Critical Limited Review

of

ATR 72 Performance Guide, Edition 2009

and

ATR 72 Airplane Flight Manual, rev. 29.0 JUN 21

on the subject of Engine-out Operations

Harry Horlings

Avio*Consult*

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Critical Limited Review of ATR 72 Performance Guide and ATR 72 Airplane Flight Manual
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This review is an initiative of and is written by Harry Horlings, Avio*Consult*, who is a graduate Flight Test Engineer of the USAF Test Pilot School, Edwards Air Force Base, CA, USA, 1985, and former Chief Flight Test of the Royal Netherlands Air Force (Lt-Col ret.).
For easy access to the referenced websites, download the most recent version of this Review here:
https://www.avioconsult.com/downloads/Review ATR-72 Pilot Manuals.pdf.

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E-mail: info@avioconsult.com.

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Executive Summary

Several ATR 72 pilots from around the globe asked Avio*Consult* questions about the safety of takeoff and approach speeds of their airplanes when an engine fails or is inoperative, after they found papers on the subject of flight with an inoperative engine on the website of Avio*Consult*. Avio*Consult* downloaded the applicable manuals from the Internet and reviewed these. It became very clear that the ATR manuals were written by people who have a different understanding of flight with an inoperative engine than is taught at aeronautical universities and experimental Test Pilot Schools. Avio*Consult* decided to support the pilots and write a critical though limited review of two of the ATR manuals and recommend ATR to improve the manuals.

The author of this limited review is retired Lieutenant-Colonel of the Royal Netherlands Air Force, graduate Flight Test Engineer of the USAF Test Pilot School, Edwards AFB, CA (1985) and has 15 years of experience in experimental flight-testing. The very few Test Pilot Schools around the globe, including EPNER in France, provide the highest level of flight and experimental flight test training; the entry level is usually an MSc degree in engineering or a BSc degree and an entry exam.

The review begins with a brief summary of the theory of flight with an inoperative engine, as taught at Aeronautical Universities and Test Pilot Schools, because most airline pilots were never taught this. Links to relevant Test Pilot School courses, academic books and Airworthiness Regulations are provided.

Major Conclusions

Performance Guide 2009. Writers of the Performance Guide were obviously and regrettably not made aware of the real meaning and value of minimum control speeds V_{MCG}, V_{MCA} and V_{MCL}, and of the flight restrictions that apply for the published V_{MC}'s to be valid. The large effect of bank angle on V_{MCA} and hence on the derived rotation speed V_R, the takeoff safety speed V_2 and on the climb performance, was not included while the unfamiliarity with this effect is the cause of most fatal accidents after engine failure.

While reviewing this Performance Guide, doubts arose about the real safety of the takeoff and approach speeds as calculated and explained, and about the correctness of performance data. This manual definitely needs a thorough review by competent people and must be improved.

ATR 72 Airplane Flight Manual. The presented definitions of V_R, V_2, V_{MCA} and V_{MCL} in this manual are the definitions that apply to airplane design engineers, but are improper for use by pilots. No guidance is given on the failure of the non-critical engine, while such a failure might turn out to be as dangerous as failure of the critical engine. Minimum control speeds apply after failure of either engine, not only after failure of the critical engine. Neither this, nor the control and performance restrictions that should be observed by pilots while using these speeds, in anticipation of and after a propulsion system (suddenly) fails or is inoperative, are included in their definitions and in legends of charts, and are not discussed either.
The take-off safety margins used in the Performance Section do not take into account the increase of minimum control speeds when the wings are kept level or during turns, and also seem pilot selectable (by applying variable V_1/V_R and V_2/V_{SR} ratios), which is not the intention of CS/FAR 25; the resulting safety margins are very small in engine-out cases, in a few cases even zero or negative. V_2 as used seems V_{2MIN}, which is too low. The minimum control and takeoff safety speeds seem underestimated in both reviewed ATR manuals, while many multi-engine airplanes crash following the loss of control after engine failure due to the not anticipated increase of these speeds. Most remarks will also apply to FCOM and QRH.

General conclusions. The limited reviewed manuals, especially the Performance Guide, seem engineering manuals while they should be manuals written for pilots, using pilot language and abbreviations/ acronyms that all pilots from around the globe understand and know from their initial training or from experience with other airplane types. Transitioning to ATR airplanes from other types is made unnecessarily difficult. The layout, section numbering and many of the used abbreviations might be acceptable to engineers, but are very uncommon for a pilots' manual. The AFM is not made with care for its intended users: the pilots of ATR airplanes. These conclusions will also apply to the other manuals: FCOM and QRH.

Major Recommendations

Replace the definitions of V_{MCA}, V_{MCG}, V_{MCL} and others with definitions that are applicable to pilots and include the flight restrictions that come with these speeds. Increase takeoff, approach, landing and go-around speeds with proper safety margins above the wings-level V_{MCA}. It is also strongly recommended to have the safety critical ATR manuals reviewed by competent, high level of experts (both flight and MSc engineering) to improve the manuals. This limited review could be used to make a start.

