Review
and
Recommendations for Improvement
of

Airplane Flying Handbook FAA-H-8083-3A

Bridging the gap between experimental flight-test and regular flight operations

Avio*Consult*

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INTRODUCTION

Quite frequently, all around the globe, small and big multi-engine airplanes crash due to the loss of control following a propulsion system malfunction or while an engine is inoperative. During the past 25 years, more than 300 of such accidents were reported by western countries on the Internet during which more than 3,100 people lost their lives. These accidents occurred despite the fact that all multi-engine airplanes are well designed, thoroughly flight-tested and certified, after which operating limitations are published in airplane flight and performance manuals for pilots to be able to continue to operate safely, including following the malfunction of a propulsion system. After reviewing many accident investigation reports, Avio*Consult*, having a strong experimental flight-test background, noticed that the minimum control speed in the air (V_{MC}/V_{MCA}) was not used by (airline) pilots in a way that was anticipated by the airplane design engineers and the experimental test pilots who conducted the flight-testing to determine V_{MCA}. The conditions that are required for the published V_{MCA} to be valid were obviously neither known to the mishap pilots, nor to the accident investigators, nor to the certifying staff, while reviewing and approving Airplane Flight Manuals/ Pilot Operating Handbooks (AFM/POH). The list of reviewed accidents is available on the downloads page of the website of Avio*Consult*.
To explain the real value of V_{MCA}, Avio*Consult* wrote several papers on the subject of airplane control after engine failure from 1999 on.

Airplane manufacturers and authors of all kinds of (course) books on the controllability and performance of multi-engine airplanes, including the authors of *Airplane Flying Handbook, FAA-H-8083-3A, Chapter 12* (ref. 1), copied paragraphs/ sections out of FAR 23 (ref. 5) into their publications (including AFM/POH), while these regulatory paragraphs are for the design and certification of an airplane, not for their operational use. The copied paragraphs/ sections of FAR 23 should have been modified before presenting them to pilots.
Chapter 12 contains information and guidance on the performance of certain maneuvers and procedures in small multiengine airplanes for the purposes of flight training and pilot certification testing. Much of the guidance however, is not in agreement with Advisory Circular 23-8C (the FAA Flight Test Guide (ref. 6)), the airplane design methods that are taught at Aeronautical Universities (ref. 8) and with Test Pilot School flying qualities training manual (ref. 10).

Avio*Consult* presents this review to bridge the obviously existing knowledge gap between experimental flight-test and regular flight operations and help prevent all accidents after engine failure in the future. Please consider this review, the explanation and recommendations for improvement as a cooperative effort for increasing flight safety.
In this review, a limited number of imperfections and deficiencies that were found in FAA-H-8083-3A Chapter 12 are discussed and explained; recommendations for improvement are presented.

The author of this review, Harry Horlings, is a retired Lt-Col of the Royal Netherlands Air Force, graduate Flight Test Engineer of the USAF Test Pilot School, Edwards Air Force Base, California, USA (Dec. 1985) and experienced private pilot. Following retirement after a career of 15 years in (experimental) flight-testing, of which the last 5 years as chief experimental flight-test, he founded Avio*Consult* and dedicated himself to improving the safety of aviation using his knowledge of experimental flight-testing.

The results of the review of Chapter 12, including brief explanations, are presented page by page. Please refer to the referenced papers to learn almost all there is to know about the subject, or ask Avio*Consult* by e-mail. If feasible, reference is also made to the FAA Flight Test Guide, Advisory Circular 23-8C (ref. 6).

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Chapter 12

Transition to Multiengine Airplanes

MULTIENGINE FLIGHT

This chapter is devoted to the factors associated with the operation of small multiengine airplanes. For the purpose of this handbook, a "small" multiengine airplane is a reciprocating or turbopropeller-powered airplane with a maximum certificated takeoff weight of 12,500 pounds or less. This discussion assumes a conventional design with two engines—one mounted on each wing. Reciprocating engines are assumed unless otherwise noted. The term "light-twin," although not formally defined in the regulations, is used herein as a small multiengine airplane with a maximum certificated takeoff weight of 6,000 pounds or less.

There are several unique characteristics of multiengine airplanes that make them worthy of a separate class rating. Knowledge of these factors and proficient flight skills are a key to safe flight in these airplanes. This chapter deals extensively with the numerous aspects of one engine inoperative (OEI) flight. However, pilots are strongly cautioned not to place undue emphasis on mastery of OEI flight as the sole key to flying multiengine airplanes safely. The inoperative engine information that follows is extensive only because this chapter emphasizes the differences between flying multiengine airplanes as contrasted to single-engine airplanes.

The modern, well-equipped multiengine airplane can be remarkably capable under many circumstances. But, as with single-engine airplanes, it must be flown prudently by a current and competent pilot to achieve the highest possible level of safety.

This chapter contains information and guidance on the performance of certain maneuvers and procedures in small multiengine airplanes for the purposes of flight training and pilot certification testing. The final authority on the operation of a particular make and model airplane, however, is the airplane manufacturer. Both the flight instructor and the student should be aware that if any of the guidance in this handbook conflicts with the airplane manufacturer's recommended procedures and guidance as contained in the FAA-approved Airplane Flight Manual and/or Pilot's Operating Handbook (AFM/POH), it is the airplane manufacturer's guidance and procedures that take precedence.

GENERAL

The basic difference between operating a multiengine airplane and a single-engine airplane is the potential problem involving an engine failure. The penalties for loss of an engine are twofold: performance and control. The most obvious problem is the loss of 50 percent of power, which reduces climb performance 80 to 90 percent, sometimes even more. The other is the control problem caused by the remaining thrust, which is now asymmetrical. Attention to both these factors is crucial to safe OEI flight. The performance and systems redundancy of a multiengine airplane is a safety advantage only to a trained and proficient pilot.

TERMS AND DEFINITIONS

Pilots of single-engine airplanes are already familiar with many performance "V" speeds and their definitions. Twin-engine airplanes have several additional V speeds unique to OEI operation. These speeds are differentiated by the notation "$_{SE}$", for single engine. A review of some key V speeds and several new V speeds unique to twin-engine airplanes follows.

- V_R – Rotation speed. The speed at which back pressure is applied to rotate the airplane to a takeoff attitude.
- V_{LOF} – Lift-off speed. The speed at which the airplane leaves the surface. (Note: some manufacturers reference takeoff performance data to V_R, others to V_{LOF}.)
- V_X – Best angle of climb speed. The speed at which the airplane will gain the greatest altitude for a given distance of forward travel.
- V_{XSE} – Best angle-of-climb speed with one engine inoperative.
- V_Y – Best rate of climb speed. The speed at which the airplane will gain the most altitude for a given unit of time.
- V_{YSE} – Best rate-of-climb speed with one engine inoperative. Marked with a blue radial line on most airspeed indicators. Above the single-engine absolute ceiling, V_{YSE} yields the minimum rate of sink.
- V_{SSE} – Safe, intentional one-engine-inoperative speed. Originally known as safe single-engine

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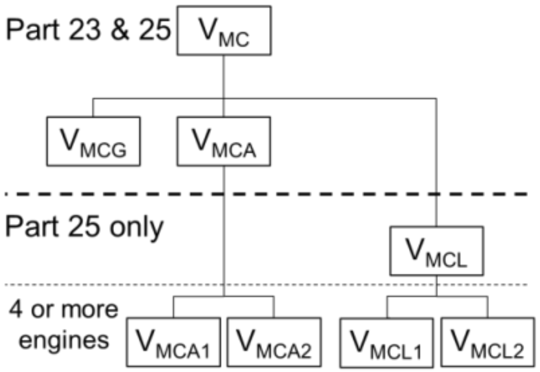
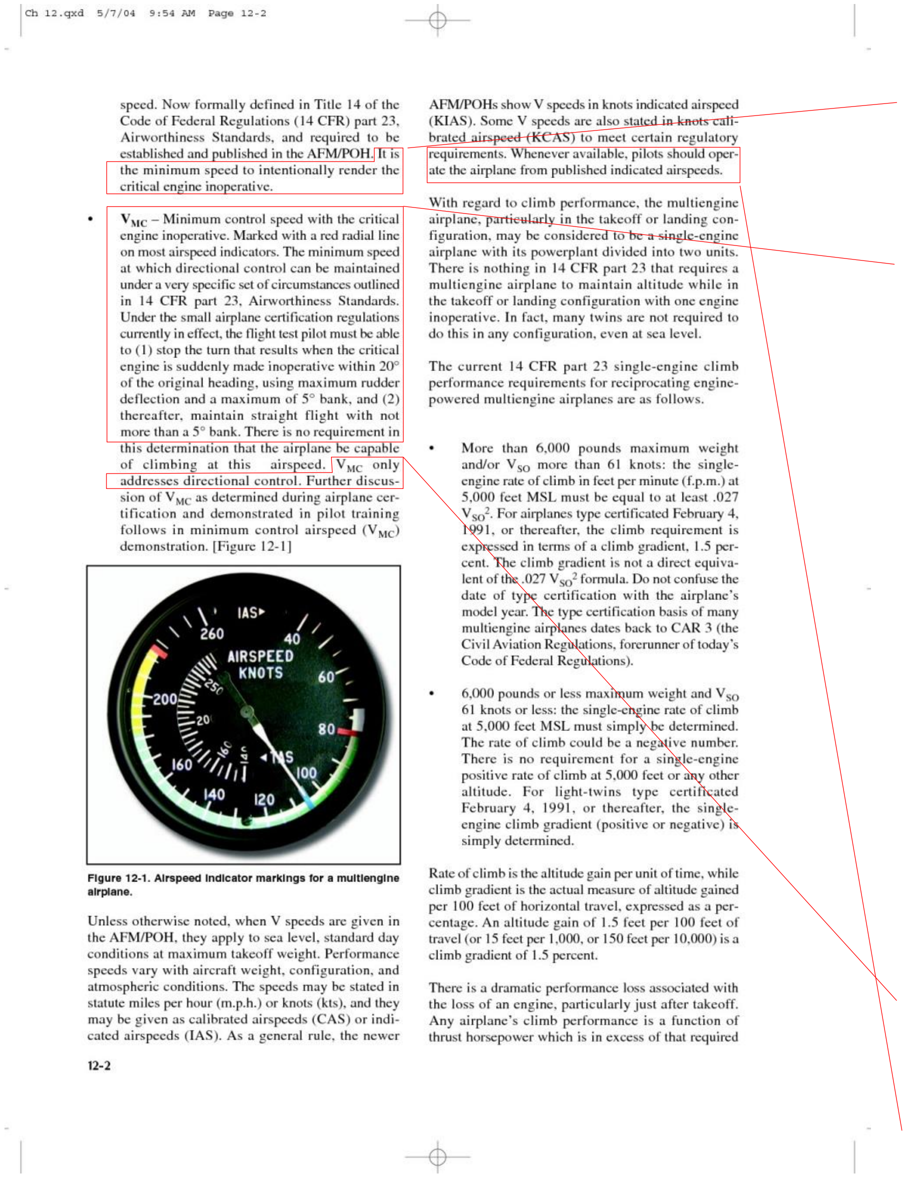
V_{MC} as used in this Chapter is defined on the next page; it is the minimum control speed marked on the airspeed indicator. V_{MC} is often used as the minimum control speed for the takeoff configuration, but a minimum control speed also applies during the remainder of the flight. Experimental test pilots and flight-test engineers always use minimum control speed airborne – V_{MCA}, rather than V_{MC}, because there are seven types of V_{MC} defined in civil and military aviation regulations, as shown in the figure below. There are even two more types of V_{MCA} that are not shown: the dynamic V_{MCA} – the minimum speed to recover after a sudden failure – and a static V_{MCA} that applies following the recovery during the remainder of the flight, including during the final turn for landing (ref. 2, § 6.1 and quotes out of the FAA Flight Test Guide (FTG) below). Furthermore, V_{MCA} might change with the configuration (gear, flaps, in- and out of ground effect, etc.). The red radial line on the airspeed indicator (shown on the next page) shows the highest V_{MCA} (dynamic or static) normally expected in service, not V_{MCG} or V_{MCL}; refer to the FTG (ref. 6, page 70 § 4a and page 73 § 8). Therefore, it is recommended to change V_{MC} into V_{MCA} in this Chapter.



Quotes out of FTG AC 23-8C (ref. 6) page 73:

> (6) *Static Minimum Control Speed.* The test pilot should select test altitude based on the capability to develop takeoff power and consistent with safe practices. It will be necessary to determine which engine is critical to the V_{MC} maneuver by conducting static tests with first one then the other engine inoperative to discover which one produces the higher V_{MC}. Power should be set to the maximum available for the ambient condition. If possible, test weights should be light enough to identify the limits of directional control without stalling or being in pre-stall buffet…
>
> (8) *Dynamic Minimum Control Speed*. After determining the critical engine static V_{MC}, and at some speed above static V_{MC}, make a series of engine cuts (using the mixture control or idle cutoff control) dynamically while gradually working speed back toward the static speed. While maintaining this speed after a dynamic engine cut, the pilot should be able to control the airplane and maintain straight flight without reducing power on the operating engine. During recovery, the airplane should not assume any dangerous attitude nor should the heading change more than 20 degrees when a pilot responds to the critical engine failure with normal skill, strength, and alertness…



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speed. Now formally defined in Title 14 of the Code of Federal Regulations (14 CFR) part 23, Airworthiness Standards, and required to be established and published in the AFM/POH. It is the minimum speed to intentionally render the critical engine inoperative.

- **V_{MC}** – Minimum control speed with the critical engine inoperative. Marked with a red radial line on most airspeed indicators. The minimum speed at which directional control can be maintained under a very specific set of circumstances outlined in 14 CFR part 23, Airworthiness Standards. Under the small airplane certification regulations currently in effect, the flight test pilot must be able to (1) stop the turn that results when the critical engine is suddenly made inoperative within 20° of the original heading, using maximum rudder deflection and a maximum of 5° bank, and (2) thereafter, maintain straight flight with not more than a 5° bank. There is no requirement in this determination that the airplane be capable of climbing at this airspeed. V_{MC} only addresses directional control. Further discussion of V_{MC} as determined during airplane certification and demonstrated in pilot training follows in minimum control airspeed (V_{MC}) demonstration. [Figure 12-1]

Figure 12-1. Airspeed indicator markings for a multiengine airplane.

Unless otherwise noted, when V speeds are given in the AFM/POH, they apply to sea level, standard day conditions at maximum takeoff weight. Performance speeds vary with aircraft weight, configuration, and atmospheric conditions. The speeds may be stated in statute miles per hour (m.p.h.) or knots (kts), and they may be given as calibrated airspeeds (CAS) or indicated airspeeds (IAS). As a general rule, the newer AFM/POHs show V speeds in knots indicated airspeed (KIAS). Some V speeds are also stated in knots calibrated airspeed (KCAS) to meet certain regulatory requirements. Whenever available, pilots should operate the airplane from published indicated airspeeds.

With regard to climb performance, the multiengine airplane, particularly in the takeoff or landing configuration, may be considered to be a single-engine airplane with its powerplant divided into two units. There is nothing in 14 CFR part 23 that requires a multiengine airplane to maintain altitude while in the takeoff or landing configuration with one engine inoperative. In fact, many twins are not required to do this in any configuration, even at sea level.

The current 14 CFR part 23 single-engine climb performance requirements for reciprocating engine-powered multiengine airplanes are as follows.

- More than 6,000 pounds maximum weight and/or V_{SO} more than 61 knots: the single-engine rate of climb in feet per minute (f.p.m.) at 5,000 feet MSL must be equal to at least .027 V_{SO}^2. For airplanes type certificated February 4, 1991, or thereafter, the climb requirement is expressed in terms of a climb gradient, 1.5 percent. The climb gradient is not a direct equivalent of the .027 V_{SO}^2 formula. Do not confuse the date of type certification with the airplane's model year. The type certification basis of many multiengine airplanes dates back to CAR 3 (the Civil Aviation Regulations, forerunner of today's Code of Federal Regulations).

- 6,000 pounds or less maximum weight and V_{SO} 61 knots or less: the single-engine rate of climb at 5,000 feet MSL must simply be determined. The rate of climb could be a negative number. There is no requirement for a single-engine positive rate of climb at 5,000 feet or any other altitude. For light-twins type certificated February 4, 1991, or thereafter, the single-engine climb gradient (positive or negative) is simply determined.

Rate of climb is the altitude gain per unit of time, while climb gradient is the actual measure of altitude gained per 100 feet of horizontal travel, expressed as a percentage. An altitude gain of 1.5 feet per 100 feet of travel (or 15 feet per 1,000, or 150 feet per 10,000) is a climb gradient of 1.5 percent.

There is a dramatic performance loss associated with the loss of an engine, particularly just after takeoff. Any airplane's climb performance is a function of thrust horsepower which is in excess of that required

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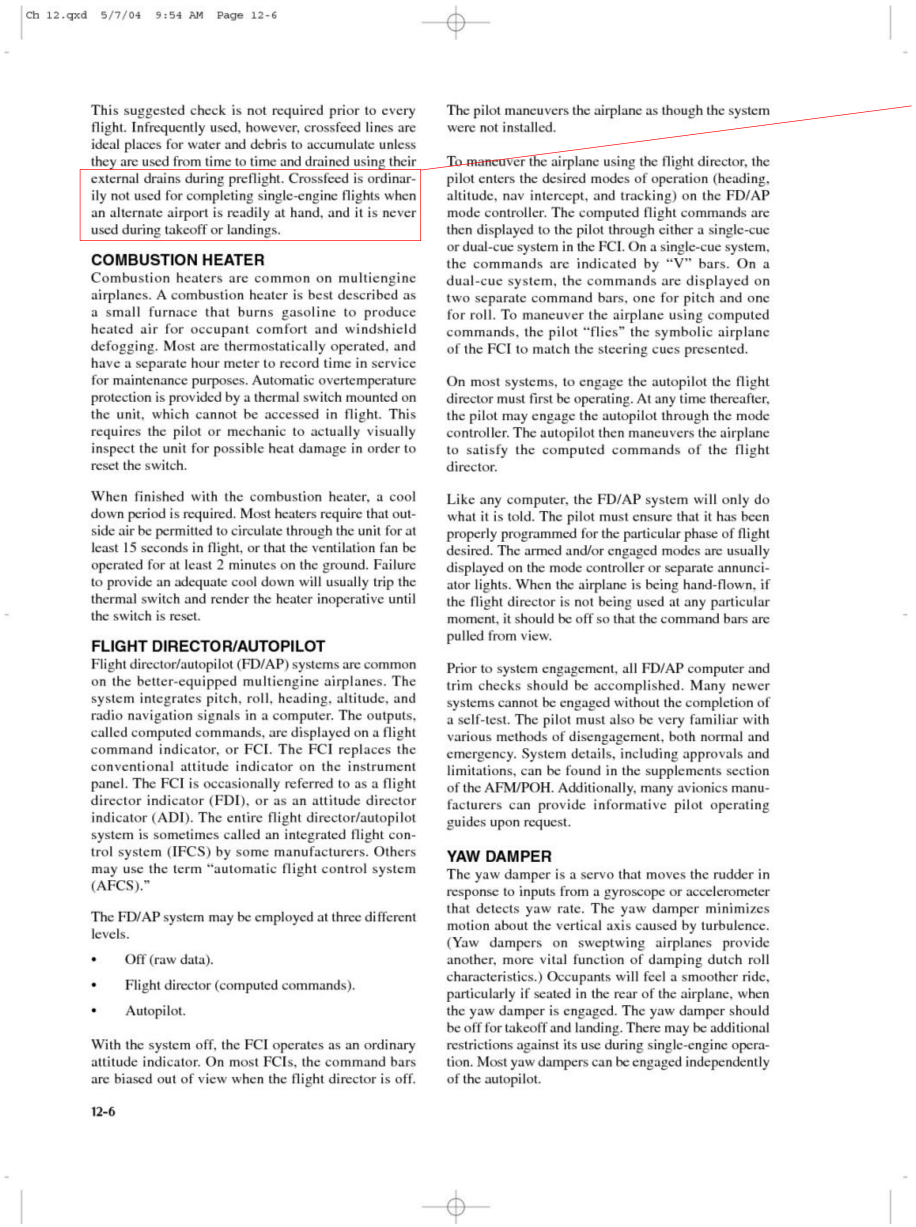
V_{YSE} and V_{XSE} (previous page) are defined for one engine inoperative, not only for the critical engine inoperative. V_{SSE} is higher than V_{XSE} and V_{YSE}. The criticality of an engine plays no role at this higher speed than V_{MCA}. Therefore, *critical engine* is used inappropriately here. V_{SSE} applies also to rendering any other engine than the critical engine inoperative, to avoid immediate loss of control due to asymmetrical power. It is recommended to change this sentence to "… intentionally decrease power on one of the engines".

