_{MC} and V_{SI}, stall speed in a clean configuration, at least for this maneuver.
2. If for some reason you must perform the V_{MC} maneuver in a Baron or Travel Air, coordinate beforehand with the instructor or examiner to affirm you will initiate recovery upon reaching V_{SSE} speed, first indication of loss of directional control, or first indication of stall (stall warning or buffet), whichever occurs first.
3. Testing done in a Baron 58 by Embry-Riddle Aeronautical University and covered in BPPP online training as well as the ABS Flight Instructor Academy revealed that maintaining wings level and slip/skid ball-centered flight during a V_{MC} maneuver (as opposed to zero sideslip bank and rudder input) can increase the speed at which the V_{MC} effect occurs by as much as 15 knots. Close attention to non-standard aileron and rudder use in the V_{MC} maneuver can increase the margin for safety, although it does not follow the technique expected during FAA Practical Tests.
4. Instructors limiting rudder travel by blocking a rudder pedal with a foot is a time-honored workaround to try to cause loss of directional control to occur at a higher indicated airspeed and therefore further away from a stall. There is no direct guidance in the amount of rudder travel restriction to be applied under specific conditions, however.

Epilog

I performed V_{MC} demonstrations in training for my multiengine rating, initially in a Twin Comanche and later in a Seneca II with the practical test occurring in the Seneca. Both of my instructors and also the examiner blocked the rudder pedal for the V_{MC} demonstration. Additionally, I have done V_{MC} demonstrations several times during flight reviews in a rented Baron 58 during my Skymaster days and later in my B55. But I was never comfortable even though the instructor, who flew a Baron 58 in her Part 135 operation, blocked the rudder pedal.

In the non-training environment, the best way to stay out of trouble is to not fly into a corner of the flight envelope where trouble lurks. Considering that the basic cause of an airplane entering a flat spin is an asymmetric-power stall, without the stall the airplane cannot enter a flat spin.