1. Introduction

1.1. Since 1996 more than 480 engine failure-related accidents with multi-engine airplanes were reported on the Internet, causing more than 4,000 casualties, despite the authoritative EASA/ FAA requirement that airplanes are thoroughly flight-tested while an engine is made inoperative, and minimum control speeds are determined and published. Avio*Consult* started reviewing Accident Investigation Reports, Airplane Flight Manuals and Multi-engine rating course material on this subject using the knowledge taught at aeronautical universities and Test Pilot Schools in an attempt to contribute to the reduction of the accident rate. It did not take long to conclude that there is an accident-causing knowledge gap between flight operations and experimental flight-test on the controllability of multi-engine airplanes after engine failure. Pilots are not made aware anymore of the real value of the minimum control speed V_{MCA} that is published as a speed limitation in the Airplane Flight Manual (AFM) and of the maneuver limitations that must be observed when an airspeed as low as or close to V_{MCA} is being maintained, neither during flight training nor in Airplane Flight and Operating Manuals. Manufacturers (except for a very few) do not publish correct definitions of the minimum control speeds and the accompanying maneuver limitations anymore in their manuals for pilots; authorities do regrettably not review and approve Airplane Flight Manuals adequately, most probably also because of the lack of knowledge. The consequence is that pilots maneuver their engine-out airplane in a way for which it was not designed and flight tested, and subsequently lose control and get killed, taking crew and passengers with them.

1.2. Following the publication of several levels of papers with thorough explanation of flight with an inoperative engine that are available from the Downloads page of the website of Avio*Consult*[1] and a video lecture on YouTube[2], Avio*Consult* received many compliments, as well as additional questions. Papers were also presented to the European Chapter of the Flight Safety Foundation[3], the EuroControl Safety Forum[4] in Brussels and to other organizations, such as FAA and LBA.
Several concerned pilots who noticed that the explanation of flight with an inoperative engine in ATR manuals does not agree with the published papers of Avio*Consult*, and who have doubts about the safety of the takeoff, landing and go-around speeds asked Avio*Consult* to review the ATR manuals on the subject.

1.3. This review was also written 'on invitation' by ATR Training & Flight Operations Services, as printed on page 156 of the Performance Guide:

> *"Dear Readers,*
> *Every effort has been made to ensure document quality.*
> *However please do not hesitate to share your comments and information with us by using the following address: flight-ops-support@atr.fr*
> *Yours faithfully,*
> *Your ATR Training and Flight Operations support team".*

but is limited to the Performance Guide and the AFM. The remarks and suggestions for improvement made in the paragraphs below may also apply to the corresponding paragraphs and data in both the ATR-72 FCOM and the QRH.

[1] Downloads page of website Avio*Consult*: https://www.avioconsult.com/downloads.htm.

[2] Harry Horlings, video lecture: *"The real value of the minimum control speed"*, https://youtu.be/Wbu6X0hSnBY.

[3] Harry Horlings, *"Staying Alive With a Dead Engine"*. Proceedings – European Aviation Safety Seminar (EASS), Athens, Greece, March 13 – 15, 2006.

[4] Harry Horlings, *"Safety Critical Procedure Development requires high level multi-disciplinary knowledge"*, https://skybrary.aero/sites/default/files/bookshelf/4665.pdf. PPT with working animations: https://www.avioconsult.com/downloads/Safety%20Forum%20slides%20AvioConsult%20June%202019%20-%20video%20links.ppsm.

1.4. Following reviewing the manuals, the author has indeed some very serious remarks on the subject of flight with an inoperative engine or when an engine suddenly fails, because not all of the provided guidance in the reviewed ATR Manuals is in agreement with airplane design methods as taught at aeronautical universities, nor with the intention of EASA and FAA airworthiness regulations, nor with (experimental) flight test techniques as issued by EASA[5] and FAA[6] and as taught at Test Pilot Schools[7] that are used worldwide to flight-test engine-out controllability and determine minimum control speeds in the air and on the ground.

1.5. The author of this limited review is graduate Flight Test Engineer of the USAF Test Pilot School, Edwards AFB, CA (1985). The very few Test Pilot Schools around the globe provide the highest level of flight training; the entry level was an MSc degree in engineering or a BSc degree and an entry exam. Test Pilot Schools teach aircraft performance, flying qualities, airborne systems and flight test management. Course duration is 11½ months; students receive academics and flight training, and conduct flight testing in some 24 different types of airplanes: gliders, fighter jets, single, twin and multi-engine propeller and turbojet transports and helicopters. Flight testing multi-engine airplanes while an engine fails or is inoperative and determining the Minimum Control Speed in the Air (V_{MCA}) is always part of the curriculum.

1.6. Prior to presenting the remarks on the ATR publications in this review, a brief summary is included of the theory of airplane control after engine failure and of the flight test techniques to determine V_{MCA} in-flight, for the remarks to be better understood. Refer to footnote 1 on page 5 for more extensive papers on the subject.

2. Airplane Control after Engine Failure

2.1. Minimum Control speed V_{MC} or V_{MCA}

2.1.1. When an engine fails, or is inoperative in-flight, the rudder is used to counteract the asymmetrical thrust yawing moment and the ailerons to counteract roll effects. The counteracting forces generated by these aerodynamic foils with control surfaces are proportional to ½ of the air density (ρ), to the square of the airspeed (V^2), to the area of the surfaces (S), and to lift coefficient (C_L) of the aerodynamic surface at the given angle of attack (α). For a given size of the vertical tail with rudder, there is a speed below which the produced rudder side force and yawing moment[8] is not large enough to counteract the asymmetrical thrust yawing moment and other forces and moments, such as those produced by sideslip, or below which the ailerons are not effective anymore to counteract the rolling tendency: the heading and/or bank angle cannot be maintained below this speed. This speed is called Minimum Control Speed.

2.1.2. CS/FAR 25.149 requires a Minimum Control Speed for straight flight only, and allows the design engineer to use a small bank angle of maximum 5° (away from the failed engine) for sizing the vertical tail. A small bank angle (ϕ) causes a component of the weight (W) to act as a side force ($W \cdot \sin \phi$) in the center of gravity along the Y (lateral) body axis[9] (Figure 1 below). This side

[5] EASA *Flight Test Guide*, https://www.easa.europa.eu/sites/default/files/dfu/agency-measures-docs-certification-specifications-CS-23-CS-23-Amdt-3.pdf#page=196 (from page 196).