Refer to the previous page for a few remarks on the use of V_{MC} and why it should be V_{MCA}. V_{MCA} is indeed measured with the critical engine inoperative i.a.w. FAR 23, ref. 5. Chapter 12 however, is for airline pilots, not for test pilots. For airline pilots, V_{MCA} is the minimum control speed when either engine fails or is inoperative, critical or not, in-board or outboard. V_{MCA} should represent the highest minimum control airspeed normally expected in service (FTG, ref. 6, page 70). There is only one V_{MCA}, like the checklists present only one engine emergency procedure. V_{MCA} is **not** the minimum speed at which *directional control* can be maintained, but V_{MCA} is only the minimum speed for maintaining **straight flight** while maintaining a small favorable bank angle (usually between 3 and maximum 5 degrees) away from the inoperative engine (ref. 5, FAR 23.149(a) and FTG ref. 6, page 71). Hence, V_{MCA} is not the minimum speed for maintaining directional control during turns or with other bank angles than the favorable bank angle! The *very specific set of circumstances* is also only for use by airplane design engineers for designing the required size of the vertical tail and for experimental test pilots for measuring V_{MCA} in-flight. The V_{MCA} presented in Flight Manuals and on the airspeed indicator is a worst-case V_{MCA}, and is safe for any value of any of the variables that have influence on V_{MCA} (cg, weight, propeller, etc.). A pilot will never experience a V_{MCA} higher than the indicated V_{MCA}, provided the favorable bank angle is being maintained (= straight flight) and the rudder is deflected far enough to stop the yawing, i.e. to maintain the heading.

The requirement for the flight test pilot during determining the dynamic V_{MCA} (1) is not *maximum 5°*, which would be impossible to achieve considering a standard reaction time after a sudden failure; normally maximum 45° bank is used. In addition, no dangerous attitudes should occur and no exceptional piloting skill should be required. *(2) thereafter, maintain straight flight with not more than 5° bank* concerns the static V_{MCA} that applies to the remainder of the flight. Experimental test pilots (quote FTG on previous page) also determine this static V_{MCA}. For airline pilots however, the bank angle limitation should definitely not be presented here as a bank angle of not more than 5°, but airline pilots should maintain the exact bank angle that was used to size the vertical tail and to determine V_{MCA}, for this V_{MCA} to be valid, because V_{MCA} varies significantly with bank angle (as is also mentioned on page 12-29). There may be no requirement to climb, but the remaining performance is max. when a small bank angle is being maintained, depending on the airspeed.

V_{MCA} does not address *directional control*; V_{MCA} addresses maintaining straight flight only (while banking with a fixed bank angle of between 3° and 5° away from the inoperative engine, as opted by the manufacturer), as described above. V_{MCA} is the calibrated airspeed at which the sideslip is zero, hence the drag minimum in the worst case airplane configuration and while maintaining the small bank angle that the design engineer used to size the fin.

Airspeeds in an AFM/POH can only be CAS, because the AFM/POH writers cannot know the instrument errors of the individual airspeed indicators (ASI) that are installed in the airplane (IAS = CAS + position error + instrument error). The sum of the two errors may not exceed 3% or 5 kt, whichever is greater (ref. 5 § 23.1323 and ref. 6 § 23.1323). If an AFM/POH lists IAS, it cannot be accurate.



This suggested check is not required prior to every flight. Infrequently used, however, crossfeed lines are ideal places for water and debris to accumulate unless they are used from time to time and drained using their external drains during preflight. Crossfeed is ordinarily not used for completing single-engine flights when an alternate airport is readily at hand, and it is never used during takeoff or landings.

COMBUSTION HEATER

Combustion heaters are common on multiengine airplanes. A combustion heater is best described as a small furnace that burns gasoline to produce heated air for occupant comfort and windshield defogging. Most are thermostatically operated, and have a separate hour meter to record time in service for maintenance purposes. Automatic overtemperature protection is provided by a thermal switch mounted on the unit, which cannot be accessed in flight. This requires the pilot or mechanic to actually visually inspect the unit for possible heat damage in order to reset the switch.

When finished with the combustion heater, a cool down period is required. Most heaters require that outside air be permitted to circulate through the unit for at least 15 seconds in flight, or that the ventilation fan be operated for at least 2 minutes on the ground. Failure to provide an adequate cool down will usually trip the thermal switch and render the heater inoperative until the switch is reset.

FLIGHT DIRECTOR/AUTOPILOT

Flight director/autopilot (FD/AP) systems are common on the better-equipped multiengine airplanes. The system integrates pitch, roll, heading, altitude, and radio navigation signals in a computer. The outputs, called computed commands, are displayed on a flight command indicator, or FCI. The FCI replaces the conventional attitude indicator on the instrument panel. The FCI is occasionally referred to as a flight director indicator (FDI), or as an attitude director indicator (ADI). The entire flight director/autopilot system is sometimes called an integrated flight control system (IFCS) by some manufacturers. Others may use the term "automatic flight control system (AFCS)."

The FD/AP system may be employed at three different levels.

- Off (raw data).
- Flight director (computed commands).
- Autopilot.

With the system off, the FCI operates as an ordinary attitude indicator. On most FCIs, the command bars are biased out of view when the flight director is off. The pilot maneuvers the airplane as though the system were not installed.

To maneuver the airplane using the flight director, the pilot enters the desired modes of operation (heading, altitude, nav intercept, and tracking) on the FD/AP mode controller. The computed flight commands are then displayed to the pilot through either a single-cue or dual-cue system in the FCI. On a single-cue system, the commands are indicated by "V" bars. On a dual-cue system, the commands are displayed on two separate command bars, one for pitch and one for roll. To maneuver the airplane using computed commands, the pilot "flies" the symbolic airplane of the FCI to match the steering cues presented.

On most systems, to engage the autopilot the flight director must first be operating. At any time thereafter, the pilot may engage the autopilot through the mode controller. The autopilot then maneuvers the airplane to satisfy the computed commands of the flight director.

Like any computer, the FD/AP system will only do what it is told. The pilot must ensure that it has been properly programmed for the particular phase of flight desired. The armed and/or engaged modes are usually displayed on the mode controller or separate annunciator lights. When the airplane is being hand-flown, if the flight director is not being used at any particular moment, it should be off so that the command bars are pulled from view.

Prior to system engagement, all FD/AP computer and trim checks should be accomplished. Many newer systems cannot be engaged without the completion of a self-test. The pilot must also be very familiar with various methods of disengagement, both normal and emergency. System details, including approvals and limitations, can be found in the supplements section of the AFM/POH. Additionally, many avionics manufacturers can provide informative pilot operating guides upon request.

YAW DAMPER

The yaw damper is a servo that moves the rudder in response to inputs from a gyroscope or accelerometer that detects yaw rate. The yaw damper minimizes motion about the vertical axis caused by turbulence. (Yaw dampers on sweptwing airplanes provide another, more vital function of damping dutch roll characteristics.) Occupants will feel a smoother ride, particularly if seated in the rear of the airplane, when the yaw damper is engaged. The yaw damper should be off for takeoff and landing. There may be additional restrictions against its use during single-engine operation. Most yaw dampers can be engaged independently of the autopilot.

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On longer flights while OEI though, the lateral cg should be moved into the good engine' side by transferring or cross feeding fuel, in order to reduce the asymmetrical thrust yawing moment and therewith reduce actual V_{MCA}.

Actual V_{MCA} is the V_{MCA} that the pilot experiences in-flight with the actual values of all variables that have influence on V_{MCA}, like bank angle, propeller, cg, weight, thrust, etc. Actual V_{MCA} might be lower than the standardized, AFM/POH published V_{MCA} or (a lot) higher. Please refer to ref. 2.

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ALTERNATOR/GENERATOR

Alternator or generator paralleling circuitry matches the output of each engine's alternator/generator so that the electrical system load is shared equally between them. In the event of an alternator/generator failure, the inoperative unit can be isolated and the entire electrical system powered from the remaining one. Depending upon the electrical capacity of the alternator/generator, the pilot may need to reduce the electrical load (referred to as load shedding) when operating on a single unit. The AFM/POH will contain system description and limitations.

NOSE BAGGAGE COMPARTMENT

Nose baggage compartments are common on multiengine airplanes (and are even found on a few single-engine airplanes). There is nothing strange or exotic about a nose baggage compartment, and the usual guidance concerning observation of load limits applies. They are mentioned here in that pilots occasionally neglect to secure the latches properly, and therein lies the danger. When improperly secured, the door will open and the contents may be drawn out, usually into the propeller arc, and usually just after takeoff. Even when the nose baggage compartment is empty, airplanes have been lost when the pilot became distracted by the open door. Security of the nose baggage compartment latches and locks is a vital preflight item.

Most airplanes will continue to fly with a nose baggage door open. There may be some buffeting from the disturbed airflow and there will be an increase in noise. Pilots should never become so preoccupied with an open door (of any kind) that they fail to fly the airplane.

Inspection of the compartment interior is also an important preflight item. More than one pilot has been surprised to find a supposedly empty compartment packed to capacity or loaded with ballast. The tow bars, engine inlet covers, windshield sun screens, oil containers, spare chocks, and miscellaneous small hand tools that find their way into baggage compartments should be secured to prevent damage from shifting in flight.

ANTI-ICING/DEICING

Anti-icing/deicing equipment is frequently installed on multiengine airplanes and consists of a combination of different systems. These may be classified as either anti-icing or deicing, depending upon function. The presence of anti-icing and deicing equipment, even though it may appear elaborate and complete, does not necessarily mean that the airplane is approved for flight in icing conditions. The AFM/POH, placards, and even the manufacturer should be consulted for specific determination of approvals and limitations.

Anti-icing equipment is provided to prevent ice from forming on certain protected surfaces. Anti-icing equipment includes heated pitot tubes, heated or non-icing static ports and fuel vents, propeller blades with electrothermal boots or alcohol slingers, windshields with alcohol spray or electrical resistance heating, windshield defoggers, and heated stall warning lift detectors. On many turboprop engines, the "lip" surrounding the air intake is heated either electrically or with bleed air. In the absence of AFM/POH guidance to the contrary, anti-icing equipment is actuated prior to flight into known or suspected icing conditions.

Deicing equipment is generally limited to pneumatic boots on wing and tail leading edges. Deicing equipment is installed to remove ice that has already formed on protected surfaces. Upon pilot actuation, the boots inflate with air from the pneumatic pumps to break off accumulated ice. After a few seconds of inflation, they are deflated back to their normal position with the assistance of a vacuum. The pilot monitors the buildup of ice and cycles the boots as directed in the AFM/POH. An ice light on the left engine nacelle allows the pilot to monitor wing ice accumulation at night.

Other airframe equipment necessary for flight in icing conditions includes an alternate induction air source and an alternate static system source. Ice tolerant antennas will also be installed.

In the event of impact ice accumulating over normal engine air induction sources, carburetor heat (carbureted engines) or alternate air (fuel injected engines) should be selected. Ice buildup on normal induction sources can be detected by a loss of engine r.p.m. with fixed-pitch propellers and a loss of manifold pressure with constant-speed propellers. On some fuel injected engines, an alternate air source is automatically activated with blockage of the normal air source.

An alternate static system provides an alternate source of static air for the pitot-static system in the unlikely event that the primary static source becomes blocked. In non-pressurized airplanes, most alternate static sources are plumbed to the cabin. On pressurized airplanes, they are usually plumbed to a non-pressurized baggage compartment. The pilot must activate the alternate static source by opening a valve or a fitting in the cockpit. Upon activation, the airspeed indicator, altimeter, and the vertical speed indicator (VSI) will be affected and will read somewhat in error. A correction table is frequently provided in the AFM/POH.

Anti-icing/deicing equipment only eliminates ice from the protected surfaces. Significant ice accumulations may form on unprotected areas, even with proper use of anti-ice and deice systems. Flight at high angles of

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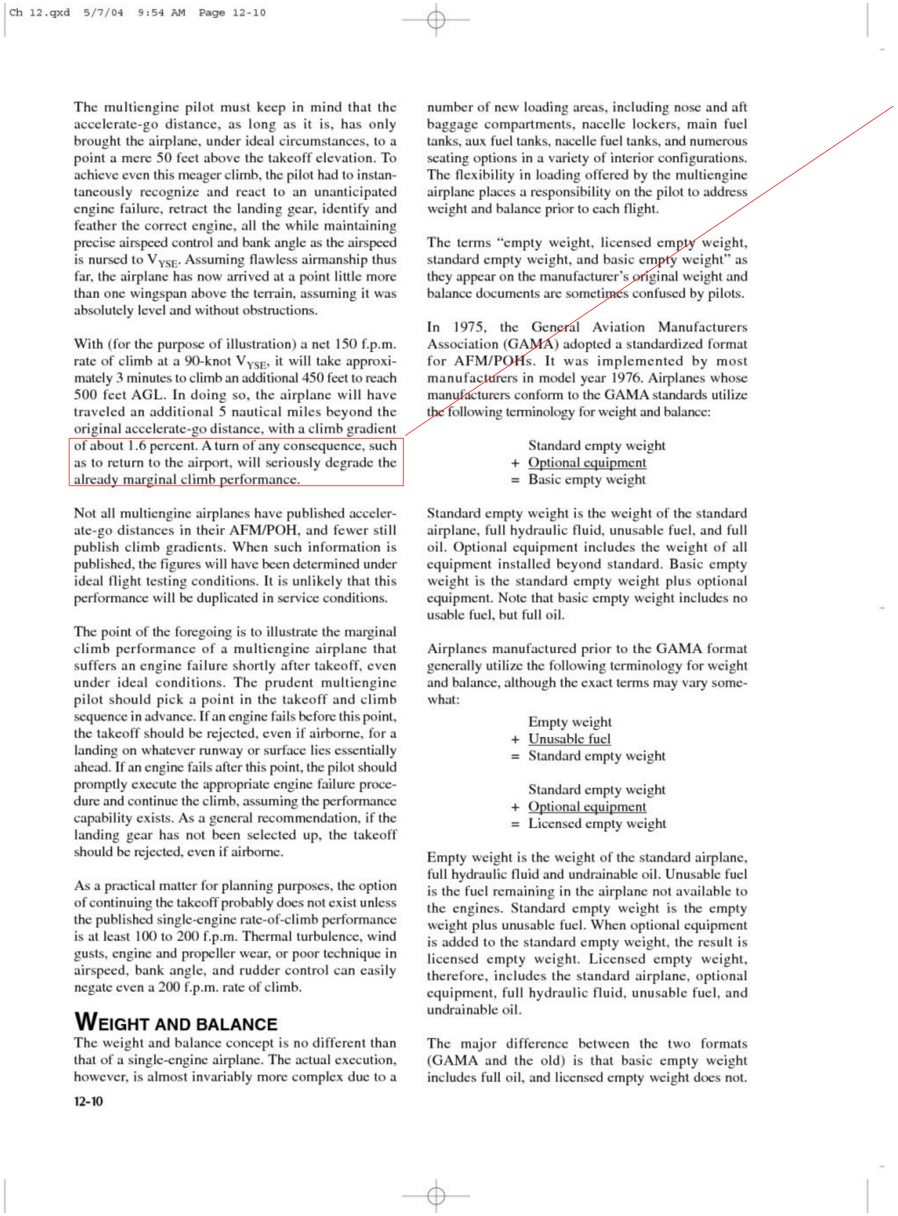
The asymmetrical drag influences the yawing moments, hence actual V_{MCA} and the remaining performance.



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The multiengine pilot must keep in mind that the accelerate-go distance, as long as it is, has only brought the airplane, under ideal circumstances, to a point a mere 50 feet above the takeoff elevation. To achieve even this meager climb, the pilot had to instantaneously recognize and react to an unanticipated engine failure, retract the landing gear, identify and feather the correct engine, all the while maintaining precise airspeed control and bank angle as the airspeed is nursed to V_{YSE}. Assuming flawless airmanship thus far, the airplane has now arrived at a point little more than one wingspan above the terrain, assuming it was absolutely level and without obstructions.

With (for the purpose of illustration) a net 150 f.p.m. rate of climb at a 90-knot V_{YSE}, it will take approximately 3 minutes to climb an additional 450 feet to reach 500 feet AGL. In doing so, the airplane will have traveled an additional 5 nautical miles beyond the original accelerate-go distance, with a climb gradient of about 1.6 percent. A turn of any consequence, such as to return to the airport, will seriously degrade the already marginal climb performance.

Not all multiengine airplanes have published accelerate-go distances in their AFM/POH, and fewer still publish climb gradients. When such information is published, the figures will have been determined under ideal flight testing conditions. It is unlikely that this performance will be duplicated in service conditions.

The point of the foregoing is to illustrate the marginal climb performance of a multiengine airplane that suffers an engine failure shortly after takeoff, even under ideal conditions. The prudent multiengine pilot should pick a point in the takeoff and climb sequence in advance. If an engine fails before this point, the takeoff should be rejected, even if airborne, for a landing on whatever runway or surface lies essentially ahead. If an engine fails after this point, the pilot should promptly execute the appropriate engine failure procedure and continue the climb, assuming the performance capability exists. As a general recommendation, if the landing gear has not been selected up, the takeoff should be rejected, even if airborne.

As a practical matter for planning purposes, the option of continuing the takeoff probably does not exist unless the published single-engine rate-of-climb performance is at least 100 to 200 f.p.m. Thermal turbulence, wind gusts, engine and propeller wear, or poor technique in airspeed, bank angle, and rudder control can easily negate even a 200 f.p.m. rate of climb.

WEIGHT AND BALANCE

The weight and balance concept is no different than that of a single-engine airplane. The actual execution, however, is almost invariably more complex due to a number of new loading areas, including nose and aft baggage compartments, nacelle lockers, main fuel tanks, aux fuel tanks, nacelle fuel tanks, and numerous seating options in a variety of interior configurations. The flexibility in loading offered by the multiengine airplane places a responsibility on the pilot to address weight and balance prior to each flight.

The terms "empty weight, licensed empty weight, standard empty weight, and basic empty weight" as they appear on the manufacturer's original weight and balance documents are sometimes confused by pilots.

In 1975, the General Aviation Manufacturers Association (GAMA) adopted a standardized format for AFM/POHs. It was implemented by most manufacturers in model year 1976. Airplanes whose manufacturers conform to the GAMA standards utilize the following terminology for weight and balance:

Standard empty weight
\+ Optional equipment
= Basic empty weight

Standard empty weight is the weight of the standard airplane, full hydraulic fluid, unusable fuel, and full oil. Optional equipment includes the weight of all equipment installed beyond standard. Basic empty weight is the standard empty weight plus optional equipment. Note that basic empty weight includes no usable fuel, but full oil.

Airplanes manufactured prior to the GAMA format generally utilize the following terminology for weight and balance, although the exact terms may vary somewhat:

Empty weight
\+ Unusable fuel
= Standard empty weight

Standard empty weight
\+ Optional equipment
= Licensed empty weight

Empty weight is the weight of the standard airplane, full hydraulic fluid and undrainable oil. Unusable fuel is the fuel remaining in the airplane not available to the engines. Standard empty weight is the empty weight plus unusable fuel. When optional equipment is added to the standard empty weight, the result is licensed empty weight. Licensed empty weight, therefore, includes the standard airplane, optional equipment, full hydraulic fluid, unusable fuel, and undrainable oil.

The major difference between the two formats (GAMA and the old) is that basic empty weight includes full oil, and licensed empty weight does not.

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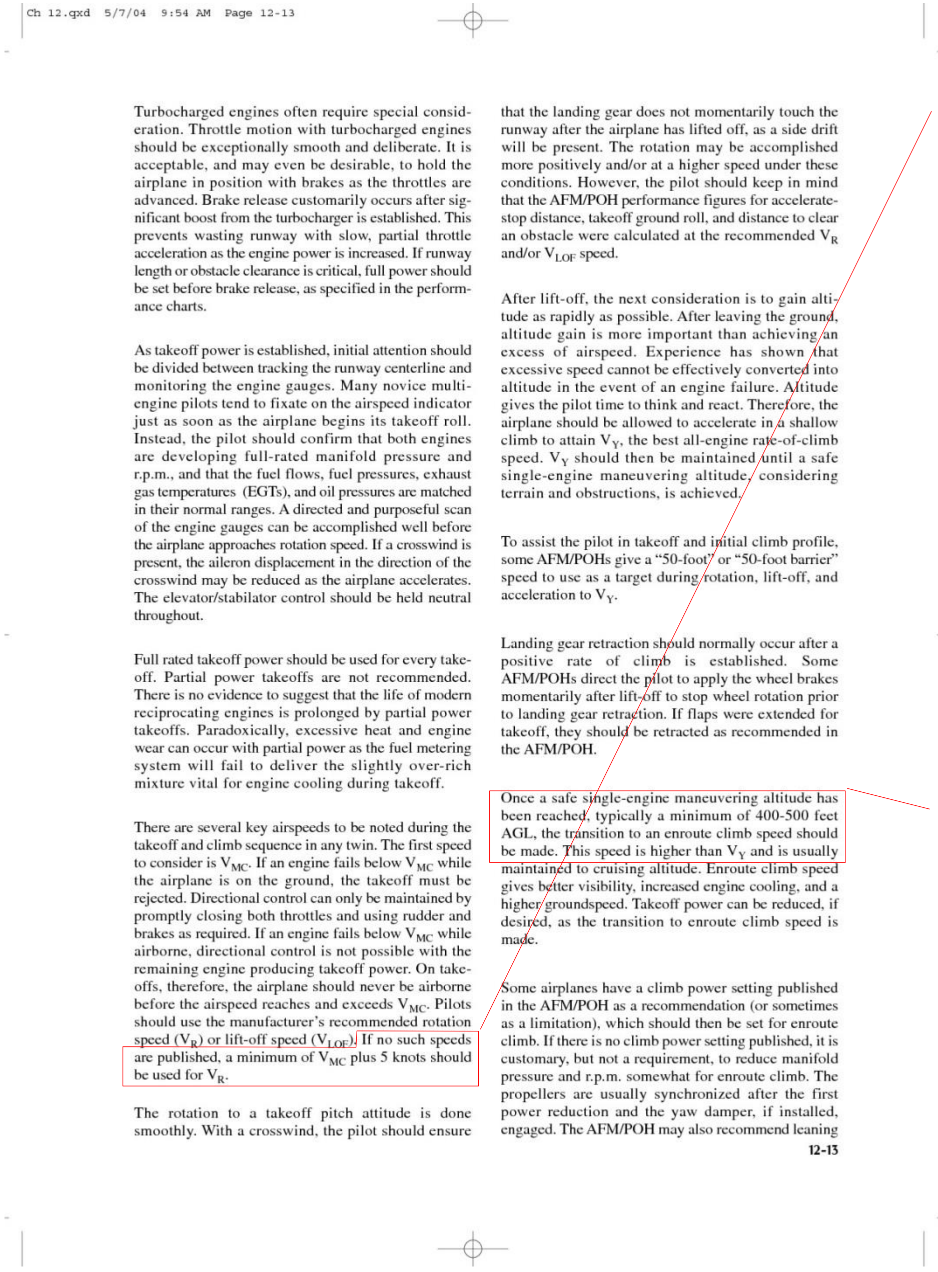
Good example, it shows that a very long straight climb-out might be required when the airplane is heavy, not only because a turn seriously degrades performance, but also because banking away from the favorable bank angle (usually 5 degrees at V_{MCA} and 2 – 3 degrees at V_{YSE}) increases actual V_{MCA} to a value much higher than the redlined, published V_{MCA} resulting in increased sideslip and drag and/ or in the loss of control.
It is recommended to add this control concern to this paragraph.