[6] FAA *Flight Test Guide* Part 25 Airplanes (Controllability and Maneuverability, including V_{MCA} testing in § 5.4), https://www.faa.gov/documentLibrary/media/Advisory_Circular/25-7D.pdf

[7] Refer to https://www.avioconsult.com/links.htm, where links are provided to downloadable textbooks on (engine-out) flying qualities of two Test Pilot Schools.

[8] A moment is the product of a force and its perpendicular distance to the center of gravity, producing a rotation.

[9] Body axes system is a coordinate system that originates in the center of gravity and is fixed to the airplane. It is used in the equations of motion. The y-axis runs in the direction of the wing tips, the x-axis through nose and tail.

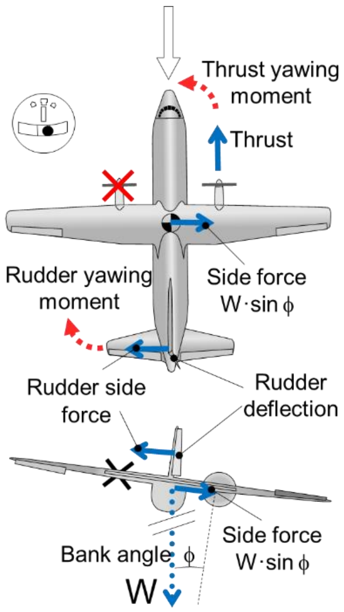


Figure 1. Equilibrium of lateral forces and moments when engine #1 inoperative.

force can be used to replace the side force due to sideslip that cannot be avoided when the wings are kept level.
Hence, the V_{MCA} of the airplane is already determined (i.e. assumed) by the airplane design engineer for sizing the vertical tail (fin)[10]. A vertical tail may not be designed that small that V_{MCA} increases above 1.13 V_S (CS/FAR 25.149). V_{MCA} is used in the calculation of takeoff speeds V_R (1.05 V_{MCA}) and V_{2MIN} (1.10 V_{MCA}). Operators want low takeoff speeds to be able to operate from shorter runways or with higher payload. This would require a low V_{MCA}, hence a large vertical tail. A large tail indeed results in a lower V_{MCA} but also in higher weight and production cost, which is not favorable to the sales of the airplane.
So. when maintaining a small bank angle into the good engine, the rudder doesn't have to overcome the side force due to sideslip, hence, the size of the vertical tail can be smaller and the airspeed lower for max. rudder. The small bank angle reduces the sideslip to zero, maximizing the one engine inoperative climb performance, and results in a lower V_{MCA}. A larger bank angle into the good engine increases the sideslip angle and might result in a fin stall because of the deflected rudder. A bank angle into the inoperative engine increases both V_{MCA} and the drag considerable, as will be shown below and might result in loss of control, even when keeping the wings level when the CAS = V_{MCA}.
Hence, the saved hardware weight of a smaller tail needs to be replaced by a quite 'heavy' software restriction for pilots (a warning on paper in the AFM to maintain straight flight and a small bank angle into the good engine) in case an engine fails or is inoperative and the thrust is increased to maximum. This restriction or condition is regrettably not included in ATR manuals; it is presented below.
To avoid misunderstanding, a bank angle alone does not always lead to a turn. A fighter jet showing a knife-edge maneuver (90° bank) still flies straight ahead. This is the reason that forces and moments in the body axes are used. Pilots are not used to work in body axes; engineers and test pilots are.
Refer to the paper '*Control and Performance during Asymmetrical Powered Flight*' (#2) on the downloads page of the website of Avio*Consult* (footnote 1 on page 5) for details on tail design and the use of V_{MCA}. The effects of bank angle and weight on V_{MCA} will be briefly discussed next.

2.1.3. Effect of Bank Angle and Weight on V_{MCA}

2.1.3.1. The chart in Fig. 2 below shows (the actual) V_{MCA} and the rudder, aileron and sideslip angle versus bank angle of a sample 4-engine airplane after failure of the left engine (#1) during equilibrium flight (the sums of all forces and moments are zero).
The airspeed at which both straight flight can be maintained with full rudder and the sideslip is zero while banking the small favorable bank angle (for min. drag), is published as standardized V_{MCA} in the AFM (in this example 85 kt). At bank angles larger than 6° away from the failed engine, for this sample airplane, the sideslip angle increases to 14°, the maximum possible angle of attack of the fin; the airspeed needs to be increased to avoid the fin to stall – the actual V_{MCA} (V-shaped line in the top graph) increases. At a larger bank angle, the rudder needs to be reversed to the other side, as shown in Fig. 2, for equilibrium of forces and moments.
The standardized AFM-published V_{MCA} is determined using a small bank angle (but <5°)

[10] *Airplane Design, 8-part set of books*, Dr Jan Roskam, KU and DARcorporation. https://shop.darcorp.com/index.php?route=product/product&product_id=59.

away from the inoperative engine.
The actual V_{MCA} is the V_{MCA} that a pilot would experience in-flight and can be lower, but is mostly higher than the standardized V_{MCA}, if the small favorable bank angle is not being maintained or the rudder is not up to maximum. The pilot "controls" actual V_{MCA} with bank angle.