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Turbocharged engines often require special consideration. Throttle motion with turbocharged engines should be exceptionally smooth and deliberate. It is acceptable, and may even be desirable, to hold the airplane in position with brakes as the throttles are advanced. Brake release customarily occurs after significant boost from the turbocharger is established. This prevents wasting runway with slow, partial throttle acceleration as the engine power is increased. If runway length or obstacle clearance is critical, full power should be set before brake release, as specified in the performance charts.

As takeoff power is established, initial attention should be divided between tracking the runway centerline and monitoring the engine gauges. Many novice multiengine pilots tend to fixate on the airspeed indicator just as soon as the airplane begins its takeoff roll. Instead, the pilot should confirm that both engines are developing full-rated manifold pressure and r.p.m., and that the fuel flows, fuel pressures, exhaust gas temperatures (EGTs), and oil pressures are matched in their normal ranges. A directed and purposeful scan of the engine gauges can be accomplished well before the airplane approaches rotation speed. If a crosswind is present, the aileron displacement in the direction of the crosswind may be reduced as the airplane accelerates. The elevator/stabilator control should be held neutral throughout.

Full rated takeoff power should be used for every takeoff. Partial power takeoffs are not recommended. There is no evidence to suggest that the life of modern reciprocating engines is prolonged by partial power takeoffs. Paradoxically, excessive heat and engine wear can occur with partial power as the fuel metering system will fail to deliver the slightly over-rich mixture vital for engine cooling during takeoff.

There are several key airspeeds to be noted during the takeoff and climb sequence in any twin. The first speed to consider is V_{MC}. If an engine fails below V_{MC} while the airplane is on the ground, the takeoff must be rejected. Directional control can only be maintained by promptly closing both throttles and using rudder and brakes as required. If an engine fails below V_{MC} while airborne, directional control is not possible with the remaining engine producing takeoff power. On takeoffs, therefore, the airplane should never be airborne before the airspeed reaches and exceeds V_{MC}. Pilots should use the manufacturer's recommended rotation speed (V_R) or lift-off speed (V_{LOF}). If no such speeds are published, a minimum of V_{MC} plus 5 knots should be used for V_R.

The rotation to a takeoff pitch attitude is done smoothly. With a crosswind, the pilot should ensure that the landing gear does not momentarily touch the runway after the airplane has lifted off, as a side drift will be present. The rotation may be accomplished more positively and/or at a higher speed under these conditions. However, the pilot should keep in mind that the AFM/POH performance figures for accelerate-stop distance, takeoff ground roll, and distance to clear an obstacle were calculated at the recommended V_R and/or V_{LOF} speed.

After lift-off, the next consideration is to gain altitude as rapidly as possible. After leaving the ground, altitude gain is more important than achieving an excess of airspeed. Experience has shown that excessive speed cannot be effectively converted into altitude in the event of an engine failure. Altitude gives the pilot time to think and react. Therefore, the airplane should be allowed to accelerate in a shallow climb to attain V_Y, the best all-engine rate-of-climb speed. V_Y should then be maintained until a safe single-engine maneuvering altitude, considering terrain and obstructions, is achieved.

To assist the pilot in takeoff and initial climb profile, some AFM/POHs give a "50-foot" or "50-foot barrier" speed to use as a target during rotation, lift-off, and acceleration to V_Y.

Landing gear retraction should normally occur after a positive rate of climb is established. Some AFM/POHs direct the pilot to apply the wheel brakes momentarily after lift-off to stop wheel rotation prior to landing gear retraction. If flaps were extended for takeoff, they should be retracted as recommended in the AFM/POH.

Once a safe single-engine maneuvering altitude has been reached, typically a minimum of 400-500 feet AGL, the transition to an enroute climb speed should be made. This speed is higher than V_Y and is usually maintained to cruising altitude. Enroute climb speed gives better visibility, increased engine cooling, and a higher groundspeed. Takeoff power can be reduced, if desired, as the transition to enroute climb speed is made.

Some airplanes have a climb power setting published in the AFM/POH as a recommendation (or sometimes as a limitation), which should then be set for enroute climb. If there is no climb power setting published, it is customary, but not a requirement, to reduce manifold pressure and r.p.m. somewhat for enroute climb. The propellers are usually synchronized after the first power reduction and the yaw damper, if installed, engaged. The AFM/POH may also recommend leaning

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Even if such speeds are indeed published, the following applies. As stated on page 12-29, V_{MCA} might increase more than 3 kt for each degree of bank angle less than 5°. Hence, the actual V_{MCA} with the wings level (at rotation) might be 15 kt higher than the published V_{MCA}, if the other factors than bank angle that have influence on V_{MCA} happen to be at their worst-case value (low weight, aft cg, etc.). The V_{MCA} increase for small twins is 8 – 10 kt. The consequence of keeping the wings level during liftoff or go-around at an airspeed that is only 5 knots above the published V_{MCA} is that control will be lost at the instant the airplane gets airborne or immediately after the power lever is advanced to maximum takeoff setting during approach or go-around. Hence, a V_R of V_{MCA} + 5 kt is not safe for a small twin under all circumstances and should be increased to V_{MCA}+10+5 kt. Loss of control means that a maximum rudder control input or a pedal force of 150 lb, and/or a maximum aileron input, whichever occurs first, cannot maintain the heading or the required bank angle. The airplane will continue to yaw and/ or roll into the dead engine side. The resulting sideslip into the dead engine side decreases climb performance; the weathercock stability and loss of speed will start pointing the nose of the airplane down. A catastrophe cannot be avoided if the altitude is low, unless the actual V_{MCA} is quickly reduced below the indicated airspeed by reducing the thrust of the operating engine (temporarily) just a little, until the controls are effective again. There is not much time to do this though, so it should be standard procedure to attain and maintain 5 degrees (or the number of degrees that the manufacturer used for designing the vertical tail and/ or to measure V_{MCA} in-flight) away from the inoperative engine for as long as the power setting is high and the altitude and airspeed are both low. Thrust, bank angle and rudder input each have effect on the magnitude of actual V_{MCA} and are under direct control of the pilot (ref. 2, § 5.1, 5,3 and 5.4).
It is recommended to add 10 kt (increase of actual V_{MCA} for wings level of a small twin) plus a 5 kt safety margin, totaling up to 15 kt to the published V_{MCA} for rotation, unless the published V_{MCA} is the wings-level V_{MCA}; then adding 5 kt will be adequate.

The safe single-engine maneuvering altitude of 400 – 500 ft AGL is way too low, especially if the maximum asymmetrical thrust is maintained. During maneuvering, the sideslip increases and therewith the drag; altitude will be lost. Actual V_{MCA} increases during banking away from the favorable bank angle and might even increase above V_{YSE} (ref. 2, § 5.1). In general, if the actual V_{MCA} increases above the indicated airspeed, control will be lost.
The airspeed should be increased before maneuvering, if necessary by exchanging altitude for airspeed, to prevent the loss of control. The alternative is to reduce the thrust before maneuvering to decrease the asymmetrical thrust yawing moment (and therewith reduce actual V_{MCA}). Some altitude will be lost until straight flight is again attained and the thrust can be safely increased to maximum while banking the favorable bank angle away from the inoperative engine.

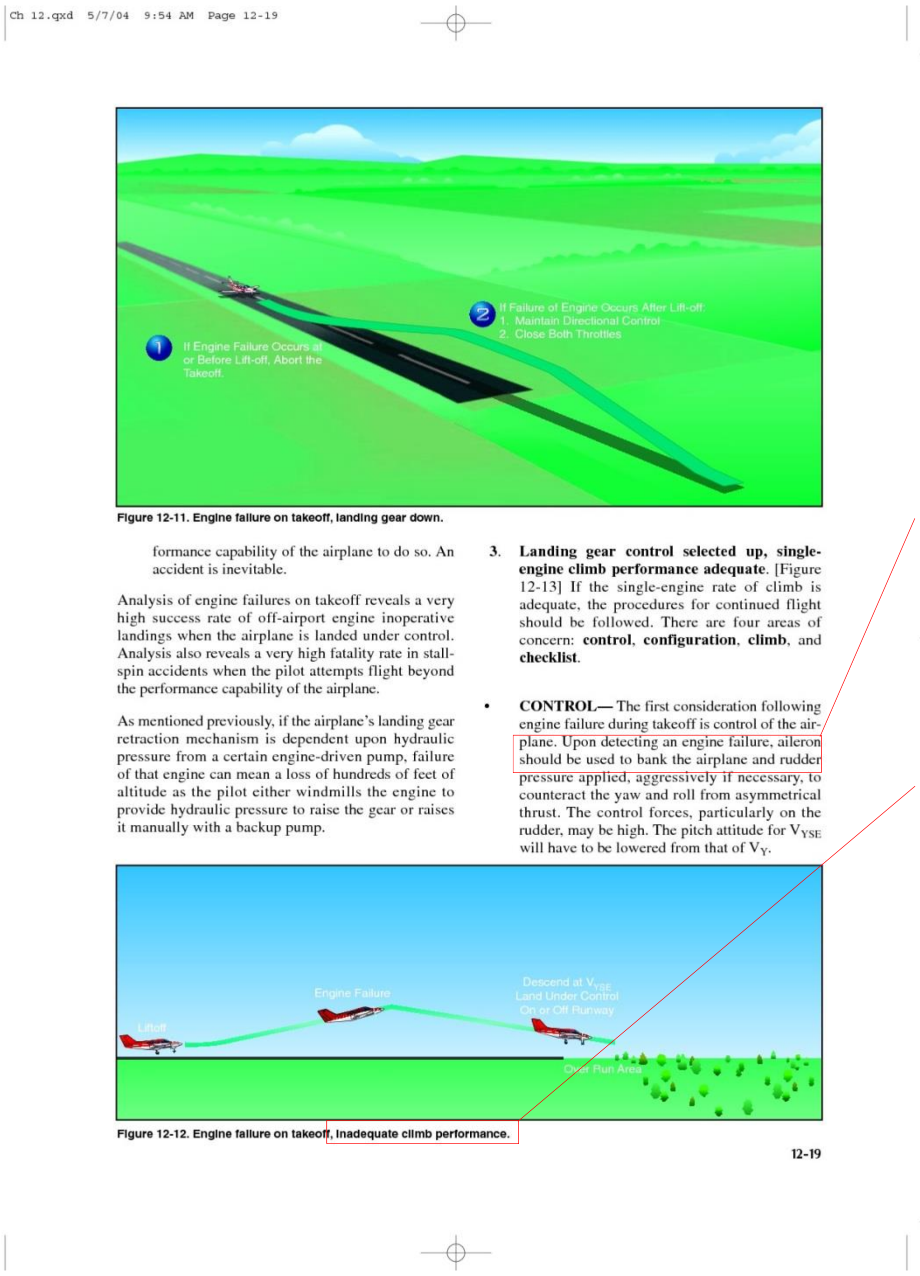

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Figure 12-11. Engine failure on takeoff, landing gear down.

formance capability of the airplane to do so. An accident is inevitable.

Analysis of engine failures on takeoff reveals a very high success rate of off-airport engine inoperative landings when the airplane is landed under control. Analysis also reveals a very high fatality rate in stall-spin accidents when the pilot attempts flight beyond the performance capability of the airplane.

As mentioned previously, if the airplane's landing gear retraction mechanism is dependent upon hydraulic pressure from a certain engine-driven pump, failure of that engine can mean a loss of hundreds of feet of altitude as the pilot either windmills the engine to provide hydraulic pressure to raise the gear or raises it manually with a backup pump.

3. **Landing gear control selected up, single-engine climb performance adequate**. [Figure 12-13] If the single-engine rate of climb is adequate, the procedures for continued flight should be followed. There are four areas of concern: **control**, **configuration**, **climb**, and **checklist**.

- **CONTROL**— The first consideration following engine failure during takeoff is control of the airplane. Upon detecting an engine failure, aileron should be used to bank the airplane and rudder pressure applied, aggressively if necessary, to counteract the yaw and roll from asymmetrical thrust. The control forces, particularly on the rudder, may be high. The pitch attitude for V_{YSE} will have to be lowered from that of V_Y.

Figure 12-12. Engine failure on takeoff, inadequate climb performance.

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Yawing after engine failure is usually observed before rolling. Apply rudder pressure immediately to avoid sideslip build-up.
It is recommended to add to … *used to bank the airplane*: 'to the specified bank angle (5° if the airspeed is V_{MCA}, 2° – 3° if the airspeed is V_{YSE}), away from the inoperative engine'.

If rudder is deflected to stop the yaw and the favorable bank angle of 5° away from the inoperative engine are applied quickly enough, there might still be some climb performance left. It is worth trying.

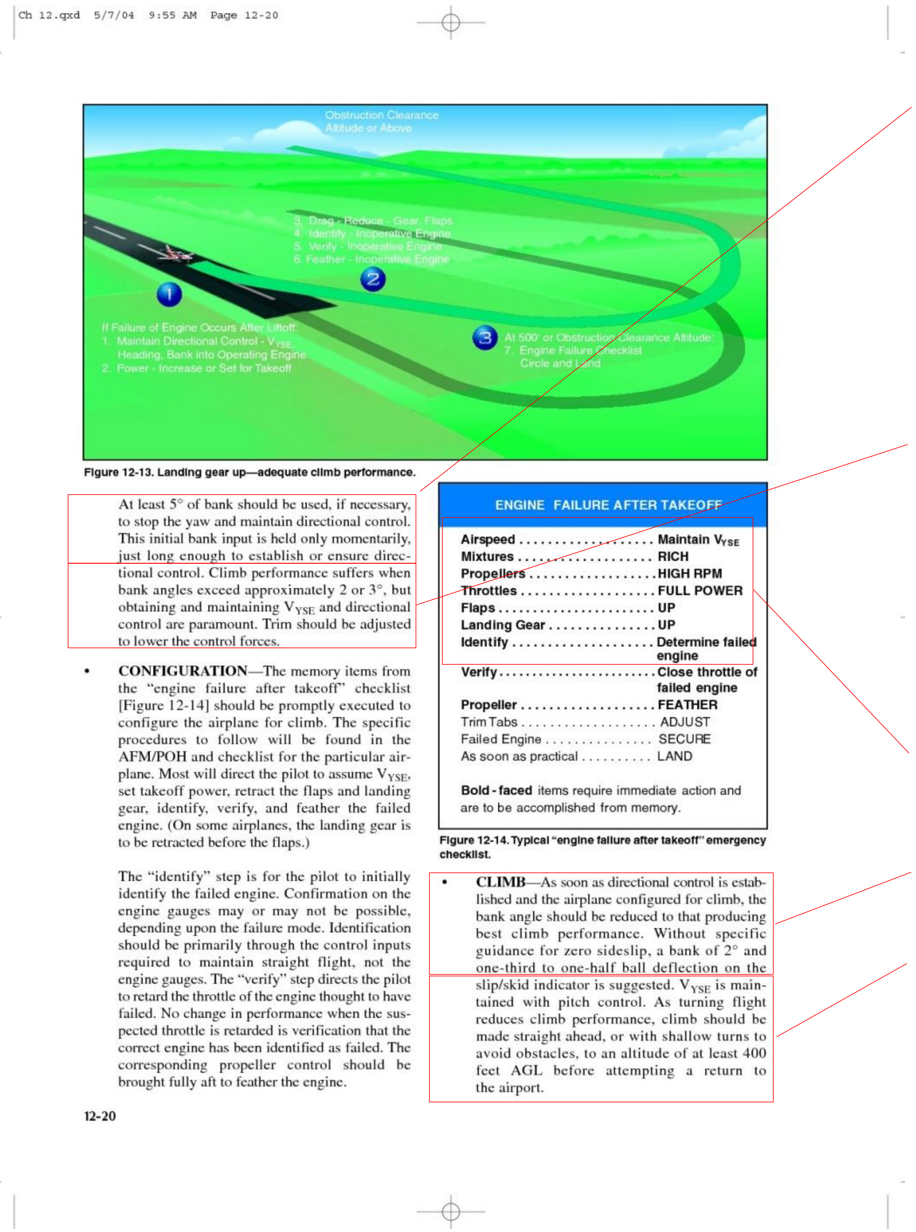

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Figure 12-13. Landing gear up—adequate climb performance.

At least 5° of bank should be used, if necessary, to stop the yaw and maintain directional control. This initial bank input is held only momentarily, just long enough to establish or ensure directional control. Climb performance suffers when bank angles exceed approximately 2 or 3°, but obtaining and maintaining V_{YSE} and directional control are paramount. Trim should be adjusted to lower the control forces.

- **CONFIGURATION**—The memory items from the "engine failure after takeoff" checklist [Figure 12-14] should be promptly executed to configure the airplane for climb. The specific procedures to follow will be found in the AFM/POH and checklist for the particular airplane. Most will direct the pilot to assume V_{YSE}, set takeoff power, retract the flaps and landing gear, identify, verify, and feather the failed engine. (On some airplanes, the landing gear is to be retracted before the flaps.)

The "identify" step is for the pilot to initially identify the failed engine. Confirmation on the engine gauges may or may not be possible, depending upon the failure mode. Identification should be primarily through the control inputs required to maintain straight flight, not the engine gauges. The "verify" step directs the pilot to retard the throttle of the engine thought to have failed. No change in performance when the suspected throttle is retarded is verification that the correct engine has been identified as failed. The corresponding propeller control should be brought fully aft to feather the engine.

ENGINE FAILURE AFTER TAKEOFF

Airspeed	**Maintain V_{YSE}**
Mixtures	**RICH**
Propellers	**HIGH RPM**
Throttles	**FULL POWER**
Flaps	**UP**
Landing Gear	**UP**
Identify	**Determine failed engine**
Verify	**Close throttle of failed engine**
Propeller	**FEATHER**
Trim Tabs	ADJUST
Failed Engine	SECURE
As soon as practical	LAND

Bold - faced items require immediate action and are to be accomplished from memory.

Figure 12-14. Typical "engine failure after takeoff" emergency checklist.

- **CLIMB**—As soon as directional control is established and the airplane configured for climb, the bank angle should be reduced to that producing best climb performance. Without specific guidance for zero sideslip, a bank of 2° and one-third to one-half ball deflection on the slip/skid indicator is suggested. V_{YSE} is maintained with pitch control. As turning flight reduces climb performance, climb should be made straight ahead, or with shallow turns to avoid obstacles, to an altitude of at least 400 feet AGL before attempting a return to the airport.

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As mentioned before, a bank angle of up to 45° might result, and is acceptable, following a sudden failure before the recovery controls by the pilot take effect; this is even allowed during the flight-test to determine the dynamic V_{MCA}. A bank angle, if large enough, might stop the yaw, but increases the drag significantly, which is definitely not recommended during takeoff. The rudder is the only aerodynamic control available to the pilot to stop the yaw and should therefore be used to counteract the asymmetrical thrust yawing moments, both after a sudden failure and during the remainder of the flight. Rudder deflection will always be required for keeping both the actual V_{MCA} and the sideslip angle (drag) low, i.e. for maintaining heading and for maximizing climb performance. Ailerons are for counteracting the propulsive lift of the wing section behind the operating propeller and the rolling moments due to sideslip and yawing. Up to maximum rudder might have to be used to stop the yaw and maintain heading, while attaining the favorable bank angle using the ailerons. *At least 5° of bank should be used* is therefore not correct.