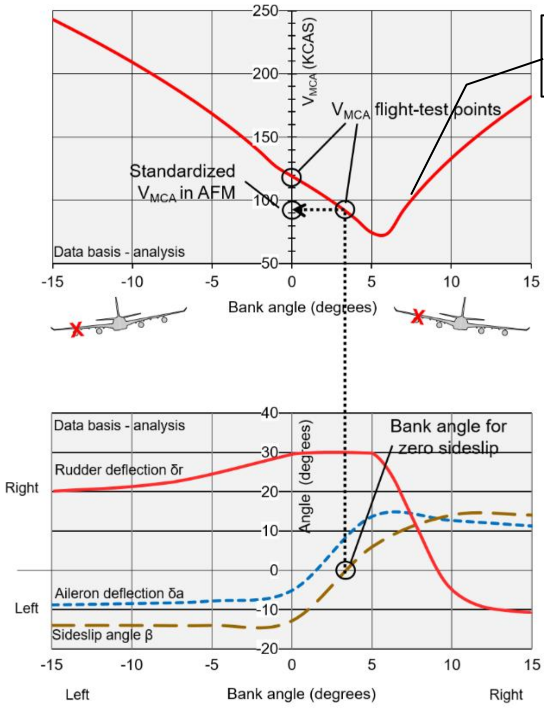


Fig. 2. Effect of bank angle on V_{MCA}.

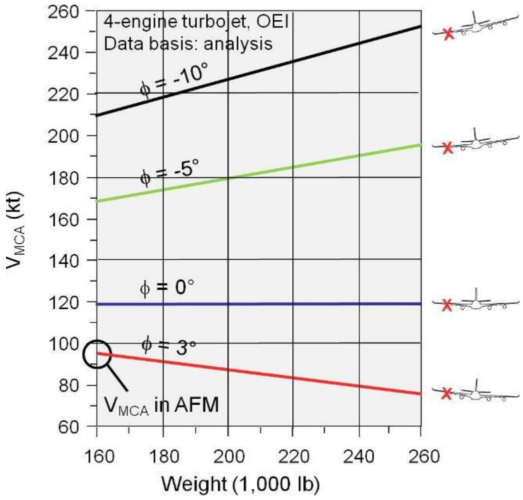


Fig. 3. Effect of bank angle ϕ and weight on V_{MCA} of a sample 4-engine airplane.

2.1.3.2. Notice that the wings-level V_{MCA} of this DC-8/ B-707 type airplane (Fig. 2) is 30 kt (!) higher than the AFM-published V_{MCA}. For smaller 2-engine airplanes, this increase might be less, down to 8 kt. For maneuvering safely with a small twin-engine airplane in the traffic pattern while an engine is inoperative, often a 30 kt higher airspeed is required.
The increase of V_{MCA} during banking away from the favorable bank angle also has effect on the safety of derived takeoff speeds V_R and V_2 because at these speeds, the wings are usually kept level; the required and calculated safety margins between takeoff speeds and the actual wings-level V_{MCA} are then smaller than anticipated.

2.1.3.3. The chart in Fig. 3 above shows the effect of bank angle and weight of the same sample airplane after failure of the outboard left engine (#1). This figure is similar to the figure that Lockheed presents in the C-130 Performance Manual SMP777. When banking into the inoperative engine, actual V_{MCA} increases with weight and the sideslip is large. If the bank angle is 3° away from the inoperative engine, the actual V_{MCA} decreases with increasing weight. While banking 3° away from the inoperative engine, during straight flight, V_{MCA} is highest at low weight, hence low weight is worst case weight for V_{MCA}, which is the reason that the fin is sized for and V_{MCA} is determined at the lowest weight possible. Airplane design engineers, by minimizing the size of the vertical tail, assume that pilots will maintain straight flight while banking a few degrees away from the inoperative engine when the airspeed is as low as V_{MCA} and the thrust on the operative engine is maximal, but AFM, FCOM and course book writers do not write about this life-saving restriction anymore, because adequate knowledge was not passed on and faded away over the years.

CS and FAR 25 regrettably do not require the manufacturer to publish the bank angle for which not only the AFM-published V_{MCA} is valid, and for which the required safety margins of the takeoff speeds above V_{MCA} can be maintained as well.

2.1.4. Flight-testing V_{MCA}

2.1.4.1. V_{MCA} is determined during experimental flight-testing using the flight-test techniques defined in EASA and FAA Flight Test Guides[5,6]. The airplane is in the test configuration, at low weight, center of gravity aft. At a safe altitude and an airspeed well above the anticipated V_{MCA}, the critical engine is shut down and its propeller feathered, the thrust of the operative engine is increased to maximum. The airspeed is slowly decreased while the wings are kept level (bank angle zero) until the heading can no longer be maintained with full rudder or 667 N (150 lbf) of foot pressure, or the bank angle cannot be maintained. This airspeed is the wings-level V_{MCA}. Then the bank angle is gradually increased into the good engine until the sideslip is zero, or to a maximum of 5° while decreasing the airspeed until again the heading (or bank angle) can no longer be maintained. The airspeed at which this occurs is the V_{MCA} of the airplane that will be published in the AFM. This V_{MCA} is approximately 8 – 10 kt lower than the wings-level V_{MCA}. If the pilot at this airspeed would return the wings to bank angle zero, the heading can obviously not be maintained; control will be lost. If a takeoff speed is maintained that is only 1.1 V_{MCA}, loss of control is imminent when the wings are kept level. Refer to the papers by Avio*Consult*[1] for further explanation of V_{MCA} and other V_{MCA} flight-tests.

2.1.5. Definition of V_{MCA}

2.1.5.1. FAR and EASA/CS 23.149 and equivalent present the definition of V_{MCA} for the design and certification of multi-engine airplanes as they apply to airplane design engineers and experimental test pilots:

> *V_{MC} is the 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 thereafter maintain straight flight at the same speed with an angle of bank of not more than 5 degrees.*

2.1.5.2. Most definitions of V_{MCA} (or V_{MC}) in publications for pilot's also state that V_{MCA} is valid with max. 5° of bank, without specifying the direction. Figures 2 and 3 on the previous page show that the airline pilot should not maintain a bank angle of maximum 5°, as is presented in V_{MCA} definitions in most AFM's, but the exact bank angle that was used to design, to size the vertical tail and at which the drag is minimal (in this example for a swept wing airplane 3°, yet usually 5°). The *"not more than"* or maximum 5° limitation is copied out of CS/FAR 25.149, which is for design and certification of airplanes, and definitely not (without adaptation) for operational use by pilots. Banking away from the so-called favorable bank angle that was used for designing the fin and for measuring V_{MCA} (usually 5°) at a calibrated airspeed that is as low as V_{MCA} while the thrust on the other engine is maximum and the rudder is maximum as well, will result in the loss of control that is not recoverable at low altitude. Many accident investigation reports were reviewed to confirm this.

2.1.5.3. Most manufacturers inappropriately copy this certification $V_{MC(A)}$ definition into their AFM's and lectures/textbooks for use by airline pilots, including ATR. However, once the airplane is designed and built, the selected tail size imposes a limitation on, i.e. a flight-restriction to, pilots, as was briefly explained above. The $V_{MC(A)}$ definition for use by pilots must therefore be different than the $V_{MC(A)}$ definition in CS/FAR 23.149 for the design and certification of airplanes by manufacturers. An improved definition of V_{MCA} for pilot's would be:

$V_{MC(A)}$ is the minimum speed for maintaining straight flight when an engine fails or is inoperative and the corresponding opposite engine is set to provide maximum thrust that the pilot can set from the cockpit [ATR: "Wall"*], provided a bank angle is being maintained of 3 – 5 degrees [exact number to be provided by the manufacturer] away from the inoperative engine.*

2.1.5.4. The manufacturer should specify the configuration for which this, and other published V_{MC}'s is/ are valid and suitably emphasize that the published V_{MC}'s are valid only for straight flight while maintaining the small specified favorable bank angle. Turns might be possible while either engine is inoperative, as long as rudder and/or ailerons are not yet maximal deflected leaving room for re-establishing and maintaining a new equilibrium of forces and moments during the turn, for preventing the loss of control. ATR should have published a minimum speed for turning with one engine inoperative.
If rudder and/or ailerons are already near maximum before initiating a turn, these controls might not have the authority for turning safely at too low a speed and a given weight (§ 2.1.3 above). The control inputs – and therewith V_{MCA} – can be decreased by (temporarily) reducing the thrust, or more specifically the asymmetrical thrust yawing and rolling moments, a little before initiating the turn. Then the safety margin between V_{MCA} and the calibrated airspeed increases, reducing the risk of losing control.
Some altitude will always be sacrificed during turns because the sideslip, hence drag increases (thrust is still asymmetrical – turns cannot be coordinated turns). Following the turn, attain the small favorable bank angle again first, then increase thrust and maintain straight flight. This also applies in the traffic pattern and during the approach for landing, because a V_{MCA} applies always when the thrust is asymmetrical.

2.1.6. **Publication of V_{MCA}**

2.1.6.1. As was explained above and shown in Figure 2, the (static) V_{MCA} flight-testing is limited to only two test points: wings level and bank angle for zero drag, both at a safe altitude. Dynamic V_{MCA} tests (sudden engine failure) are conducted at several airspeeds, down to dynamic V_{MCA}. The highest of static and dynamic V_{MCA} is published as the (standardized) V_{MCA} of the airplane in pilot manuals after extrapolating to sea level. The amount of V_{MCA} data is intentionally very limited to reduce the flight-test efforts and avoid errors by pilots while looking up V_{MCA} data in manuals.

2.1.6.2. CS/FAR 25.1513 states: *"The minimum control speed V_{MC} determined under CS 25.149 must be established as an operating limitation".* This paragraph requires only one V_{MC}, the standardized V_{MCA}, which of course is the worst-case V_{MC}. Still, CS and FAR allow the use of hot & high V_{MCA} data in tables or charts to allow for flight operations at lower takeoff speeds at hot & high airports, because then the maximum asymmetrical engine thrust is lower. ATR manuals publish V_{MCA} in charts with altitude and OAT as entry variables for use during all takeoffs, but the limitations and restrictions that come with V_{MCA} are not presented in the legend of the charts, as will be discussed below.

2.2. Critical Engine

2.2.1. The critical engine is the engine that, after its failure or when inoperative, results in the highest V_{MCA}. The difference in V_{MCA} after failure of engines #1 and #2 is caused by the shift of the thrust vectors (propulsion vector – P-vector[11]) in the propeller discs when the airspeed decreases and hence, the angle of attack increases. If the propellers are turning clockwise, like on

[11] P-vector (the Propulsion force with a magnitude and direction) is often written as P-factor. This is OK when the P-vector becomes a factor for directional control, i.e. when the P-vector laterally shifts in a propeller disc due to an increased angle of attack (at lower speeds) and results in increased rudder to counteract or, if already maximum, a higher required airspeed (V_{MCA}) during flight-testing. The effect of P-factor is included in the AFM-published V_{MCA}.

the ATR, the moment arm of the thrust of engine #1 decreases and the moment arm of the thrust of engine #2 increases. To counteract this thrust yawing moment for maintaining straight flight, a larger rudder deflection is required if engine #1 fails or, if the rudder is already maximum deflected, a higher airspeed: V_{MCA} will be higher. The minimum control speed (V_{MCA}) with maximum rudder after failure of engine #2 will be lower. Since V_{MCA} after failure of engine #1 is higher, engine #1 is called the critical engine.
The critical engine is the worst-case engine for the magnitude of V_{MCA} and is therefore assumed inoperative for designing, i.e. for calculating the required size of the vertical tail and is made inoperative during flight-testing to determine V_{MCA}. Refer to the paper #3 on the downloads page of website of Avio*Consult* (footnote 1 on page 5) for many more details.