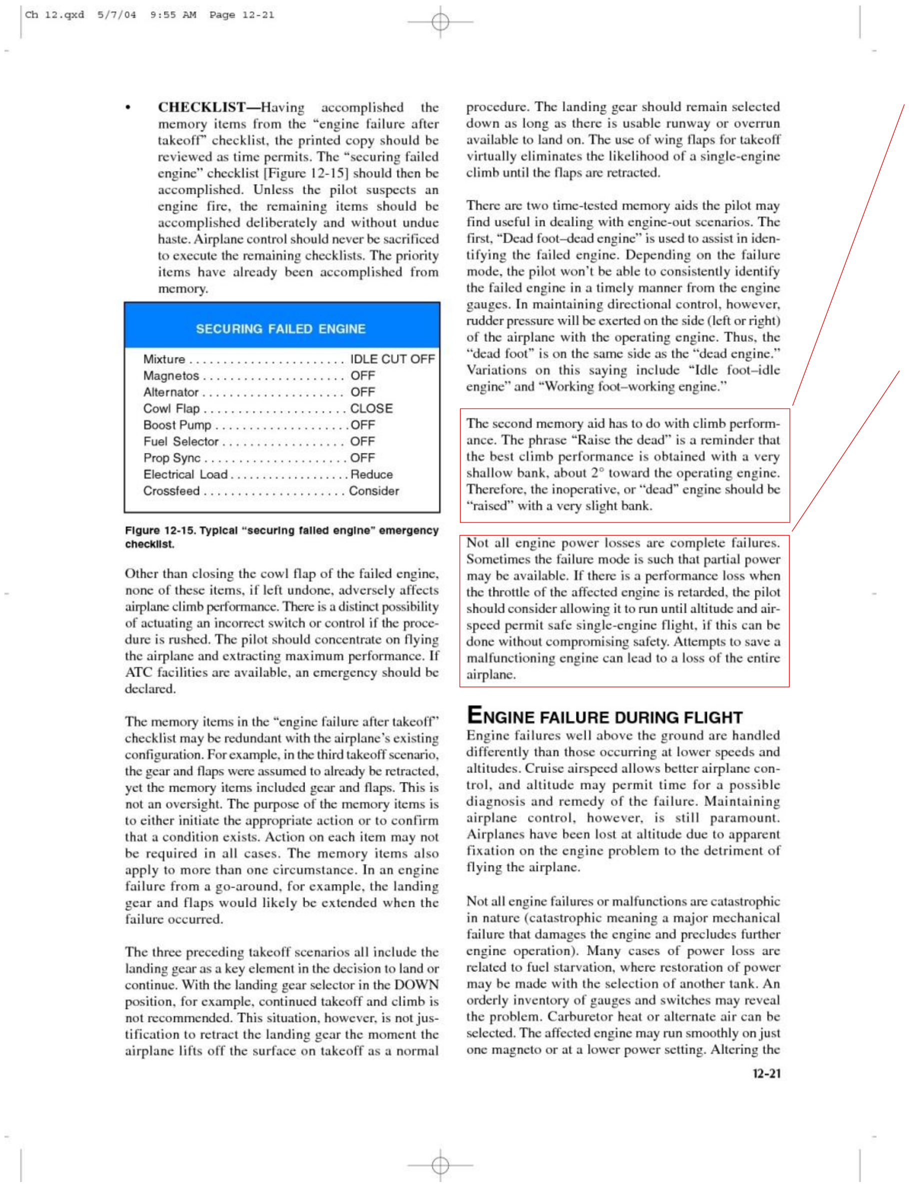
However, following recovery, not *at least 5 degrees should be used*, because at bank angles greater than 5° the sideslip angle increases resulting in a stall of the vertical fin! During flight with an inoperative engine at airspeeds down to V_{MCA}, the maximum bank angle should be 5° (or as opted by the manufacturer) while maintaining straight flight – if the thrust is maximal.
It is recommended to split this paragraph in recovery after a sudden failure and continuing the flight while an engine is inoperative.

The *suffering* of climb performance depends on bank angle and airspeed. If the airspeed is as low as V_{MCA}, the drag is minimal when the bank angle is 5 degrees away from the inoperative engine on most Part 23 airplanes. If the airspeed is V_{YSE}, the drag is minimal when the bank angle is 2 to 3 degrees.

The most important **bold-faced** steps for maintaining control after engine failure are missing here: Stop the yaw with rudder, bank 5 degrees away from the inoperative engine as soon as possible and maintain straight flight. Dead leg or foot – dead engine (page 12-21), or bank to the same side as the foot pressure.

OEI performance diagrams in the AFM/POH present the OEI climb data and the required bank angle and airspeed.

Turning flight not only reduces climb performance (because of increased sideslip/ drag), but also increases the actual V_{MCA} because the equilibrium of forces and moments that existed for straight flight is disturbed, requiring larger rudder deflection or a higher airspeed. A turn at 400 ft AGL while the thrust is maximal might increase actual V_{MCA} to a value higher than the actual airspeed (V_{YSE}) and reduce the climb performance to less than zero, refer to ref. 2, figures 14 and 25. Recommended is to maintain straight flight and climb to an altitude that permits altitude loss during turns at a thrust level less than maximum (to keep actual V_{MCA} low).
Turning at 400 ft AGL is not safe. Refer also to page 12-23 where is stated: *"losses of 500 ft or more are not unusual"*. To maintain safety, it is recommended to climb straight ahead to at least 1,000 ft AGL before turning 'shallow'.



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- **CHECKLIST**—Having accomplished the memory items from the "engine failure after takeoff" checklist, the printed copy should be reviewed as time permits. The "securing failed engine" checklist [Figure 12-15] should then be accomplished. Unless the pilot suspects an engine fire, the remaining items should be accomplished deliberately and without undue haste. Airplane control should never be sacrificed to execute the remaining checklists. The priority items have already been accomplished from memory.

SECURING FAILED ENGINE

Mixture . . . . IDLE CUT OFF
Magnetos . . . . OFF
Alternator . . . . OFF
Cowl Flap . . . . CLOSE
Boost Pump . . . . .OFF
Fuel Selector . . . . OFF
Prop Sync . . . . OFF
Electrical Load . . . . Reduce
Crossfeed . . . . Consider

Figure 12-15. Typical "securing failed engine" emergency checklist.

Other than closing the cowl flap of the failed engine, none of these items, if left undone, adversely affects airplane climb performance. There is a distinct possibility of actuating an incorrect switch or control if the procedure is rushed. The pilot should concentrate on flying the airplane and extracting maximum performance. If ATC facilities are available, an emergency should be declared.

The memory items in the "engine failure after takeoff" checklist may be redundant with the airplane's existing configuration. For example, in the third takeoff scenario, the gear and flaps were assumed to already be retracted, yet the memory items included gear and flaps. This is not an oversight. The purpose of the memory items is to either initiate the appropriate action or to confirm that a condition exists. Action on each item may not be required in all cases. The memory items also apply to more than one circumstance. In an engine failure from a go-around, for example, the landing gear and flaps would likely be extended when the failure occurred.

The three preceding takeoff scenarios all include the landing gear as a key element in the decision to land or continue. With the landing gear selector in the DOWN position, for example, continued takeoff and climb is not recommended. This situation, however, is not justification to retract the landing gear the moment the airplane lifts off the surface on takeoff as a normal procedure. The landing gear should remain selected down as long as there is usable runway or overrun available to land on. The use of wing flaps for takeoff virtually eliminates the likelihood of a single-engine climb until the flaps are retracted.

There are two time-tested memory aids the pilot may find useful in dealing with engine-out scenarios. The first, "Dead foot–dead engine" is used to assist in identifying the failed engine. Depending on the failure mode, the pilot won't be able to consistently identify the failed engine in a timely manner from the engine gauges. In maintaining directional control, however, rudder pressure will be exerted on the side (left or right) of the airplane with the operating engine. Thus, the "dead foot" is on the same side as the "dead engine." Variations on this saying include "Idle foot–idle engine" and "Working foot–working engine."

The second memory aid has to do with climb performance. The phrase "Raise the dead" is a reminder that the best climb performance is obtained with a very shallow bank, about 2° toward the operating engine. Therefore, the inoperative, or "dead" engine should be "raised" with a very slight bank.

Not all engine power losses are complete failures. Sometimes the failure mode is such that partial power may be available. If there is a performance loss when the throttle of the affected engine is retarded, the pilot should consider allowing it to run until altitude and airspeed permit safe single-engine flight, if this can be done without compromising safety. Attempts to save a malfunctioning engine can lead to a loss of the entire airplane.

ENGINE FAILURE DURING FLIGHT

Engine failures well above the ground are handled differently than those occurring at lower speeds and altitudes. Cruise airspeed allows better airplane control, and altitude may permit time for a possible diagnosis and remedy of the failure. Maintaining airplane control, however, is still paramount. Airplanes have been lost at altitude due to apparent fixation on the engine problem to the detriment of flying the airplane.

Not all engine failures or malfunctions are catastrophic in nature (catastrophic meaning a major mechanical failure that damages the engine and precludes further engine operation). Many cases of power loss are related to fuel starvation, where restoration of power may be made with the selection of another tank. An orderly inventory of gauges and switches may reveal the problem. Carburetor heat or alternate air can be selected. The affected engine may run smoothly on just one magneto or at a lower power setting. Altering the

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Good point, but raising the dead, i.e. banking a few degrees away from the failed engine (to the same side as the foot pressure), reduces actual V_{MCA} as well (ref. 2, § 5.1).
The number of degrees depends on the airspeed, though. If the airspeed is V_{MCA}, the bank angle (for lowest drag) will have to be 5 degrees on most airplanes; if the airspeed is V_{YSE}, the bank angle for lowest drag can be reduced to 2 – 3 degrees. This bank angle should be included in the legend of the one-engine inoperative climb performance charts in the AFM/POH.
Bank angle ties engine-out performance to controllability (ref. 8). It is recommended to add control to this paragraph.

It is recommended to add that leaving an engine running while its propeller is windmilling increases the asymmetrical drag, decreases performance and also increases the yawing moments and therewith increases actual V_{MCA} to a much higher value! When the malfunctioning engine does not contribute to the total power, consider shutting it down and feather the propeller to reduce its drag.
This recommendation also applies to the second paragraph on the next page.

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mixture may help. If fuel vapor formation is suspected, fuel boost pump operation may be used to eliminate flow and pressure fluctuations.

Although it is a natural desire among pilots to save an ailing engine with a precautionary shutdown, the engine should be left running if there is any doubt as to needing it for further safe flight. Catastrophic failure accompanied by heavy vibration, smoke, blistering paint, or large trails of oil, on the other hand, indicate a critical situation. The affected engine should be feathered and the "securing failed engine" checklist completed. The pilot should divert to the nearest suitable airport and declare an emergency with ATC for priority handling.

Fuel crossfeed is a method of getting fuel from a tank on one side of the airplane to an operating engine on the other. Crossfeed is used for extended single-engine operation. If a suitable airport is close at hand, there is no need to consider crossfeed. If prolonged flight on a single-engine is inevitable due to airport non-availability, then crossfeed allows use of fuel that would otherwise be unavailable to the operating engine. It also permits the pilot to balance the fuel consumption to avoid an out-of-balance wing heaviness.

AFM/POH procedures for crossfeed vary widely. Thorough fuel system knowledge is essential if crossfeed is to be conducted. Fuel selector positions and fuel boost pump usage for crossfeed differ greatly among multiengine airplanes. Prior to landing, crossfeed should be terminated and the operating engine returned to its main tank fuel supply.

If the airplane is above its single-engine absolute ceiling at the time of engine failure, it will slowly lose altitude. The pilot should maintain V_{YSE} to minimize the rate of altitude loss. This "drift down" rate will be greatest immediately following the failure and will decrease as the single-engine ceiling is approached. Due to performance variations caused by engine and propeller wear, turbulence, and pilot technique, the airplane may not maintain altitude even at its published single-engine ceiling. Any further rate of sink, however, would likely be modest.

An engine failure in a descent or other low power setting can be deceiving. The dramatic yaw and performance loss will be absent. At very low power settings, the pilot may not even be aware of a failure. If a failure is suspected, the pilot should advance both engine mixtures, propellers, and throttles significantly, to the takeoff settings if necessary, to correctly identify the failed engine. The power on the operative engine can always be reduced later.

ENGINE INOPERATIVE APPROACH AND LANDING

The approach and landing with one engine inoperative is essentially the same as a two-engine approach and landing. The traffic pattern should be flown at similar altitudes, airspeeds, and key positions as a two-engine approach. The differences will be the reduced power available and the fact that the remaining thrust is asymmetrical. A higher-than-normal power setting will be necessary on the operative engine.

With adequate airspeed and performance, the landing gear can still be extended on the downwind leg. In which case it should be confirmed DOWN no later than abeam the intended point of landing. Performance permitting, initial extension of wing flaps (10°, typically) and a descent from pattern altitude can also be initiated on the downwind leg. The airspeed should be no slower than V_{YSE}. The direction of the traffic pattern, and therefore the turns, is of no consequence as far as airplane controllability and performance are concerned. It is perfectly acceptable to make turns toward the failed engine.

On the base leg, if performance is adequate, the flaps may be extended to an intermediate setting (25°, typically). If the performance is inadequate, as measured by a decay in airspeed or high sink rate, delay further flap extension until closer to the runway. V_{YSE} is still the minimum airspeed to maintain.

On final approach, a normal, 3° glidepath to a landing is desirable. VASI or other vertical path lighting aids should be utilized if available. Slightly steeper approaches may be acceptable. However, a long, flat, low approach should be avoided. Large, sudden power applications or reductions should also be avoided. Maintain V_{YSE} until the landing is assured, then slow to 1.3 V_{SO} or the AFM/POH recommended speed. The final flap setting may be delayed until the landing is assured, or the airplane may be landed with partial flaps.

The airplane should remain in trim throughout. The pilot must be prepared, however, for a rudder trim change as the power of the operating engine is reduced to idle in the roundout just prior to touchdown. With drag from only one windmilling propeller, the airplane will tend to float more than on a two-engine approach. Precise airspeed control therefore is essential, especially when landing on a short, wet and/or slippery surface.

Some pilots favor resetting the rudder trim to neutral on final and compensating for yaw by holding rudder pressure for the remainder of the approach. This eliminates the rudder trim change close to the ground as

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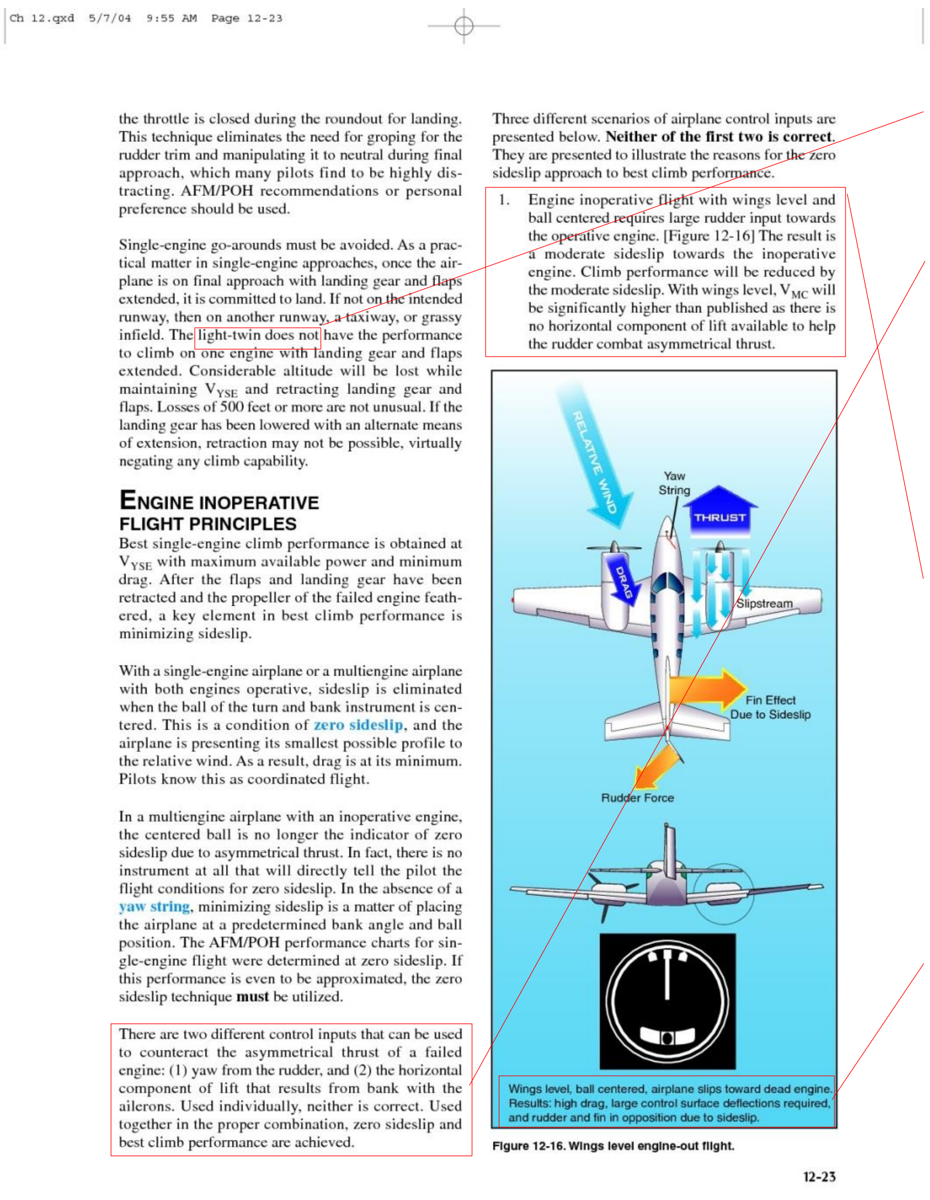
Refer to the recommendation presented on the previous page. It is also recommended to request a long straight is approach to avoid adverse effects on the controllability due to large thrust changes and during turns when the asymmetrical thrust is high or needs to be increased.

Cross-feeding fuel or transferring fuel to the operating engine' side will shift the cg laterally into that engine therewith reducing the thrust yawing moment, reducing the rudder requirement and therewith actual V_{MCA} (refer to figure 12-20 on page 12-29 and to ref. 2, § 5.7).

No, this is definitely not the same, simply because the thrust is asymmetrical and a rudder deflection is required at all times to counteract the asymmetrical thrust, when greater than zero. Many accidents happened in the traffic pattern while one engine is inoperative! The statement is correct if the asymmetrical thrust level can stay low. However, if during the turns to downwind, to base leg or to final the power has to be increased to maximum for maintaining the required altitude or flight path, the actual V_{MCA} will increase to a value much higher than the redlined V_{MCA} or even the blue-lined V_{YSE}. Control will definitely be lost; disaster is imminent, because recovery from the low traffic pattern altitude is not possible. It is much safer to conduct a long straight-in approach when one engine is inoperative (ref. 2, § 8.2), because the favorable bank angle to keep actual V_{MCA} low can easily be attained and maintained in case the thrust needs to be increased. Remember, the published and redlined V_{MCA} is only valid for straight flight while maintaining a small favorable bank angle.

A long approach is recommended, because turns at low altitude, when high power setting might be required to maintain the approach/glide path, can be avoided. Increasing thrust during turns in the traffic pattern, including the final turn, resulted in many catastrophic accidents.
Rudder pressure should change proportional with thrust changes to maintain the heading. If the rudder is near maximum for maintaining the heading, the indicated airspeed is close to the actual V_{MCA}. Do not increase the asymmetrical thrust any further at the current airspeed, or control will be lost.



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the throttle is closed during the roundout for landing. This technique eliminates the need for groping for the rudder trim and manipulating it to neutral during final approach, which many pilots find to be highly distracting. AFM/POH recommendations or personal preference should be used.

Single-engine go-arounds must be avoided. As a practical matter in single-engine approaches, once the airplane is on final approach with landing gear and flaps extended, it is committed to land. If not on the intended runway, then on another runway, a taxiway, or grassy infield. The light-twin does not have the performance to climb on one engine with landing gear and flaps extended. Considerable altitude will be lost while maintaining V_{YSE} and retracting landing gear and flaps. Losses of 500 feet or more are not unusual. If the landing gear has been lowered with an alternate means of extension, retraction may not be possible, virtually negating any climb capability.

ENGINE INOPERATIVE FLIGHT PRINCIPLES

Best single-engine climb performance is obtained at V_{YSE} with maximum available power and minimum drag. After the flaps and landing gear have been retracted and the propeller of the failed engine feathered, a key element in best climb performance is minimizing sideslip.

With a single-engine airplane or a multiengine airplane with both engines operative, sideslip is eliminated when the ball of the turn and bank instrument is centered. This is a condition of **zero sideslip**, and the airplane is presenting its smallest possible profile to the relative wind. As a result, drag is at its minimum. Pilots know this as coordinated flight.

In a multiengine airplane with an inoperative engine, the centered ball is no longer the indicator of zero sideslip due to asymmetrical thrust. In fact, there is no instrument at all that will directly tell the pilot the flight conditions for zero sideslip. In the absence of a **yaw string**, minimizing sideslip is a matter of placing the airplane at a predetermined bank angle and ball position. The AFM/POH performance charts for single-engine flight were determined at zero sideslip. If this performance is even to be approximated, the zero sideslip technique **must** be utilized.

There are two different control inputs that can be used to counteract the asymmetrical thrust of a failed engine: (1) yaw from the rudder, and (2) the horizontal component of lift that results from bank with the ailerons. Used individually, neither is correct. Used together in the proper combination, zero sideslip and best climb performance are achieved.