2.2.2. Flight manuals publish the V_{MCA} that is determined after failure of the (or a) critical engine. This worst case V_{MCA} is valid as long as the bank angle is the same as was used for sizing the vertical tail and during V_{MCA} testing (usually 3° - 5° away from the inoperative engine) while the asymmetrical thrust is the maximum that can be set from the cockpit. A few more configuration items apply, such as an aft center of gravity (smallest rudder authority).
Many pilot-publications state that V_{MCA} increases when the critical engine fails. This is wrong, it is the other way around: when a non-critical engine fails, the actual V_{MCA} is (a little) lower – which is safer.

2.2.3. Hence, the term *'critical engine'* is only of use to airplane design engineers to ensure that they design a large enough vertical fin with rudder (for the worst case), and for test pilots to make sure they determine the highest, the worst case V_{MCA} after failure of any of the engines in-flight. The V_{MCA} published in the Flight Manual is a safe minimum speed to maintain straight flight for either inoperative engine as well as for any cg, provided the small bank angle is being maintained as well. Therefore, airline pilots should not have to worry whether a failing engine is *critical* or not; they should not even have to learn about the criticality of an engine. Just a single V_{MCA}, that is a safe minimum control speed before (i.e. in anticipation of) and after failure of either engine, applies, as does only a single engine emergency procedure. Maintaining the small bank angle away from the inoperative engine(s) is a life-saving restriction/condition for the lowest, safest possible actual V_{MCA} and also for minimum drag, whether the inoperative engine is the critical engine or not, as long as the thrust of the operative engine(s) is maximal.

2.2.4. Bank angle has a much larger effect on V_{MCA} than the critical engine, as was shown above. It is incomprehensible that the critical engine is mentioned and that the favorable bank angle is not included with V_{MCA} by manufacturers in their manuals.

2.2.5. During the take-off run, the effect of P-factor is less than in-flight; the angle of attack of the relative wind is the same on all propeller blades. Unless the propellers are not mounted exactly vertical, the Propulsion vector is out of the center of the propeller spinners for both engines; there is no thrust asymmetry and both engines are equally critical during the take-off run.

2.2.6. The outboard engines on turbofan/jet equipped airplanes are also equally critical, no P-factor, no thrust asymmetry with increasing angle of attack during take-off and in-flight. These airplanes do not have a "critical engine"; the outboard engines are equally critical. However, when on whatever type of airplane only one of the engines powers the rudder boosting system, that engine might be the critical engine.

2.2.7. When taking off in large crosswind, rudder is required to maintain the runway centerline. When the upwind engine fails, less rudder increase will be available to counteract the thrust yawing moment of the downwind engine; V_{MCG} and V_1 might have to be higher (depending on nose-wheel steering power – which was not used during determining V_{MCG}). The direction of the crosswind might determine which engine is critical (while in the take-off run); the critical engine on the ground might not be the critical engine in-flight.

2.3. Rotation Speed V_R and Take-Off Safety Speeds V_{2MIN} and V_2

2.3.1. The AFM-published V_{MCA} is one of the factors for calculating both the rotation speed V_R and the minimum take-off safety speed V_{2MIN}. Since this V_{MCA} is valid only for straight flight while maintaining a bank angle of 3 to 5 degrees, as should be specified by the manufacturer, away from the inoperative engine, both the calculated V_R (1.05 V_{MCA}) and V_{2MIN} (1.1 V_{MCA}) are also valid only when maintaining nearly the same bank angle (when the thrust setting is maximum take-off). It would be safer to use the wings-level V_{MCA} for calculating V_R and V_{2MIN}. Refer to the figures in § 2.1.3 above.

2.3.2. V_{2MIN} is a minimum V_2 used within CS/FAR 25 as entry variable to calculate takeoff safety speeds V_2. This V_{2MIN} may not be less than 1.13 V_{SR} and 1.1 V_{MCA}. The takeoff safety speed V_2 used during takeoff may not be less than V_{2MIN}, V_R plus the speed increment attained before reaching 35 ft, or a speed that provides maneuvering capability specified in CS 25.143(h).
If V_{2MIN} is used as V_2 by pilots, this V_2 might be only 10% higher than (worst case) V_{MCA}, that is determined with a constant small bank angle, and will allow hardly any maneuvering capability (refer to Fig. 2 in § 2.1.3 above). Hence, the V_{2MIN} used in CS/FAR is not the minimum, the lowest V_2 speed intended to be used by pilots during takeoff; they should use a higher takeoff safety speed V_2 (V_R + speed increment, + speed providing maneuver capability, ref. CS/FAR 25.149 - § 3.3.4 below). V_{2MIN} is not the lowest takeoff safety speed that provides the safety margin above the actual V_{MCA} that V_2 is supposed to provide. Regrettably V_{2MIN} is used by ATR as takeoff safety speed, rather than the higher V_2.

2.4. Recommendation

2.4.1. The paragraphs above will have presented theory of engine-out flight and data that many manual writers and pilots, who are responsible for writing and reviewing course material or calculating takeoff performance, have never heard of, and in many cases do not believe or even conclude 'cannot be right'. Those writers and pilots, without realizing, suffer from some kind of poverty of aviation knowledge and are, as a cure, strongly recommended to review Airplane Design college books as used at aeronautical universities, review the formal Flight Test Guides by EASA and FAA (footnotes 5 and 6 on page 6), or refer to the paper (#3) on the Downloads page of the website of Avio*Consult* (footnote 1 on page 5) titled: *"Airplane Control and Analysis of Accidents after Engine Failure"* that was written for Multi-Engine Flight Instructors and Accident Investigators. This paper includes a thorough review of most factors that have influence on engine-out controllability. As already mentioned, links to the formal EASA and FAA documents and to the courses of two Test Pilot Schools on asymmetrical flight are included on the Links page of the website of Avio*Consult* (footnote 7 on page 6). Also an experimental test pilot or a flight test engineer, graduates of one of the Test Pilot Schools, could be consulted. There is always more to learn.