Three different scenarios of airplane control inputs are presented below. **Neither of the first two is correct**. They are presented to illustrate the reasons for the zero sideslip approach to best climb performance.

1. Engine inoperative flight with wings level and ball centered requires large rudder input towards the operative engine. [Figure 12-16] The result is a moderate sideslip towards the inoperative engine. Climb performance will be reduced by the moderate sideslip. With wings level, V_{MC} will be significantly higher than published as there is no horizontal component of lift available to help the rudder combat asymmetrical thrust.

Wings level, ball centered, airplane slips toward dead engine. Results: high drag, large control surface deflections required, and rudder and fin in opposition due to sideslip.

Figure 12-16. Wings level engine-out flight.

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If low weight, a light- twin might still have performance to climb if and only if straight flight is maintained, while banking the favorable bank angle away from the inoperative engine. The AFM/POH should give the answer.

No, not quite right. Only the rudder can counteract the asymmetrical thrust, because both moments act about the same yaw axis. The side force generated by the rudder does not only provide for the required yawing moment to counteract the asymmetrical thrust yawing moment, but also accelerates the airplane to the dead engine side, until the increasing side force due to sideslip equals the rudder side force. Then equilibrium of side forces is established; the sideslip does not increase any further. It is this side force due to sideslip that can be replaced by the side force due to banking; the effect is that the sideslip decreases to zero with only a few degrees of bank (ref. 2, § 3.3 and 3.4). A component of the weight (W) of the airplane, the side force W·sin φ, is also one of the forces acting on the airplane and is a factor during calculating the balance of forces and moments during one engine inoperative flight.

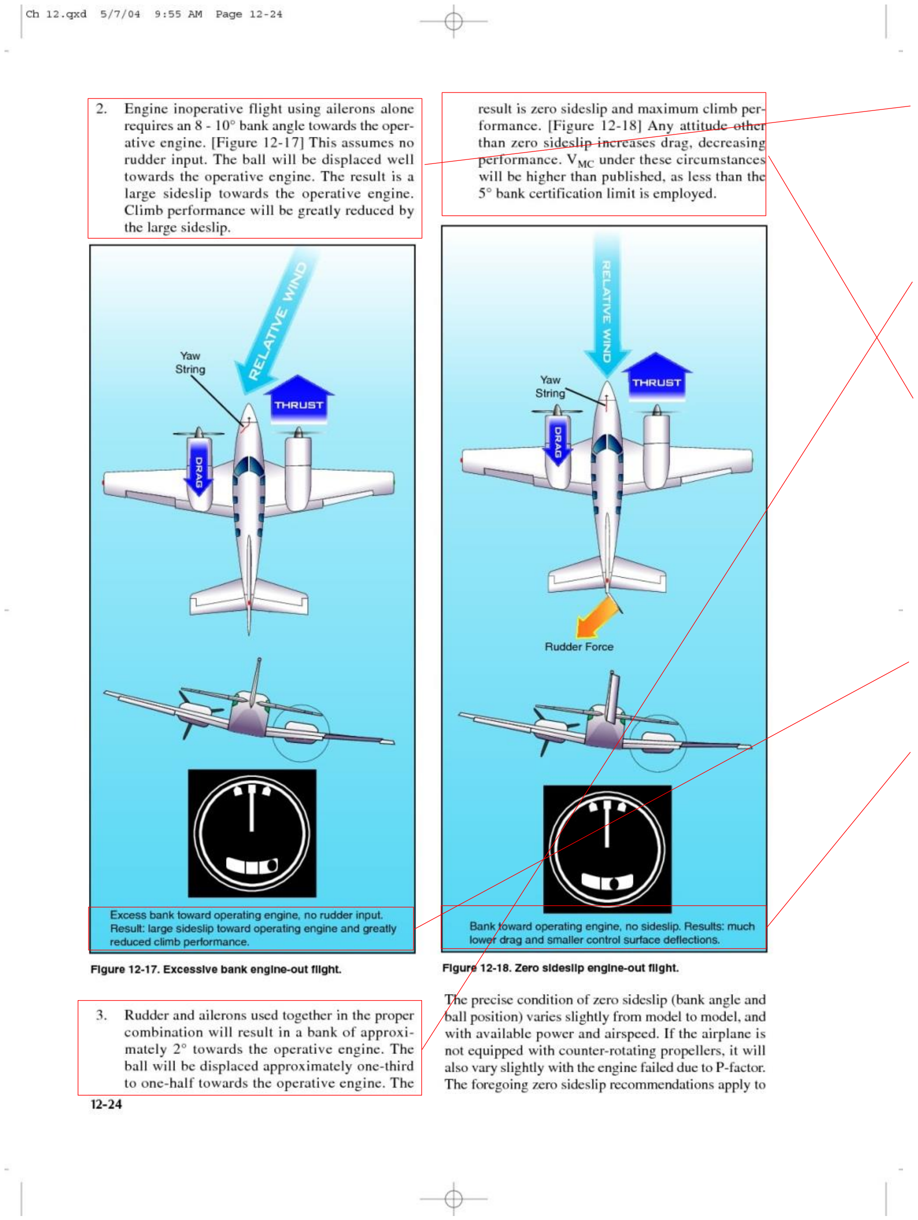
The horizontal components of lift and weight do not *help the rudder combat asymmetrical thrust* (during straight flight), but replace the side force due to sideslip, as briefly explained above and as thoroughly explained in ref. 2, § 3.4.

Rudder is required to counteract the asymmetrical thrust. The rudder side force not only provides for the yawing moment, but also causes the airplane to start slipping to the dead engine side; this sideslip causes a side force to the good engine side (here called fin effect due to sideslip). The sideslip increases until an equilibrium of side forces is established.

In this wings level scenario, the rudder not only needs to combat the asymmetrical thrust yawing moment, but also the yawing moment due to sideslip. This side force acts at some distance from the cg and hence, results in a yawing moment. This yawing moment adds to the thrust yawing moment and requires larger rudder deflection to compensate for. If the rudder is already maximal, a higher airspeed is required for the vertical tail to generate a larger side force; V_{MCA} is higher (ref. 2, § 3.3).

Rudder and fin are not really *in opposition due to sideslip*. Actual V_{MCA} is higher than the published and redlined V_{MCA}.

Please refer to ref. 2, § 3 for a thorough explanation of the three options/ scenarios of this and the next page.



2. Engine inoperative flight using ailerons alone requires an 8 - 10° bank angle towards the operative engine. [Figure 12-17] This assumes no rudder input. The ball will be displaced well towards the operative engine. The result is a large sideslip towards the operative engine. Climb performance will be greatly reduced by the large sideslip.

3. Rudder and ailerons used together in the proper combination will result in a bank of approximately 2° towards the operative engine. The ball will be displaced approximately one-third to one-half towards the operative engine. The result is zero sideslip and maximum climb performance. [Figure 12-18] Any attitude other than zero sideslip increases drag, decreasing performance. V_{MC} under these circumstances will be higher than published, as less than the 5° bank certification limit is employed.

Excess bank toward operating engine, no rudder input. Result: large sideslip toward operating engine and greatly reduced climb performance.

Figure 12-17. Excessive bank engine-out flight.

Bank toward operating engine, no sideslip. Results: much lower drag and smaller control surface deflections.

Figure 12-18. Zero sideslip engine-out flight.

The precise condition of zero sideslip (bank angle and ball position) varies slightly from model to model, and with available power and airspeed. If the airplane is not equipped with counter-rotating propellers, it will also vary slightly with the engine failed due to P-factor. The foregoing zero sideslip recommendations apply to

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A yawing moment is required to counteract the thrust yawing moment; in this case, this is generated by the sideslip from the good engine' side. It is recommended to add the fin effect due to sideslip in the drawing and vector $W \cdot \sin \varphi$ in the cg.
Also recommended is to add that a fin stall is nearby when the bank angle increases above 8 – 10 degrees, from which a recovery at low altitude might not be possible.

As was mentioned before, the required bank angle depends on the airspeed. At V_{MCA}, the bank angle might have to be up to 5 degrees for zero sideslip; at V_{YSE}, approximately 2 degrees might be adequate for zero sideslip (refer to the OEI performance data in the AFM/POH).

The certification limit is 5°, but the bank angle used to design the vertical tail and determine V_{MCA} during flight-test may also be smaller as opted by the manufacturer. FAR 23.149 (a) (ref. 5) allows the manufacturer to design the vertical tail and to determine V_{MCA} using a bank angle of maximum 5°. The manufacturer will select the bank angle for which the sideslip at V_{MCA} is zero (ref. 2, § 4). If the manufacturer selected 3°, that bank angle will be used for flight test and certification. The actual V_{MCA} will be higher than published as less than the bank angle is used that was applied during designing the vertical tail and flight-testing to determine V_{MCA}, not as less than the 5° bank certification limit.
The manufacturer should publish the favorable bank angle with V_{MCA} in the AFM/POH.

If no rudder input, bank angle larger than 5° required for maintaining heading. Results, add: highr drag and an actual V_{MCA} that is higher than the published and redlined V_{MCA}.

Rudder to stop yaw, bank toward operating engine for zero sideslip. Results: maximum climb performance, actual V_{MCA} as low as possible and not higher than published and redlined V_{MCA}.

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reciprocating engine multiengine airplanes flown at V_{YSE} with the inoperative engine feathered. The zero sideslip ball position for straight flight is also the zero sideslip position for turning flight.

When bank angle is plotted against climb performance for a hypothetical twin, zero sideslip results in the best (however marginal) climb performance or the least rate of descent. Zero bank (all rudder to counteract yaw) degrades climb performance as a result of moderate sideslip. Using bank angle alone (no rudder) severely degrades climb performance as a result of a large sideslip.

The actual bank angle for zero sideslip varies among airplanes from one and one-half to two and one-half degrees. The position of the ball varies from one-third to one-half of a ball width from instrument center.

For any multiengine airplane, zero sideslip can be confirmed through the use of a yaw string. A yaw string is a piece of string or yarn approximately 18 to 36 inches in length, taped to the base of the windshield, or to the nose near the windshield, along the airplane centerline. In two-engine coordinated flight, the relative wind will cause the string to align itself with the longitudinal axis of the airplane, and it will position itself straight up the center of the windshield. This is zero sideslip. Experimentation with slips and skids will vividly display the location of the relative wind. Adequate altitude and flying speed must be maintained while accomplishing these maneuvers.

With an engine set to zero thrust (or feathered) and the airplane slowed to V_{YSE}, a climb with maximum power on the remaining engine will reveal the precise bank angle and ball deflection required for zero sideslip and best climb performance. Zero sideslip will again be indicated by the yaw string when it aligns itself vertically on the windshield. There will be very minor changes from this attitude depending upon the engine failed (with noncounter-rotating propellers), power available, airspeed and weight; but without more sensitive testing equipment, these changes are difficult to detect. The only significant difference would be the pitch attitude required to maintain V_{YSE} under different density altitude, power available, and weight conditions.

If a yaw string is attached to the airplane at the time of a V_{MC} demonstration, it will be noted that V_{MC} occurs under conditions of sideslip. V_{MC} was **not** determined under conditions of zero sideslip during aircraft certification and zero sideslip is **not** part of a V_{MC} demonstration for pilot certification.

To review, there are two different sets of bank angles used in one-engine-inoperative flight.

- To maintain directional control of a multiengine airplane suffering an engine failure at low speeds (such as climb), momentarily bank **at least** 5°, and a maximum of 10° towards the operative engine as the pitch attitude for V_{YSE} is set. This maneuver should be instinctive to the proficient multiengine pilot and take only 1 to 2 seconds to attain. It is held just long enough to assure directional control as the pitch attitude for V_{YSE} is assumed.
- To obtain the best climb performance, the airplane must be flown at V_{YSE} and zero sideslip, with the failed engine feathered and maximum available power from the operating engine. Zero sideslip is approximately 2° of bank toward the operating engine and a one-third to one-half ball deflection, also toward the operating engine. The precise bank angle and ball position will vary somewhat with make and model and power available. If above the airplane's single-engine ceiling, this attitude and configuration will result in the minimum rate of sink.

In OEI flight at low altitudes and airspeeds such as the initial climb after takeoff, pilots must operate the airplane so as to guard against the three major accident factors: (1) loss of directional control, (2) loss of performance, and (3) loss of flying speed. All have equal potential to be lethal. Loss of flying speed will not be a factor, however, when the airplane is operated with due regard for directional control and performance.

SLOW FLIGHT

There is nothing unusual about maneuvering during slow flight in a multiengine airplane. Slow flight may be conducted in straight-and-level flight, turns, in the clean configuration, landing configuration, or at any other combination of landing gear and flaps. Pilots should closely monitor cylinder head and oil temperatures during slow flight. Some high performance multiengine airplanes tend to heat up fairly quickly under some conditions of slow flight, particularly in the landing configuration.

Simulated engine failures should not be conducted during slow flight. The airplane will be well below V_{SSE} and very close to V_{MC}. Stability, stall warning or stall avoidance devices should not be disabled while maneuvering during slow flight.

STALLS

Stall characteristics vary among multiengine airplanes just as they do with single-engine airplanes, and therefore, it is important to be familiar with them. The application of power upon stall recovery, however, has a significantly greater effect during stalls in a

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This might not be the case at speeds lower than V_{YSE} when rudder and/or aileron are (near) maximum.

Add: when the airspeed is V_{YSE}. When airspeed is lower than V_{YSE}, bank angle needs to be increased. V_{MCA} is measured while the bank angle is 5 degrees away from the inoperative engine on most airplanes.

This is definitely not true and is neither in agreement with airplane design methods, as taught by aeronautical universities, nor with flight test techniques prescribed in FAA FTG's (ref. 6). The airplane design engineer sized the vertical tail (fin) for zero sideslip (minimum drag) while banking a number of degrees (max. 5°) away from the inoperative engine at V_{MCA} (FAR 23.149). The engineer determined this required bank angle for zero sideslip at V_{MCA}. During experimental flight-testing to determine and verify V_{MCA}, first, a wings-level V_{MCA} is determined and then V_{MCA} with the bank angle that was used to size the vertical tail, i.e. for zero sideslip. This latter V_{MCA} is 8 – 10 kt lower than wings level V_{MCA} for most small twins and is published in AFM/POH and redlined on the ASI. On big 4-engine airplanes, the difference can be up to 30 kt!
Hence, the published V_{MCA} is the V_{MCA} determined under conditions of ***zero*** sideslip.
Refer to ref. 2 and/ or ref. 3 for further explanation.

Pilots will not see the same V_{MCA} that test pilots determined, because the conditions are not the same as during the experimental flight-tests. The V_{MCA} in an AFM/POH is a worst-case V_{MCA}, the highest V_{MCA} a pilot would experience in-flight and is therefore a safe V_{MCA}, provided the pilot maintains maximum thrust and deflects the rudder to stop the yaw and attains the favorable bank angle (that should have been provided by the manufacturer). This might be the reason the writer noticed the sideslip not being zero during V_{MCA} demonstrations.

The difference between wings-level V_{MCA} and V_{MCA} with a favorable bank angle should be demonstrated for pilot certification.

Continued on the next page.

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STALLS

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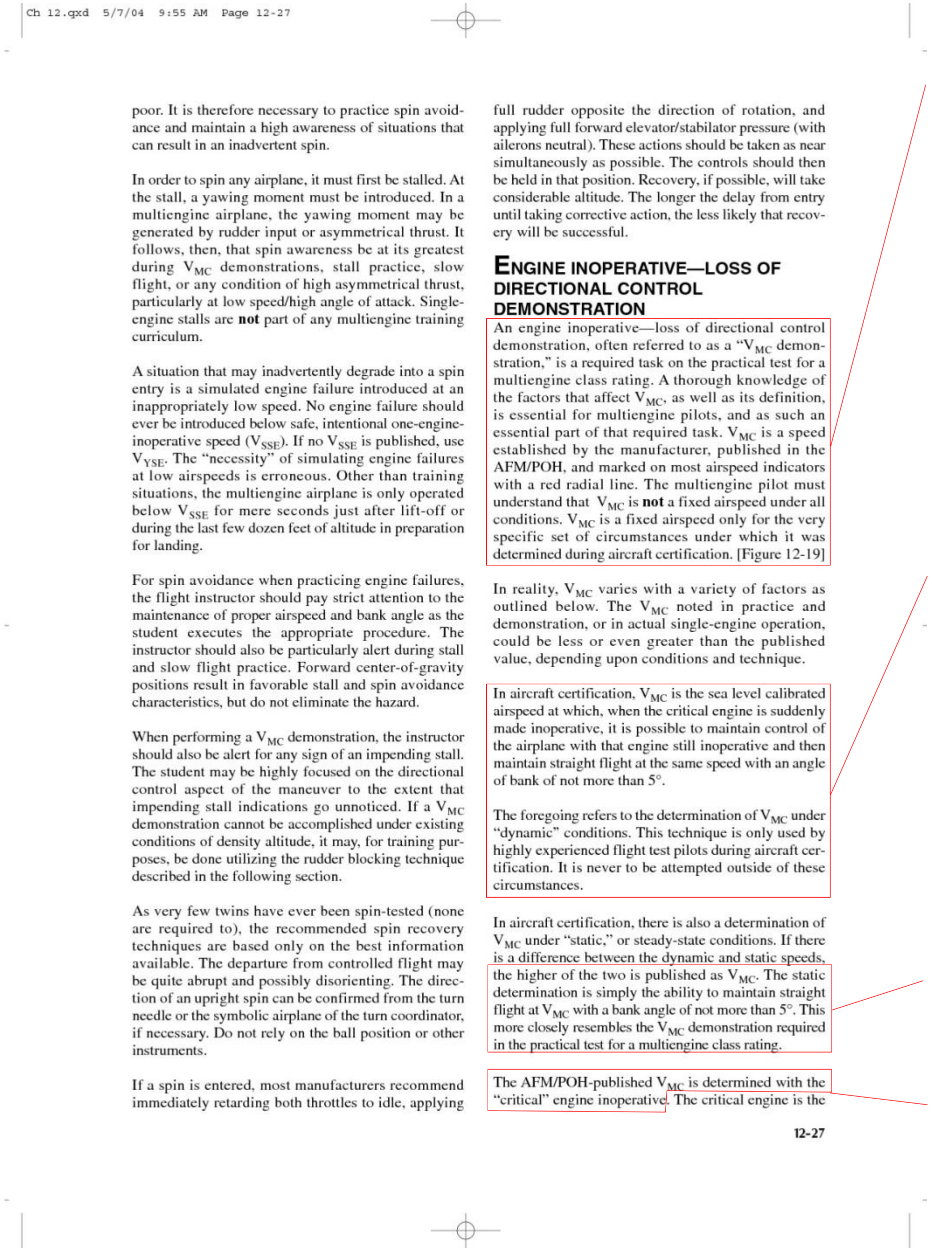
The rudder is the only control available to the pilot to counteract the asymmetrical yawing moment; the rudder should be used immediately to stop the yaw and maintain heading. Ailerons are required to counteract the rolling moment due to thrust (wing section behind the operative propeller), sideslip and due to yawing.
Definitely **do not *bank at least 5 degrees***, but bank 5 degrees, or the lower number of degrees the manufacturer selected for minimum sideslip/ drag during sizing the vertical tail. A bank angle in excess of 5 degrees increases the sideslip instantaneously, increasing the drag as well as the (horizontal) angle of attack of the fin. Climb performance suffers and a fin stall is imminent!
Recommended text:
To maintain directional control, input rudder to maintain heading (which might not and need not be the runway heading following the dynamics of a sudden failure). Simultaneously bank and maintain 5 degrees away from the inoperative engine to reduce the sideslip and keep the actual V_{MCA} as low as possible. Gradually reduce the bank angle to the value presented in the OEI performance data while accelerating to V_{YSE}. Refer to figure 14 in ref. 2 and to the engine inop trainer of UND, ref. 7).

There is indeed nothing unusual about maneuvering, but only if all engines are operating. If however OEI, a very different equilibrium of forces and moments is in effect, as was already mentioned above on page 10. Slow, maneuvering flight with max. thrust **is definitely not recommended**; it will end in a catastrophe, as happened so many times already and still happens every month. The vertical tail of the airplane was not designed and is too small for maneuvering during slow flight while OEI, but only for straight flight (at speeds as low as V_{MCA} while the thrust is maximum asymmetrical). FAR 23 does not require maneuvering at airspeeds as low as V_{MCA}; the airplane was not flight-tested for maneuvering at this low speed.

Simulating engine failures during slow flight should not be conducted, but slowing down while OEI from V_{SSE} at maximum thrust and at a safe altitude is highly recommended to demonstrate both the real value of V_{MCA} and the effect of bank angle, and to gain the proper appreciation for this life saving airspeed limitation.
Maneuvering during slow flight while OEI and with maximum thrust is very dangerous during takeoff, in the traffic pattern, during final approach and go-around (at low altitude).
During takeoff and approach while an engine is inoperative, maintain a straight flight path when the thrust is maximal, or has to be increased to maximum and attain the favorable bank angle (for best climb performance and minimum actual V_{MCA}.



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poor. It is therefore necessary to practice spin avoidance and maintain a high awareness of situations that can result in an inadvertent spin.