3. ATR Performance Guide, ATC 2009

3.1. This Performance Guide, edition 2009, was issued by ATR Training & Flight Operations Services, as printed on the cover sheet, and downloaded from the Internet. As already mentioned in § 1.1, this version might not be the most recent one. If the paragraphs of the current version were improved, please ignore the remarks presented below. In this chapter, remarks that are already presented above will be repeated or referred to, if applicable.

3.2. ATR Performance Guide Chapter A. General

3.2.1. **Remark**. While browsing this chapter, it became clear that several improvements can be made. It is recommended to have this chapter reviewed by an aviator-expert, to present the contents in a format recognizable by pilots and to limit the content to what pilots really need for transitioning to ATR aircraft. This chapter is not intended for initial pilot training, is it?

3.3. ATR Performance Guide Chapter B. Aircraft Limitations

3.3.1. ATR Performance Guide Chapter B § 1.3.1. Minimum Control Speed on the Ground: V_{MCG}.

Paragraph CS/FAR 25.149 (e) is copied into this ATR Manual.

> *"(e) V_{MCG}, the minimum control speed on the ground, is the calibrated airspeed during the take-off run, at which, when the critical engine is suddenly made inoperative, it is possible to maintain control of the aeroplane with the use of the primary aerodynamic controls alone (without the use of nose-wheel steering) to enable the take-off to be safely continued using normal piloting skill.*
>
> *In the determination of V_{MCG}, assuming that the path of the aeroplane accelerating with all engines operating is along the centreline of the runway, its path from the point at which the critical engine is made inoperative to the point at which recovery to a direction parallel to the centreline is completed, may not deviate more than 30 ft laterally from the centreline at any point.*
>
> *V_{MCG} must be established, with:*
>
> *(1) The aeroplane in each take-off configuration or, at the option of the applicant, in the most critical take-off configuration;*
>
> *(2) Maximum available take-off power or thrust on the operating engines;*
>
> *(3) The most unfavorable center of gravity;*
>
> *(4) The aeroplane trimmed for take-off; and*
>
> *(5) The most unfavorable weight in the range of take-off weights."*

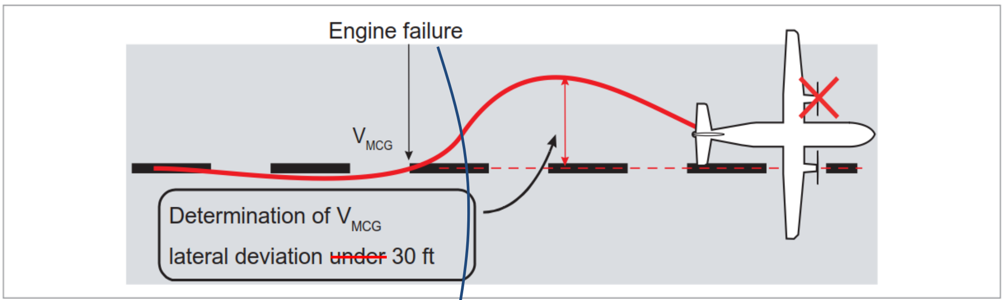
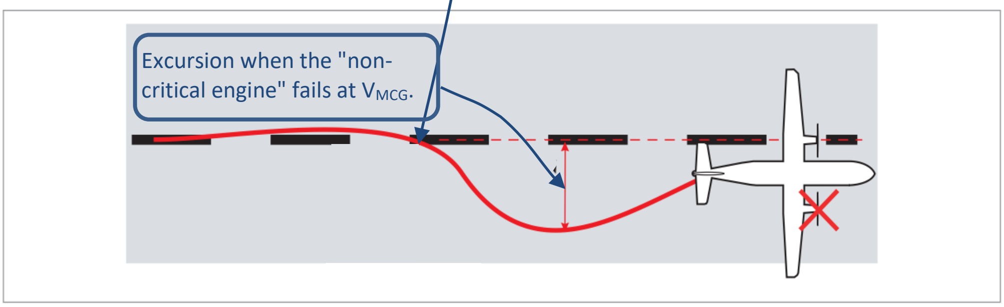


Figure B2: *Minimum Control speed on the Ground: V_{MCG}*



3.3.1.1. **Remarks**. CS/FAR 25.149(e) are Specifications/ Regulations that provide guidance to airplane manufacturers for the design and certification of airplanes, and for experimental flight-testing the airplanes. V_{MCG} is the airspeed at which the deviation is

30 ft (9.1 m) from the projected ground track when during the takeoff run one of the engines, critical or non-critical, fails while maximum takeoff thrust is selected on all engines. At airspeeds lower than V_{MCG}, the excursion will be more than 30 ft (9.1 m), when the throttles are not immediately closed when either engine fails; the takeoff needs to be aborted. At airspeeds higher than V_{MCG} (such as V_1) the excursion will be less and the takeoff can continue. The dangerous experimental flight tests to determine V_{MCG} start at a speed well above V_{MCG}. The path after the failure of the non-critical engine should be added in Figure B2, as shown above.

3.3.1.2. The conditions listed in subparagraphs (1) to (5) above represent the worst-case conditions to be used for airplane design and experimental flight test. An airline pilot should not have to know these, they might even cause confusion. An airline pilot will be allowed to additionally use the nose wheel steering and hence will experience less deviation on the runway after engine failure.