In order to spin any airplane, it must first be stalled. At the stall, a yawing moment must be introduced. In a multiengine airplane, the yawing moment may be generated by rudder input or asymmetrical thrust. It follows, then, that spin awareness be at its greatest during V_{MC} demonstrations, stall practice, slow flight, or any condition of high asymmetrical thrust, particularly at low speed/high angle of attack. Single-engine stalls are **not** part of any multiengine training curriculum.

A situation that may inadvertently degrade into a spin entry is a simulated engine failure introduced at an inappropriately low speed. No engine failure should ever be introduced below safe, intentional one-engine-inoperative speed (V_{SSE}). If no V_{SSE} is published, use V_{YSE}. The "necessity" of simulating engine failures at low airspeeds is erroneous. Other than training situations, the multiengine airplane is only operated below V_{SSE} for mere seconds just after lift-off or during the last few dozen feet of altitude in preparation for landing.

For spin avoidance when practicing engine failures, the flight instructor should pay strict attention to the maintenance of proper airspeed and bank angle as the student executes the appropriate procedure. The instructor should also be particularly alert during stall and slow flight practice. Forward center-of-gravity positions result in favorable stall and spin avoidance characteristics, but do not eliminate the hazard.

When performing a V_{MC} demonstration, the instructor should also be alert for any sign of an impending stall. The student may be highly focused on the directional control aspect of the maneuver to the extent that impending stall indications go unnoticed. If a V_{MC} demonstration cannot be accomplished under existing conditions of density altitude, it may, for training purposes, be done utilizing the rudder blocking technique described in the following section.

As very few twins have ever been spin-tested (none are required to), the recommended spin recovery techniques are based only on the best information available. The departure from controlled flight may be quite abrupt and possibly disorienting. The direction of an upright spin can be confirmed from the turn needle or the symbolic airplane of the turn coordinator, if necessary. Do not rely on the ball position or other instruments.

If a spin is entered, most manufacturers recommend immediately retarding both throttles to idle, applying full rudder opposite the direction of rotation, and applying full forward elevator/stabilator pressure (with ailerons neutral). These actions should be taken as near simultaneously as possible. The controls should then be held in that position. Recovery, if possible, will take considerable altitude. The longer the delay from entry until taking corrective action, the less likely that recovery will be successful.

ENGINE INOPERATIVE—LOSS OF DIRECTIONAL CONTROL DEMONSTRATION

An engine inoperative—loss of directional control demonstration, often referred to as a "V_{MC} demonstration," is a required task on the practical test for a multiengine class rating. A thorough knowledge of the factors that affect V_{MC}, as well as its definition, is essential for multiengine pilots, and as such an essential part of that required task. V_{MC} is a speed established by the manufacturer, published in the AFM/POH, and marked on most airspeed indicators with a red radial line. The multiengine pilot must understand that V_{MC} is **not** a fixed airspeed under all conditions. V_{MC} is a fixed airspeed only for the very specific set of circumstances under which it was determined during aircraft certification. [Figure 12-19]

In reality, V_{MC} varies with a variety of factors as outlined below. The V_{MC} noted in practice and demonstration, or in actual single-engine operation, could be less or even greater than the published value, depending upon conditions and technique.

In aircraft certification, V_{MC} is the sea level calibrated airspeed at which, when the critical engine is suddenly made inoperative, it is possible to maintain control of the airplane with that engine still inoperative and then maintain straight flight at the same speed with an angle of bank of not more than 5°.

The foregoing refers to the determination of V_{MC} under "dynamic" conditions. This technique is only used by highly experienced flight test pilots during aircraft certification. It is never to be attempted outside of these circumstances.

In aircraft certification, there is also a determination of V_{MC} under "static," or steady-state conditions. If there is a difference between the dynamic and static speeds, the higher of the two is published as V_{MC}. The static determination is simply the ability to maintain straight flight at V_{MC} with a bank angle of not more than 5°. This more closely resembles the V_{MC} demonstration required in the practical test for a multiengine class rating.

The AFM/POH-published V_{MC} is determined with the "critical" engine inoperative. The critical engine is the

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A thorough knowledge of all of the factors that affect V_{MCA} is not required, but it is required to understand that the pilot controls the magnitude of the actual V_{MCA} with thrust, rudder and bank angle. The redlined, published V_{MCA} is determined using the worst case of all other factors that have influence on V_{MCA} and with maximum thrust, maximum rudder and with a favorable bank angle of (mostly) 5°.
The definitions of V_{MCA} presented in most AFM/POH and textbooks are not correct; they are copied from FAR 23.149 that is for designing and certification of airplanes, not for their operational use. The definition of V_{MCA} for pilots is different, refer to ref. 2, § 8.1.
It is correct that V_{MCA} is not a fixed airspeed. However, the redlined V_{MCA} is the highest V_{MCA} that the pilot will experience in-flight while the thrust is maximal, a bank angle of 5° is maintained away from the inoperative engine **and** the rudder is deflected to maintain the heading.
The multi-engine pilot must understand that the actual, the in-flight experienced V_{MCA} will be lower if the thrust is not maximal but will be higher than the redlined V_{MCA} if the rudder is not deflected adequately to stop the yawing and when the bank angle is not the favorable bank angle, i.e. the bank angle used by the tail design engineer to size the vertical tail and by test pilots to determine V_{MCA} in-flight, which usually is between 3 and 5 degrees away from the inoperative engine. The thorough knowledge of the other factors that affect V_{MCA}, like cg, critical engine, etc. is not required; the worst case of these factors is included in the displayed and published V_{MCA}. The effect of bank angle on V_{MCA} is mentioned in Chapter 12, but not with the attention that would be required.

This definition indeed applies to certification, but not to airplane operations and pilots. Why is it presented here? That is confusing; pilots need a pilot-definition for V_{MCA}.
When the critical engine is suddenly made inoperative, V_{MCA} is referring to the dynamic V_{MCA}. As is also stated in the next paragraph on this page, the published V_{MCA} is the higher of static and dynamic V_{MCA} normally expected in service (refer to FTG, ref. 6, page 74). V_{MCA} is determined with the critical engine failing (suddenly - dynamic) or inoperative (static), but applies also when another engine fails. V_{MCA} is not the minimum speed for maintaining control, only for recovering after a sudden failure and for maintaining straight flight while banking the fixed favorable bank angle away from the inoperative engine.
The foregoing is not for dynamic conditions, because the FTG (ref. 6) does not specify a maximum bank angle, but merely that recovery must be possible after a sudden failure with heading within 20° and no exceptional piloting skill required. The maximum 5° degrees are for the static V_{MCA}. During flight-testing, bank angles of up to 45 degrees after a sudden failure are acceptable.
No, not with a bank angle of not more than 5°, but with a fixed bank angle (usually between 3 and 5 degrees) that was used to design the vertical tail, and that results in zero sideslip when the airspeed is V_{MCA}.

Not the static determination, but the determination of the static V_{MCA}. The use of the word *simply* shows that static V_{MCA}, which applies during the remainder of the flight while OEI, is underestimated. Its ignorance caused many, if not all engine failure related accidents. Refer to the FTG, ref. 6, page 73. The bank angle needs not be maximum 5°, but the exact bank angle that was used to design the fin.

… and with maximum thrust, favorable bank angle between 3 and 5 degrees (as determined by the manufacturer), aft cg, lowest possible weight, feathered propeller (if automatic), maximum rudder and/ or ailerons, a certain flap setting, etc.

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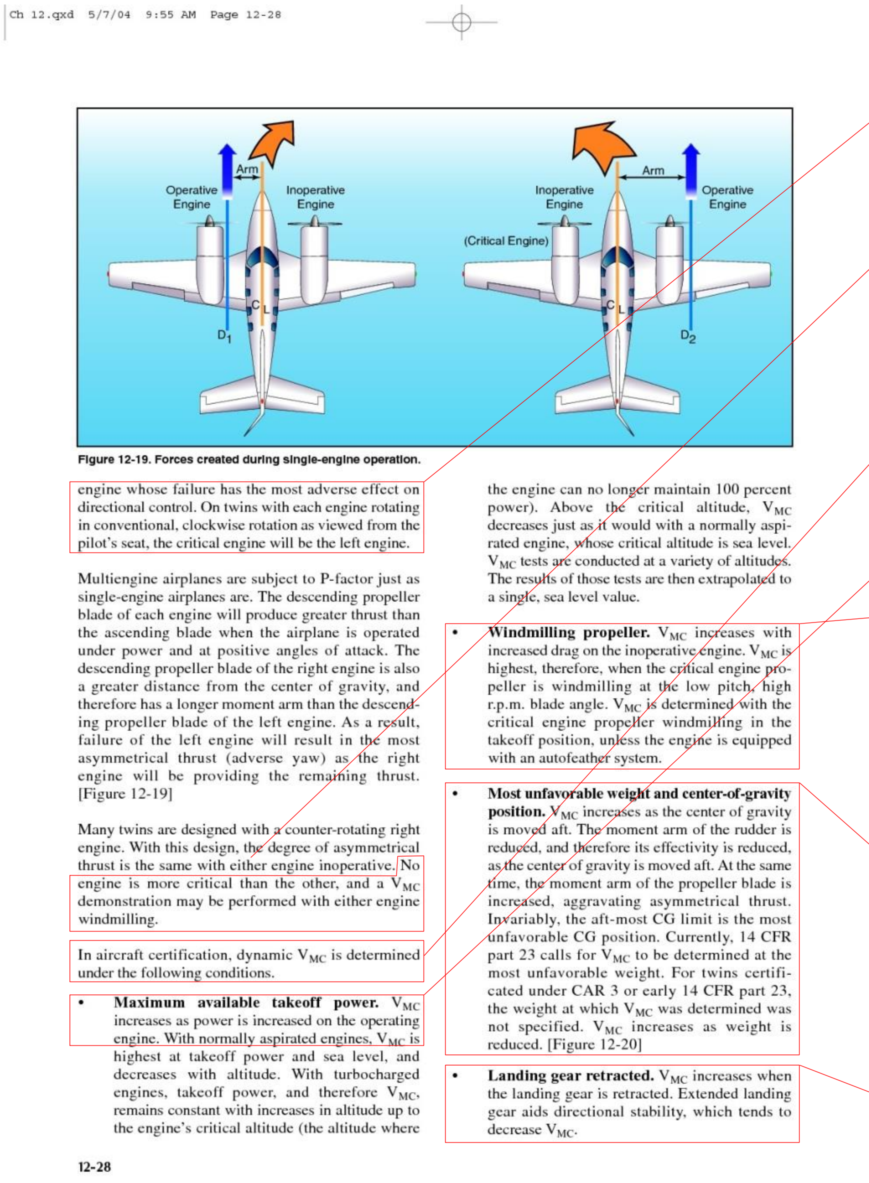

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Figure 12-19. Forces created during single-engine operation.

engine whose failure has the most adverse effect on directional control. On twins with each engine rotating in conventional, clockwise rotation as viewed from the pilot's seat, the critical engine will be the left engine.

Multiengine airplanes are subject to P-factor just as single-engine airplanes are. The descending propeller blade of each engine will produce greater thrust than the ascending blade when the airplane is operated under power and at positive angles of attack. The descending propeller blade of the right engine is also a greater distance from the center of gravity, and therefore has a longer moment arm than the descending propeller blade of the left engine. As a result, failure of the left engine will result in the most asymmetrical thrust (adverse yaw) as the right engine will be providing the remaining thrust. [Figure 12-19]

Many twins are designed with a counter-rotating right engine. With this design, the degree of asymmetrical thrust is the same with either engine inoperative. No engine is more critical than the other, and a V_{MC} demonstration may be performed with either engine windmilling.

In aircraft certification, dynamic V_{MC} is determined under the following conditions.

- **Maximum available takeoff power.** V_{MC} increases as power is increased on the operating engine. With normally aspirated engines, V_{MC} is highest at takeoff power and sea level, and decreases with altitude. With turbocharged engines, takeoff power, and therefore V_{MC}, remains constant with increases in altitude up to the engine's critical altitude (the altitude where the engine can no longer maintain 100 percent power). Above the critical altitude, V_{MC} decreases just as it would with a normally aspirated engine, whose critical altitude is sea level. V_{MC} tests are conducted at a variety of altitudes. The results of those tests are then extrapolated to a single, sea level value.
- **Windmilling propeller.** V_{MC} increases with increased drag on the inoperative engine. V_{MC} is highest, therefore, when the critical engine propeller is windmilling at the low pitch, high r.p.m. blade angle. V_{MC} is determined with the critical engine propeller windmilling in the takeoff position, unless the engine is equipped with an autofeather system.
- **Most unfavorable weight and center-of-gravity position.** V_{MC} increases as the center of gravity is moved aft. The moment arm of the rudder is reduced, and therefore its effectivity is reduced, as the center of gravity is moved aft. At the same time, the moment arm of the propeller blade is increased, aggravating asymmetrical thrust. Invariably, the aft-most CG limit is the most unfavorable CG position. Currently, 14 CFR part 23 calls for V_{MC} to be determined at the most unfavorable weight. For twins certificated under CAR 3 or early 14 CFR part 23, the weight at which V_{MC} was determined was not specified. V_{MC} increases as weight is reduced. [Figure 12-20]
- **Landing gear retracted.** V_{MC} increases when the landing gear is retracted. Extended landing gear aids directional stability, which tends to decrease V_{MC}.

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Critical engine sounds very interesting, but bank angle has a much greater adverse effect on directional control. Bank angle, which is under direct control of the pilot, is a lot more critical to maintaining directional control than the critical engine and should be discussed here instead of the critical engine. There is only one engine emergency procedure that applies after the failure of either engine.

A V_{MCA} demonstration on any airplane, conventional propeller rotation or not, may always be performed with either engine windmilling. The difference in V_{MCA} between both engines for conventional rotation is just a few knots. It is doubtful whether a demo will show the V_{MCA} that is published in the AFM/POH and redlined on the airspeed indicator, because the factors used to determine V_{MCA} during the test flight are not the same as during the demo flight. Demonstrating the effect of bank angle would be much more valuable, because many accidents happen while maneuvering at low speed when OEI.

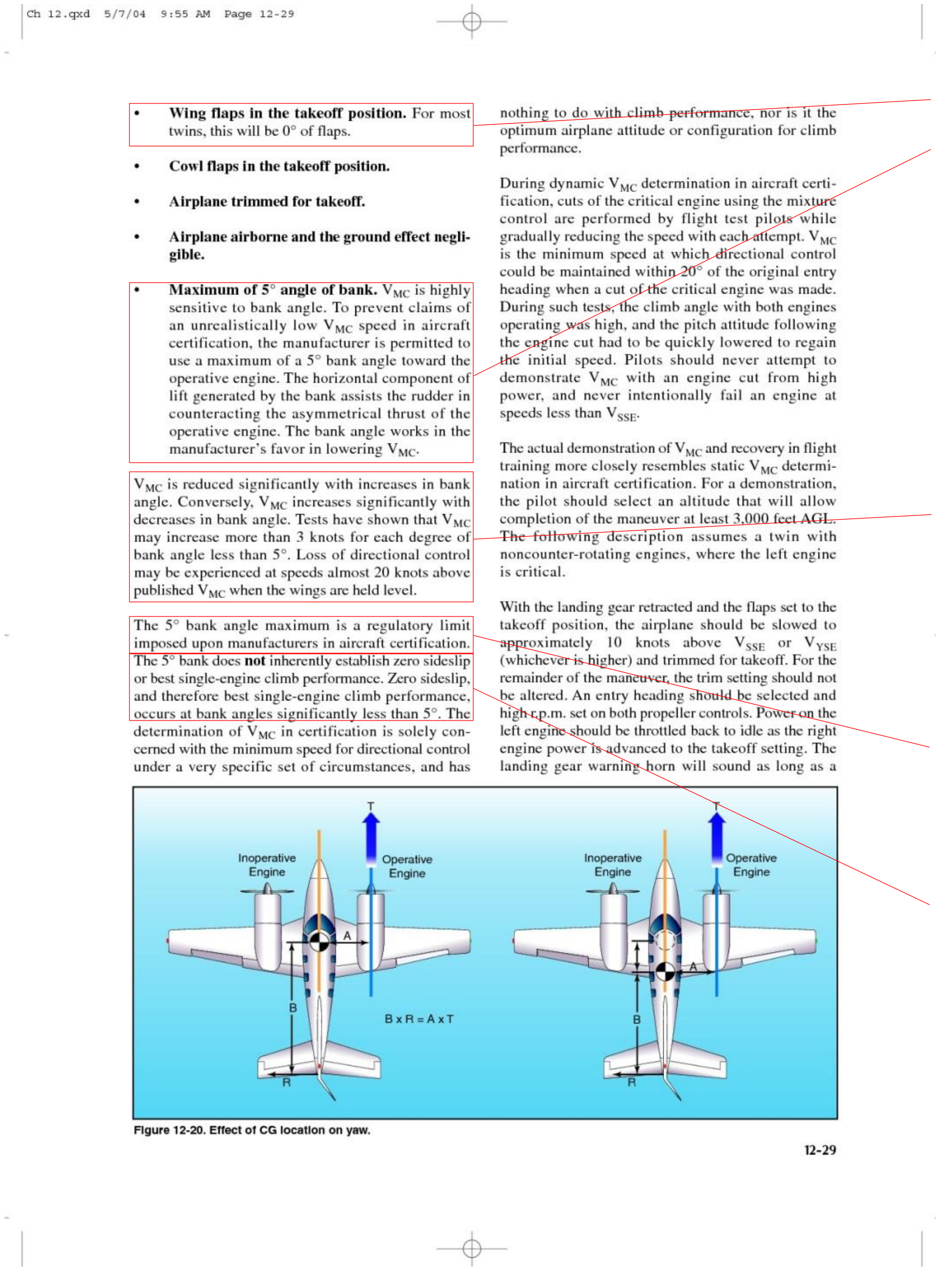
Not only the dynamic V_{MCA} is determined under the following conditions (except for the last bullet), also the static V_{MCA}. Please refer to the FAA Flight Test Guide, ref. 2, page 73.
The conditions are indeed as used during airplane design and certification, but why are these not changed for better understanding and use by pilots, i.e. from their perspective?

For pilots it would be better to say: V_{MCA} decreases (below the redlined V_{MCA}) as power is decreased on the operating engine.

V_{MCA} does not increase with increased drag on the inoperative engine; this is also included in V_{MCA}, because V_{MCA} is determined with the propeller in the position it achieves without pilot intervention when the engine fails or is switched off, which might be windmilling, except when equipped with an autofeather system; then V_{MCA} is determined using that system. For pilots it is of relevance to know that the actual V_{MCA} decreases below the published and redlined V_{MCA} when the drag of the inoperative engine decreases as the propeller is feathered (if not automatic). If however, the automatic autofeather does not function, the propeller is not manually feathered or if the pilots leave the engine, if not completely failed, running as a "power standby", the propeller drag increases the thrust yawing moments and V_{MCA} will be higher than the V_{MCA} published in the AFM/POH.

V_{MCA} is determined while the cg is aft; then V_{MCA} is (mostly) highest (ref. 2, § 5.7). For pilots, the second sentence should be "V_{MCA} decreases as the cg is moved forward."
The moment arm of the propeller blade does not change with a shift of the longitudinal cg (fwd – aft), but only if the cg is laterally shifted (fuel imbalance). V_{MCA} decreases as well, because the maximum lateral location of the cg away from the operating engine is used to measure V_{MCA}.
V_{MCA} is usually determined at the lowest weight possible, and decreases as weight increases, provided a bank angle is being maintained away from the inoperative engine. If not, V_{MCA} increases with weight (ref. 2, § 5.1).

Change of V_{MCA} with a retracting landing gear depends on the sideslip angle and on whether the airplane is equipped with a nose or a tail wheel, and on rudder boosting, if applicable.



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- **Wing flaps in the takeoff position.** For most twins, this will be 0° of flaps.
- **Cowl flaps in the takeoff position.**
- **Airplane trimmed for takeoff.**
- **Airplane airborne and the ground effect negligible.**
- **Maximum of 5° angle of bank.** V_{MC} is highly sensitive to bank angle. To prevent claims of an unrealistically low V_{MC} speed in aircraft certification, the manufacturer is permitted to use a maximum of a 5° bank angle toward the operative engine. The horizontal component of lift generated by the bank assists the rudder in counteracting the asymmetrical thrust of the operative engine. The bank angle works in the manufacturer's favor in lowering V_{MC}.

V_{MC} is reduced significantly with increases in bank angle. Conversely, V_{MC} increases significantly with decreases in bank angle. Tests have shown that V_{MC} may increase more than 3 knots for each degree of bank angle less than 5°. Loss of directional control may be experienced at speeds almost 20 knots above published V_{MC} when the wings are held level.

The 5° bank angle maximum is a regulatory limit imposed upon manufacturers in aircraft certification. The 5° bank does **not** inherently establish zero sideslip or best single-engine climb performance. Zero sideslip, and therefore best single-engine climb performance, occurs at bank angles significantly less than 5°. The determination of V_{MC} in certification is solely concerned with the minimum speed for directional control under a very specific set of circumstances, and has nothing to do with climb performance, nor is it the optimum airplane attitude or configuration for climb performance.

During dynamic V_{MC} determination in aircraft certification, cuts of the critical engine using the mixture control are performed by flight test pilots while gradually reducing the speed with each attempt. V_{MC} is the minimum speed at which directional control could be maintained within 20° of the original entry heading when a cut of the critical engine was made. During such tests, the climb angle with both engines operating was high, and the pitch attitude following the engine cut had to be quickly lowered to regain the initial speed. Pilots should never attempt to demonstrate V_{MC} with an engine cut from high power, and never intentionally fail an engine at speeds less than V_{SSE}.

The actual demonstration of V_{MC} and recovery in flight training more closely resembles static V_{MC} determination in aircraft certification. For a demonstration, the pilot should select an altitude that will allow completion of the maneuver at least 3,000 feet AGL. The following description assumes a twin with noncounter-rotating engines, where the left engine is critical.

With the landing gear retracted and the flaps set to the takeoff position, the airplane should be slowed to approximately 10 knots above V_{SSE} or V_{YSE} (whichever is higher) and trimmed for takeoff. For the remainder of the maneuver, the trim setting should not be altered. An entry heading should be selected and high r.p.m. set on both propeller controls. Power on the left engine should be throttled back to idle as the right engine power is advanced to the takeoff setting. The landing gear warning horn will sound as long as a

Figure 12-20. Effect of CG location on yaw.

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The flap setting for which the published V_{MCA} is valid should be listed with V_{MCA} data in AFM/POH.

Maximum of 5° angle of bank is not correct for the dynamic V_{MCA} for which this list is applicable according to the header on page 12-28. As already mentioned a few times above, the requirement for the flight test pilot during determining the dynamic V_{MCA} is not *maximum 5°*, but 45° of bank. In addition, no dangerous attitudes should occur and no exceptional piloting skill should be required. The 5° limit applies to determining the static V_{MCA} (FTG ref. 6, page 71).
The manufacturer is permitted to use a bank angle of maximum 5° toward the operative engine, not to prevent claims, but to be able to reduce the required size of the vertical tail and therewith save cost and weight (ref. 2, § 4). The tail may however not be so small that V_{MCA} increases above 1.2 V_S (FAR 23.149 (b)). A V_{MCA} lower than V_S (a large tail) is advantageous, because the airplane is said to be controllable down to the stall (as long as the favorable bank angle is being maintained). The horizontal component of the lift does not assist the rudder, but reduces the sideslip. The bank angle works in the manufacturer's (and operator's) favor for a smaller, cheaper and less weighing vertical tail and works in the pilot's favor for lowering the actual V_{MCA} to a value below the standardized published V_{MCA}.
Paragraphs above also apply to determining static V_{MCA}. Dynamic V_{MCA} is the minimum speed for recovery after a sudden failure, static V_{MCA} is the minimum speed for maintaining control during the remainder of the flight while OEI.

OK, good paragraph, but for pilots either delete the first sentence, because the use of a bank angle is included in the published V_{MCA}, or write "Actual V_{MCA} is reduced significantly with bank angle". This paragraph applies to static V_{MCA}, though, not for dynamic V_{MCA} as the header on page 12-28 suggests. Refer to figure 14 in ref. 2 § 5.1.
Pilots need to maintain the favorable bank angle when the airspeed is low and the thrust maximal, therefore it is better to replace the first three sentences with: "V_{MCA} is determined with a bank angle of 5° away from the inoperative engine. The actual V_{MCA}, i.e. the V_{MCA} that the pilot experiences in-flight, will increase significantly above the redlined standardized V_{MCA} when the bank angle is less than 5° or to the other side. Bank angles greater than 5° result in increased sideslip and risk of fin stall. In both cases the climb performance decreases as well."

The 5° bank angle maximum (for straight equilibrium flight) is indeed a regulatory limit imposed on manufacturers for sizing the vertical tail and for certification, because bank angles larger than 5° away from the inoperative engine increase the sideslip, which might result in a fin stall. That is why the limit is 5°. The small bank angle is used to determine V_{MCA}. At V_{MCA}, the sideslip angle is minimal, by design of the vertical tail. The 5° bank angle maximum therefore also applies to pilots for minimum sideslip and for the published and redlined V_{MCA} to be valid.

The side force introduced by the bank angle (W·sin φ, ref. 2) replaces the side force due to sideslip, that exists when the wings are kept level for balancing the side forces, establishing zero sideslip and therewith lowest drag and best OEI climb performance (ref. 2, § 3.4).
Hence, the 5° bank angle **does** indeed establish zero sideslip; that is inherent to the design of the vertical tail. However, zero sideslip at 5° bank only occurs only when the indicated airspeed is V_{MCA}. At higher airspeeds the vertical tail develops a larger side force for balancing the asymmetrical thrust yawing moment; then the rudder deflection can be smaller and the required opposite side force for equilibrium of side forces generated by the bank angle (W·sin φ) can also be smaller; weight W does not change, so bank angle φ can be smaller. This is why zero sideslip at higher speeds indeed occurs at bank angles less than 5°. Some airplanes require 3° of bank away from the inoperative engine for lowest drag, hence maximum climb performance, when the airspeed is V_{YSE}. Refer to the OEI performance data in the AFM/POH.

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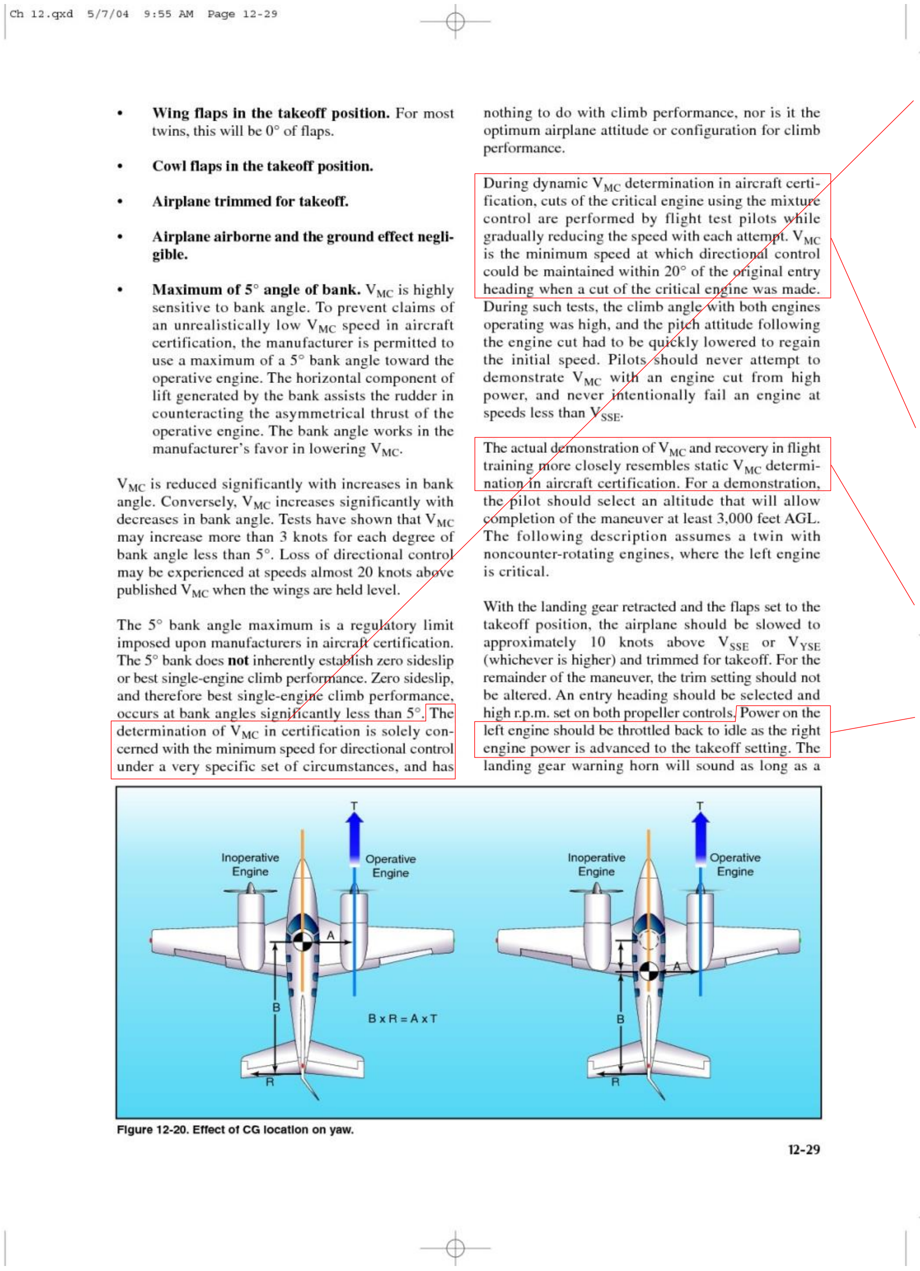

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- **Wing flaps in the takeoff position.** For most twins, this will be 0° of flaps.
- **Cowl flaps in the takeoff position.**
- **Airplane trimmed for takeoff.**
- **Airplane airborne and the ground effect negligible.**
- **Maximum of 5° angle of bank.** V_{MC} is highly sensitive to bank angle. To prevent claims of an unrealistically low V_{MC} speed in aircraft certification, the manufacturer is permitted to use a maximum of a 5° bank angle toward the operative engine. The horizontal component of lift generated by the bank assists the rudder in counteracting the asymmetrical thrust of the operative engine. The bank angle works in the manufacturer's favor in lowering V_{MC}.

V_{MC} is reduced significantly with increases in bank angle. Conversely, V_{MC} increases significantly with decreases in bank angle. Tests have shown that V_{MC} may increase more than 3 knots for each degree of bank angle less than 5°. Loss of directional control may be experienced at speeds almost 20 knots above published V_{MC} when the wings are held level.

The 5° bank angle maximum is a regulatory limit imposed upon manufacturers in aircraft certification. The 5° bank does **not** inherently establish zero sideslip or best single-engine climb performance. Zero sideslip, and therefore best single-engine climb performance, occurs at bank angles significantly less than 5°. The determination of V_{MC} in certification is solely concerned with the minimum speed for directional control under a very specific set of circumstances, and has nothing to do with climb performance, nor is it the optimum airplane attitude or configuration for climb performance.

During dynamic V_{MC} determination in aircraft certification, cuts of the critical engine using the mixture control are performed by flight test pilots while gradually reducing the speed with each attempt. V_{MC} is the minimum speed at which directional control could be maintained within 20° of the original entry heading when a cut of the critical engine was made. During such tests, the climb angle with both engines operating was high, and the pitch attitude following the engine cut had to be quickly lowered to regain the initial speed. Pilots should never attempt to demonstrate V_{MC} with an engine cut from high power, and never intentionally fail an engine at speeds less than V_{SSE}.

The actual demonstration of V_{MC} and recovery in flight training more closely resembles static V_{MC} determination in aircraft certification. For a demonstration, the pilot should select an altitude that will allow completion of the maneuver at least 3,000 feet AGL. The following description assumes a twin with noncounter-rotating engines, where the left engine is critical.

With the landing gear retracted and the flaps set to the takeoff position, the airplane should be slowed to approximately 10 knots above V_{SSE} or V_{YSE} (whichever is higher) and trimmed for takeoff. For the remainder of the maneuver, the trim setting should not be altered. An entry heading should be selected and high r.p.m. set on both propeller controls. Power on the left engine should be throttled back to idle as the right engine power is advanced to the takeoff setting. The landing gear warning horn will sound as long as a

Figure 12-20. Effect of CG location on yaw.

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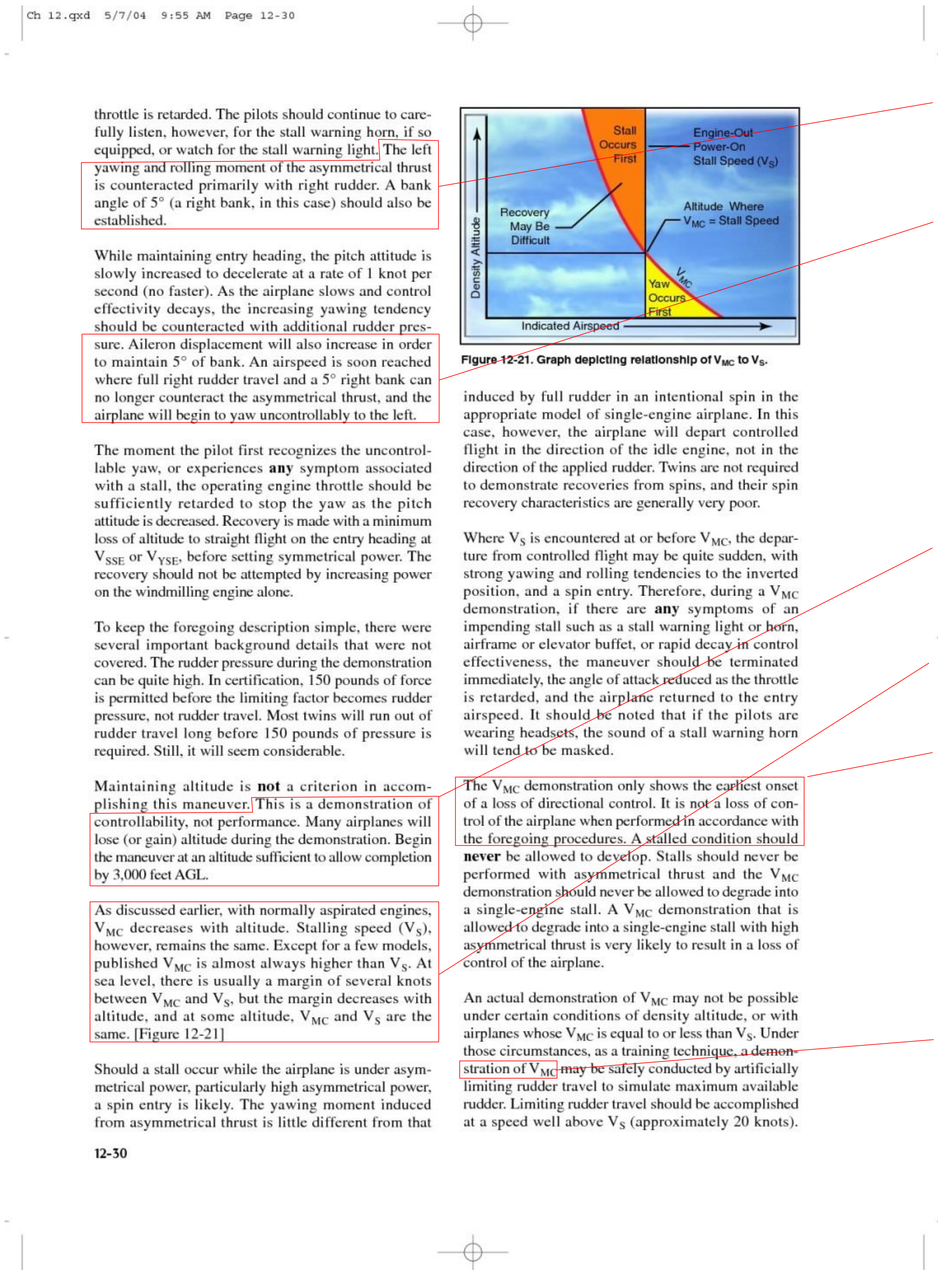
No, definitely not true. V_{MCA} is determined as minimum speed for maintaining straight flight only, definitely not for maintaining directional control at all bank angles. The specific circumstances result in a V_{MCA} that is always safe, whatever the values of the individual circumstances are, provided the small bank angle is being maintained while the thrust is maximal and the rudder is deflected to stop the yaw, up to maximum. The required bank angle for zero sideslip is already determined at the drawing board for sizing the vertical tail. V_{MCA} decreases with increasing bank angle, even beyond 5°, but V_{MCA} is determined at the bank angle for which the sideslip angle is zero, the drag minimal. As mentioned before, at bank angles larger than 5°, sideslip increases, which might result in a fin stall.
Bank angle, i.e. V_{MCA} (minimum airspeed for maintaining straight flight), ties minimum drag (maximum climb performance) to controllability (ref. 8).

It might not have been clear to the writers of Chapter 12 that a multi-engine airplane has both a static and a dynamic V_{MCA}. This paragraph is about the dynamic V_{MCA}, not about the dynamic determination of V_{MCA}. During determining the dynamic V_{MCA}, not only the heading could be maintained within 20° of the original heading, but in addition, the bank angle did not exceed 45°, no dangerous attitudes occurred and no exceptional piloting skill was required (FAR 23.149 (e)).

Static does not refer to a test (or demo) method, as might be referred to here, but to **the static V_{MCA}** of the airplane. It is recommended to read ref. 2 and the FAA Flight Test Guide, ref. 6 page 73.

For V_{MCA} demo, the engine should not be throttled back to idle, but to the zero drag or zero thrust/ torque setting (of the propeller). The AFM/ POH should provide this setting. When throttled back to idle, the drag of the idling propeller is not minimal; V_{MCA} will be higher than the published V_{MCA}.
The power of the operative engine should be advanced to the maximum power that the pilot can set, i.e. to full throttle. Takeoff power, in some cases, might be a little lower.



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throttle is retarded. The pilots should continue to carefully listen, however, for the stall warning horn, if so equipped, or watch for the stall warning light. The left yawing and rolling moment of the asymmetrical thrust is counteracted primarily with right rudder. A bank angle of 5° (a right bank, in this case) should also be established.

While maintaining entry heading, the pitch attitude is slowly increased to decelerate at a rate of 1 knot per second (no faster). As the airplane slows and control effectivity decays, the increasing yawing tendency should be counteracted with additional rudder pressure. Aileron displacement will also increase in order to maintain 5° of bank. An airspeed is soon reached where full right rudder travel and a 5° right bank can no longer counteract the asymmetrical thrust, and the airplane will begin to yaw uncontrollably to the left.

The moment the pilot first recognizes the uncontrollable yaw, or experiences **any** symptom associated with a stall, the operating engine throttle should be sufficiently retarded to stop the yaw as the pitch attitude is decreased. Recovery is made with a minimum loss of altitude to straight flight on the entry heading at V_{SSE} or V_{YSE}, before setting symmetrical power. The recovery should not be attempted by increasing power on the windmilling engine alone.

To keep the foregoing description simple, there were several important background details that were not covered. The rudder pressure during the demonstration can be quite high. In certification, 150 pounds of force is permitted before the limiting factor becomes rudder pressure, not rudder travel. Most twins will run out of rudder travel long before 150 pounds of pressure is required. Still, it will seem considerable.

Maintaining altitude is **not** a criterion in accomplishing this maneuver. This is a demonstration of controllability, not performance. Many airplanes will lose (or gain) altitude during the demonstration. Begin the maneuver at an altitude sufficient to allow completion by 3,000 feet AGL.

As discussed earlier, with normally aspirated engines, V_{MC} decreases with altitude. Stalling speed (V_S), however, remains the same. Except for a few models, published V_{MC} is almost always higher than V_S. At sea level, there is usually a margin of several knots between V_{MC} and V_S, but the margin decreases with altitude, and at some altitude, V_{MC} and V_S are the same. [Figure 12-21]

Should a stall occur while the airplane is under asymmetrical power, particularly high asymmetrical power, a spin entry is likely. The yawing moment induced from asymmetrical thrust is little different from that induced by full rudder in an intentional spin in the appropriate model of single-engine airplane. In this case, however, the airplane will depart controlled flight in the direction of the idle engine, not in the direction of the applied rudder. Twins are not required to demonstrate recoveries from spins, and their spin recovery characteristics are generally very poor.

Figure 12-21. Graph depicting relationship of V_{MC} to V_S.

Where V_S is encountered at or before V_{MC}, the departure from controlled flight may be quite sudden, with strong yawing and rolling tendencies to the inverted position, and a spin entry. Therefore, during a V_{MC} demonstration, if there are **any** symptoms of an impending stall such as a stall warning light or horn, airframe or elevator buffet, or rapid decay in control effectiveness, the maneuver should be terminated immediately, the angle of attack reduced as the throttle is retarded, and the airplane returned to the entry airspeed. It should be noted that if the pilots are wearing headsets, the sound of a stall warning horn will tend to be masked.

The V_{MC} demonstration only shows the earliest onset of a loss of directional control. It is not a loss of control of the airplane when performed in accordance with the foregoing procedures. A stalled condition should **never** be allowed to develop. Stalls should never be performed with asymmetrical thrust and the V_{MC} demonstration should never be allowed to degrade into a single-engine stall. A V_{MC} demonstration that is allowed to degrade into a single-engine stall with high asymmetrical thrust is very likely to result in a loss of control of the airplane.

An actual demonstration of V_{MC} may not be possible under certain conditions of density altitude, or with airplanes whose V_{MC} is equal to or less than V_S. Under those circumstances, as a training technique, a demonstration of V_{MC} may be safely conducted by artificially limiting rudder travel to simulate maximum available rudder. Limiting rudder travel should be accomplished at a speed well above V_S (approximately 20 knots).

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The rudder can only counteract the yawing moments and the rolling moments due to yawing and sideslip. The ailerons can only counteract the rolling moment caused by propulsive lift of the wing section behind the operative propeller and can establish the 5° favorable bank angle.

While slowing down, increased rudder is required to maintain heading, while gradually increasing the bank angle to maximum 5°, or to the value less than 5° if specified by the manufacturer.
It is recommended to first decelerate while the wings are kept level and note the airspeed when the yaw begins, and then gradually bank to 5° while slowing down further. This will show the effect of bank angle on V_{MCA}. For a small twin, the difference will be 8 – 10 kt. The V_{MCA} that is observed during this demo is an actual V_{MCA}, which might be higher (because of the idling engine) or lower than the standardized published and redlined V_{MCA}, because the factors that have influence on V_{MCA} happen not to be at their worst-case values, like a cg that is forward and into the operative engine, weight is not as low as possible, etc.

It is recommended to also demo (actual) V_{MCA} while the other engine is off.

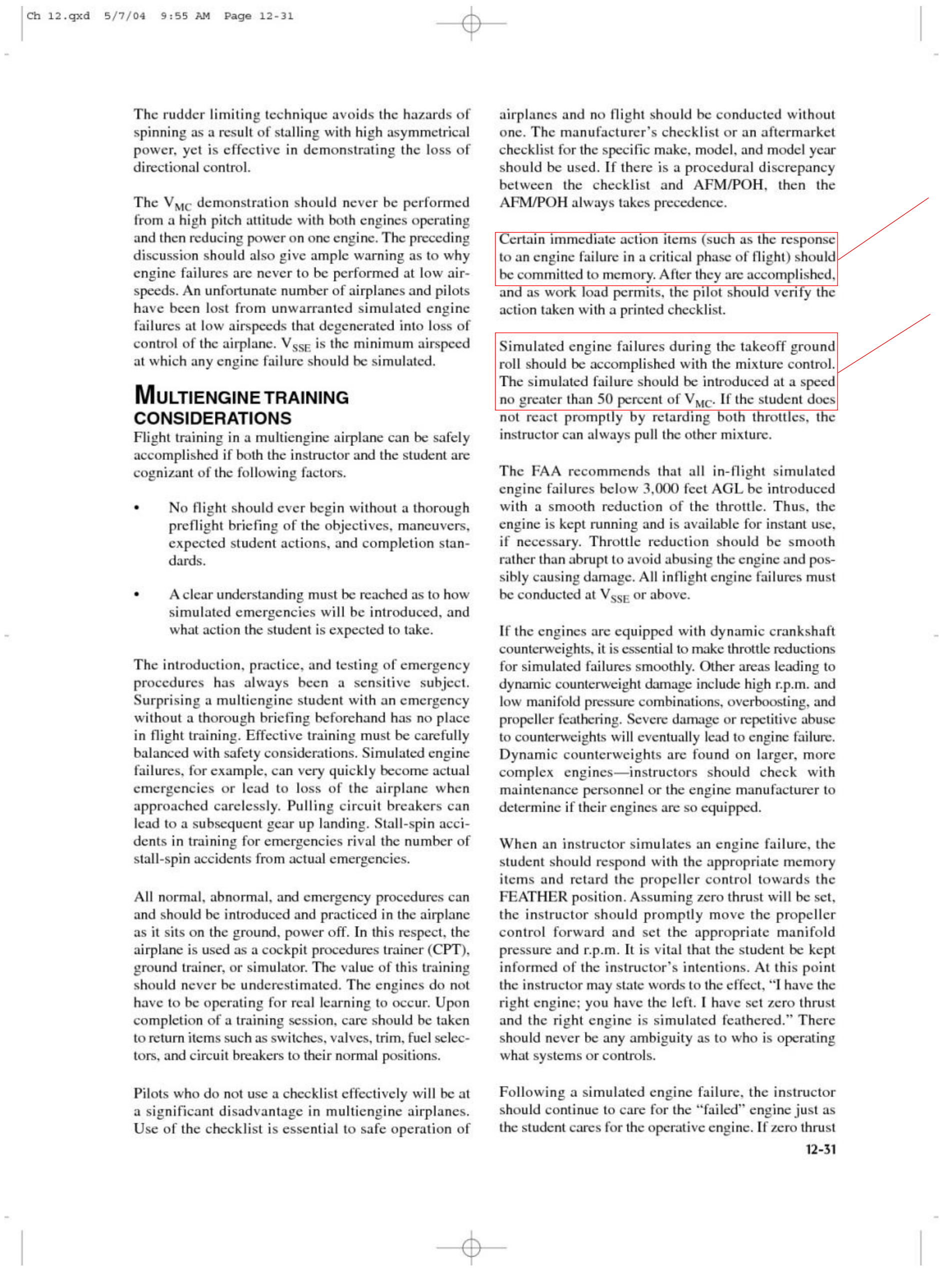
On the contrary, this can be and is a maneuver for demo of both controllability and performance. The rate of climb/ descend at V_{MCA} and at the current weight while OEI is a measure of performance. It is also recommended to jot down the ROC/D at the wings-level V_{MCA} and at the V_{MCA} with the favorable bank angle.

The decrease of V_{MCA} with altitude results from the decrease of engine thrust at altitude (lower thrust yawing moment). The decrease is usually linear, not curved as the figure shows.

This V_{MCA} demonstration shows an actual static V_{MCA}, which occurs when the airplane starts yawing to the dead engine side, despite full opposite rudder and/or aileron. This actual V_{MCA} will be lower than the published V_{MCA} unless the factors that have influence on V_{MCA} are at their worst-case values. It is a loss of control, because the heading cannot be maintained with full rudder and/ or full aileron. Only a reduction of asymmetrical thrust at the current airspeed, or an increase of airspeed results in regaining control.
The second sentence might refer to the dynamic V_{MCA} that, besides the dynamic $V_{MCA,}$ is also determined by experimental test flight crew.
In many cases the dynamic V_{MCA} of an airplane is lower than the static V_{MCA}. The highest of static and dynamic V_{MCA} is published in the AFM/POH as is also mentioned on page 12-.

Recommended is to change to: "a demonstration of an actual V_{MCA}", because this will not be the V_{MCA} of the airplane.

FAA-H-8083-3A, page 12-31.



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The rudder limiting technique avoids the hazards of spinning as a result of stalling with high asymmetrical power, yet is effective in demonstrating the loss of directional control.

The V_{MC} demonstration should never be performed from a high pitch attitude with both engines operating and then reducing power on one engine. The preceding discussion should also give ample warning as to why engine failures are never to be performed at low airspeeds. An unfortunate number of airplanes and pilots have been lost from unwarranted simulated engine failures at low airspeeds that degenerated into loss of control of the airplane. V_{SSE} is the minimum airspeed at which any engine failure should be simulated.

MULTIENGINE TRAINING CONSIDERATIONS

Flight training in a multiengine airplane can be safely accomplished if both the instructor and the student are cognizant of the following factors.

- No flight should ever begin without a thorough preflight briefing of the objectives, maneuvers, expected student actions, and completion standards.
- A clear understanding must be reached as to how simulated emergencies will be introduced, and what action the student is expected to take.

The introduction, practice, and testing of emergency procedures has always been a sensitive subject. Surprising a multiengine student with an emergency without a thorough briefing beforehand has no place in flight training. Effective training must be carefully balanced with safety considerations. Simulated engine failures, for example, can very quickly become actual emergencies or lead to loss of the airplane when approached carelessly. Pulling circuit breakers can lead to a subsequent gear up landing. Stall-spin accidents in training for emergencies rival the number of stall-spin accidents from actual emergencies.

All normal, abnormal, and emergency procedures can and should be introduced and practiced in the airplane as it sits on the ground, power off. In this respect, the airplane is used as a cockpit procedures trainer (CPT), ground trainer, or simulator. The value of this training should never be underestimated. The engines do not have to be operating for real learning to occur. Upon completion of a training session, care should be taken to return items such as switches, valves, trim, fuel selectors, and circuit breakers to their normal positions.

Pilots who do not use a checklist effectively will be at a significant disadvantage in multiengine airplanes. Use of the checklist is essential to safe operation of airplanes and no flight should be conducted without one. The manufacturer's checklist or an aftermarket checklist for the specific make, model, and model year should be used. If there is a procedural discrepancy between the checklist and AFM/POH, then the AFM/POH always takes precedence.

Certain immediate action items (such as the response to an engine failure in a critical phase of flight) should be committed to memory. After they are accomplished, and as work load permits, the pilot should verify the action taken with a printed checklist.

Simulated engine failures during the takeoff ground roll should be accomplished with the mixture control. The simulated failure should be introduced at a speed no greater than 50 percent of V_{MC}. If the student does not react promptly by retarding both throttles, the instructor can always pull the other mixture.

The FAA recommends that all in-flight simulated engine failures below 3,000 feet AGL be introduced with a smooth reduction of the throttle. Thus, the engine is kept running and is available for instant use, if necessary. Throttle reduction should be smooth rather than abrupt to avoid abusing the engine and possibly causing damage. All inflight engine failures must be conducted at V_{SSE} or above.

If the engines are equipped with dynamic crankshaft counterweights, it is essential to make throttle reductions for simulated failures smoothly. Other areas leading to dynamic counterweight damage include high r.p.m. and low manifold pressure combinations, overboosting, and propeller feathering. Severe damage or repetitive abuse to counterweights will eventually lead to engine failure. Dynamic counterweights are found on larger, more complex engines—instructors should check with maintenance personnel or the engine manufacturer to determine if their engines are so equipped.

When an instructor simulates an engine failure, the student should respond with the appropriate memory items and retard the propeller control towards the FEATHER position. Assuming zero thrust will be set, the instructor should promptly move the propeller control forward and set the appropriate manifold pressure and r.p.m. It is vital that the student be kept informed of the instructor's intentions. At this point the instructor may state words to the effect, "I have the right engine; you have the left. I have set zero thrust and the right engine is simulated feathered." There should never be any ambiguity as to who is operating what systems or controls.

Following a simulated engine failure, the instructor should continue to care for the "failed" engine just as the student cares for the operative engine. If zero thrust

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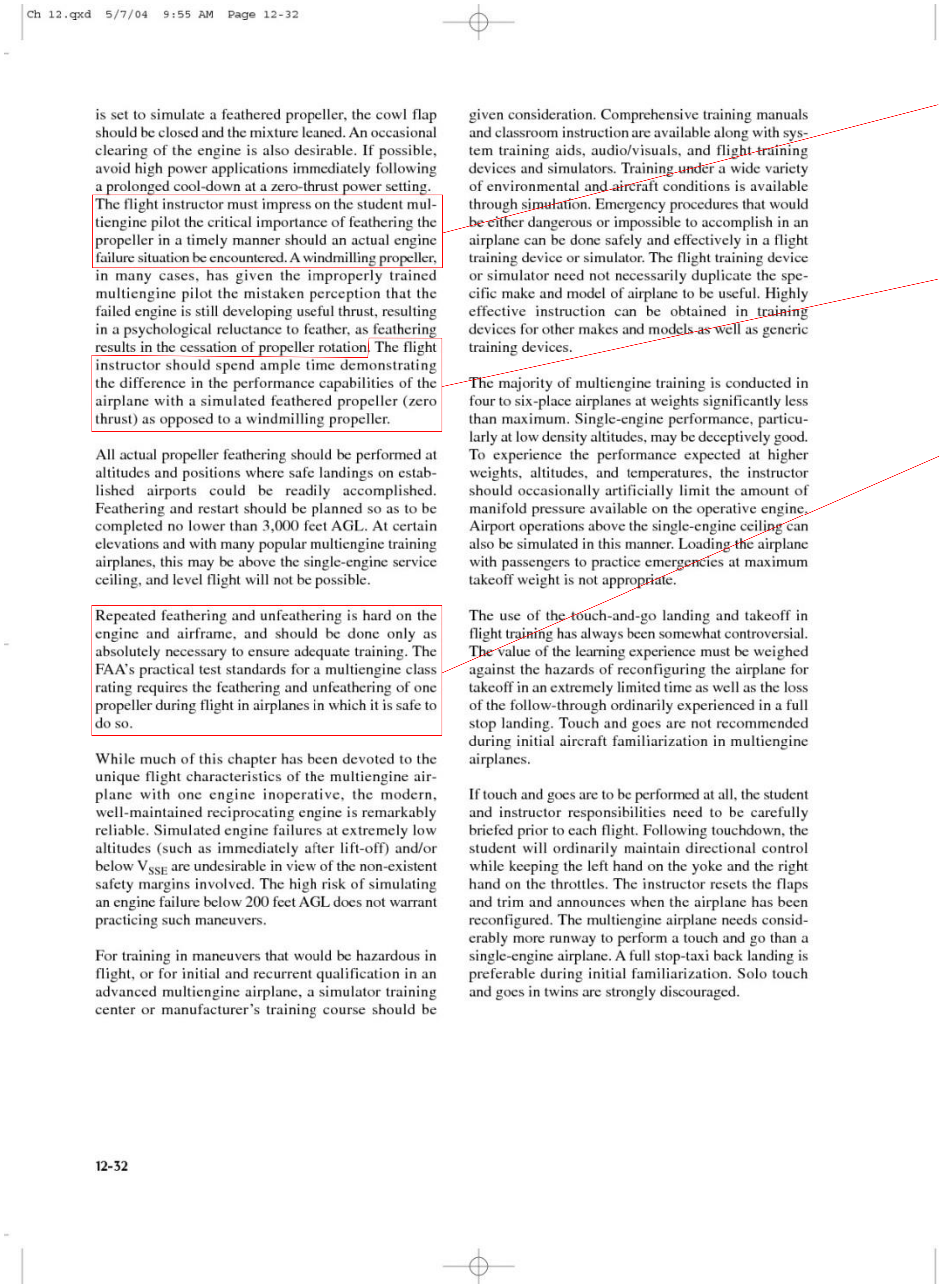
It is recommended to add to the first sentence: ", such as rudder to stop the yaw and aileron to bank 5° away from the failed engine".

Is V_{MC} meant here V_{MCG} or V_{MCA}? V_{MCG} was not mentioned earlier in this Chapter.
Why is it approved to use mixture control here? How much time does it take for the engine to respond? The speed will have increased by then!
It is recommended to close the throttle, rather than shutting down the engine.



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is set to simulate a feathered propeller, the cowl flap should be closed and the mixture leaned. An occasional clearing of the engine is also desirable. If possible, avoid high power applications immediately following a prolonged cool-down at a zero-thrust power setting. The flight instructor must impress on the student multiengine pilot the critical importance of feathering the propeller in a timely manner should an actual engine failure situation be encountered. A windmilling propeller, in many cases, has given the improperly trained multiengine pilot the mistaken perception that the failed engine is still developing useful thrust, resulting in a psychological reluctance to feather, as feathering results in the cessation of propeller rotation. The flight instructor should spend ample time demonstrating the difference in the performance capabilities of the airplane with a simulated feathered propeller (zero thrust) as opposed to a windmilling propeller.

All actual propeller feathering should be performed at altitudes and positions where safe landings on established airports could be readily accomplished. Feathering and restart should be planned so as to be completed no lower than 3,000 feet AGL. At certain elevations and with many popular multiengine training airplanes, this may be above the single-engine service ceiling, and level flight will not be possible.

Repeated feathering and unfeathering is hard on the engine and airframe, and should be done only as absolutely necessary to ensure adequate training. The FAA's practical test standards for a multiengine class rating requires the feathering and unfeathering of one propeller during flight in airplanes in which it is safe to do so.

While much of this chapter has been devoted to the unique flight characteristics of the multiengine airplane with one engine inoperative, the modern, well-maintained reciprocating engine is remarkably reliable. Simulated engine failures at extremely low altitudes (such as immediately after lift-off) and/or below V_{SSE} are undesirable in view of the non-existent safety margins involved. The high risk of simulating an engine failure below 200 feet AGL does not warrant practicing such maneuvers.

For training in maneuvers that would be hazardous in flight, or for initial and recurrent qualification in an advanced multiengine airplane, a simulator training center or manufacturer's training course should be given consideration. Comprehensive training manuals and classroom instruction are available along with system training aids, audio/visuals, and flight training devices and simulators. Training under a wide variety of environmental and aircraft conditions is available through simulation. Emergency procedures that would be either dangerous or impossible to accomplish in an airplane can be done safely and effectively in a flight training device or simulator. The flight training device or simulator need not necessarily duplicate the specific make and model of airplane to be useful. Highly effective instruction can be obtained in training devices for other makes and models as well as generic training devices.

The majority of multiengine training is conducted in four to six-place airplanes at weights significantly less than maximum. Single-engine performance, particularly at low density altitudes, may be deceptively good. To experience the performance expected at higher weights, altitudes, and temperatures, the instructor should occasionally artificially limit the amount of manifold pressure available on the operative engine. Airport operations above the single-engine ceiling can also be simulated in this manner. Loading the airplane with passengers to practice emergencies at maximum takeoff weight is not appropriate.

The use of the touch-and-go landing and takeoff in flight training has always been somewhat controversial. The value of the learning experience must be weighed against the hazards of reconfiguring the airplane for takeoff in an extremely limited time as well as the loss of the follow-through ordinarily experienced in a full stop landing. Touch and goes are not recommended during initial aircraft familiarization in multiengine airplanes.

If touch and goes are to be performed at all, the student and instructor responsibilities need to be carefully briefed prior to each flight. Following touchdown, the student will ordinarily maintain directional control while keeping the left hand on the yoke and the right hand on the throttles. The instructor resets the flaps and trim and announces when the airplane has been reconfigured. The multiengine airplane needs considerably more runway to perform a touch and go than a single-engine airplane. A full stop-taxi back landing is preferable during initial familiarization. Solo touch and goes in twins are strongly discouraged.

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FAA-H-8083-3A, page 12-32.

It is recommended to add the most important condition for maintaining control: attaining and maintaining a small bank angle away from the inoperative engine as the rudder is near maximum (which is an indication for being close to the actual V_{MCA}). In addition, the instructor must impress on the student the importance of maintaining straight flight until reaching a safe altitude (refer to page 12-10 above).

Add: spend ample time to demonstrate the effect of bank angle on V_{MCA}.

It is recommended to alternate the feathering of the right and the left engine. The difference of V_{MCA} and climb performance after shutting down or idling the left and right engines might not even be noticed. In addition, the pilot gets to experience failures of both the left and the right engine, which really ensures adequate training.

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CONCLUSIONS

Handbook FAA-H-8083-3A, as stated in the preface, '*conforms to pilot training and certification concepts established by the FAA. There are different ways of teaching, as well as performing flight procedures and maneuvers, and many variations in the explanations of aerodynamic theories and principles*.'
Many of the *variations* presented in Chapter 12 however, are regrettably neither in accordance with Advisory Circular 23-8C (FAA Flight Test Guide, ref. 6), nor with general airplane design methods as presented in the Airplane Design series of books by Dr. Jan Roskam (ref. 8) and Test Pilot School Engine-out training manual (ref. 10).
It seems that several writers wrote parts of this Chapter and that neither had proper knowledge about the subject and that no final review was conducted for differences that might confuse the readers. A thorough review by a qualified experimental test pilot, flight test engineer or even by an airplane design engineer at MSc level might have never taken place. The consequence is that Chapter 12 does not prevent the inappropriate crew response to propulsion system malfunctions, because both airplane performance and controllability after engine failure are not explained adequately and without errors. If used by accident investigators, the correct conclusions and recommendations will not be made (ref. 3).

Main conclusion is that there is indeed a huge knowledge and experience gap on the subject of airplane operations when an engine fails or is inoperative, between the worlds of experimental flight test and regular flight operations. This gap must be bridged to be able to increase flight safety.

Chapter 12, as it is today, *does not introduce basic pilot skills and knowledge* that are essential for continuing a flight safely while an engine fails or when an engine is inoperative. Some paragraphs, including the definition of V_{MCA}, are copied from FAR 23, which however is for designing and certifying airplanes, not for their operational use. Chapter 12 is not entirely written for pilots. All ingredients are present though, only the recipe is imperfect.

Some of the conclusions are that this Chapter does not teach that the AFM/POH published V_{MC}, which should be listed as V_{MCA}, not only applies after a sudden failure of the critical engine, but also after failure of the other engine and during the remainder of the flight as well. Further, it is not very clearly included that the published and redlined V_{MCA} is valid only during straight flight while banking a specified (fixed) number of degrees away from the inoperative engine and not a maximum of 5°. Turning when the airspeed is V_{MCA}, or even at an airspeed that is 20 kt higher than V_{MCA}, such as single engine climb speed V_{YSE}, might result in the loss of control if the thrust is high. The recommended altitudes of 400 ft and 500 ft AGL for turning while an engine is inoperative is dangerously low if the thrust is maintained at maximum setting. Turning while the airspeed is low and the thrust is high not only reduces climb performance, but also increases the actual V_{MCA}, which might result in the loss of control and hence in catastrophes. FAR 23 does not require the vertical tail of multi-engine airplanes to be designed large enough to maintain control during turns when the airspeed is V_{MCA}, but only for straight flight.

RECOMMENDATIONS

Chapter 12 should be improved for use by pilots; quite a few paragraphs require rewriting for this purpose. Several recommendations were already presented throughout this review.
Until Chapter 12 is improved, it is strongly recommended to take it off the Internet, because pilots using it might not survive an engine failure.

Prior to rewriting Chapter 12, it is recommended to review the FAA Flight Test Guide (ref. 6) and the free paper *Control and Performance during Asymmetrical Powered Flight* (ref. 2), or the more complete paper *Airplane Control and Accident Investigation after Engine Failure* (ref. 3) in which almost all there is to learn about flight with an inoperative engine and about V_{MCA} is explained; refer to the downloads page of www.avioconsult.com. The accidents page of this website presents a number of reviews and supplementary analyses of engine failure related accidents, to learn from.

Please feel free to contact Avio*Consult* via e-mail (info@avioconsult.com) for assistance.

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