3.3.1.3. The term *"Critical Engine"* should not be used in the V_{MCG} definition for pilots because during acceleration on the ground, there is no or hardly any shift in P-vector in the propeller disks, refer also to § 2.2.5 above on the Critical Engine. If the propellers are tilted down a little, the shift is opposite from the shift while airborne. An airline pilot doesn't need to know about the criticality of a failing engine, unless this engine is the only engine that provides the (hydraulic) power to the rudder boosting system, although this will also be one of the factors for determining a single, worst-case V_{MCG}.

3.3.1.4. **Recommendation**. Delete the CS/FAR paragraph and include the following suggested V_{MCG} definition as it applies to pilots:

> *"V_{MCG} is the minimum calibrated airspeed at which the airplane is safely controllable after failure of either engine if the takeoff is continued. The deviation from pre-failure ground track will not exceed 9.1 m (30 ft).*
>
> *When the airspeed is below V_{MCG} [or the derived V_1] when an engine fails, both throttles need to be closed at once to avoid a runway excursion accident"*.

3.3.2. **ATR Performance Guide Chapter B § 1.3.1 continues:**

> *"V_{MCG} is increased in case of narrow runway. ATR aircraft are certified to operate normally on runways whose widths are at least 30m (98ft). However, a specific modification allows to operate on runways down to 14-meter (46ft) wide, please refer to AFM 7.01.09 or FCOM 3.11.10, Operations on narrow runways. In this case, the V_{MCG} is increased, and as a consequence V1 (please refer to Paragraph C.2.2.2, Decision Speed.)*
>
> *Example: For ATR 72-500, when the runway width is down to 14m, V_{MCG} is increased by 5 kt."*

3.3.2.1. **Remarks**. On a narrow runway, V_{MCG} will of course be higher because the lateral deviation after engine failure needs to be smaller. Not clear is whether the term "*specific modification"* means a hardware modification or only an adjusted/ increased V_{MCG} 'condition' on paper. Should it not be emphasized that the response time to close the throttles after engine failure or after an uncommanded deviation from the pre-failure ground track, when CAS < V_1, must be as short as possible, in any case < one second?

3.3.2.2. In addition, an increase of V_{MCG} and the derived V_1 might also apply during a takeoff in crosswind conditions when the upwind engine fails, which is not discussed. The pilot needs to apply (decreasing) rudder from the beginning of the takeoff roll, for counteracting the weathercock (sideslip) yawing moment due to crosswind. If the upwind engine fails just after passing V_{MCG} (or V_1, for example at 110 kt) and the crosswind component happens to be (the max. approved) 35 kt, then the equivalent sideslip (crab) angle that needs to be counteracted by the rudder (and nose wheel steering) is still 17° ($\tan^{-1}$ (35/110), which requires a substantial amount of rudder. The sideslip yawing moment due to the crosswind component enlarges the engine yawing moment, resulting in less available rudder increase to counteract the asymmetrical engine thrust yawing moment as well and consequently in a higher V_{MCG}.

3.3.2.3. It should be further analyzed whether or not it is safer to increase V_1 and/or runway width during operations in crosswind conditions.

3.3.3. **The following NOTE is also included in ATR Performance Guide Chapter B § 1.3.1:**

> *"The V_{MCG} of the ATR 72-500 are lower than the ATR 42-500, because they are both equipped with the same engine PW127M, but as the ATR 42 is smaller, in case of engine failure, for the same power, the dissymetry will be more important, and a higher speed is needed to control the aircraft."*

3.3.3.1. **Remark.** As both airplane types are said to be equipped with the same engines that are positioned at the same distance (thrust moment arm) from the center of the fuselage, there is no *"dissemetry"* (usually called asymmetry); the thrust yawing moments of the engines of both airplane types are equal. The size of the vertical tail with rudder also seems identical. The only difference is a shorter moment arm from the center of gravity to the rudder on the ATR 42 as compared to the ATR 72, requiring a higher speed to produce the rudder yawing moment to counteract the asymmetrical thrust yawing moment after engine failure, hence V_{MCG} is higher.
Including this note raises the question whether the published V_{MCG} is determined with an ATR-42, an ATR-72 or both, with what engine type or derated engine, with what power setting (must be the maximum a pilot can set from the cockpit), and therewith whether the published V_{MCG} and the derived V_1 and V_R comply with the Regulations.

3.3.4. **ATR Performance Guide Chapter B § 1.3.2. Minimum Control Speed in the Air: V_{MCA}**

3.3.4.1. The definition of V_{MCA} is also copied out of CS/FAR 25.149 (b) into this ATR Manual and seems used to explain V_{MCA}. But CS/FAR are for the certification of airplanes, not for their operational use.

> *"(b) $V_{MC[A]}$ is the calibrated airspeed, at which, when the critical engine is suddenly made inoperative, it is possible to maintain control of the aeroplane with that engine still inoperative, and maintain straight flight with an angle of bank of not more than 5 degrees.*
>
> *(c) $V_{MC[A]}$ may not exceed 1.13 V_{SR} with*
>
> *(1) Maximum available take-off power or thrust on the engines;*
>
> *(2) The most unfavorable center of gravity;*
>
> *(3) The aeroplane trimmed for take-off;*
>
> *(4) The maximum sea-level take-off weight;*
>
> *(5) The aeroplane in the most critical take-off configuration existing along the flight path after the aeroplane becomes airborne, except with the landing gear retracted; and*
>
> *(6) The aeroplane airborne and the ground effect negligible.*
>
> *(d) During recovery, the aeroplane may not assume any dangerous attitude or require exceptional piloting skill, alertness, or strength to prevent a heading change of more than 20 degrees".*

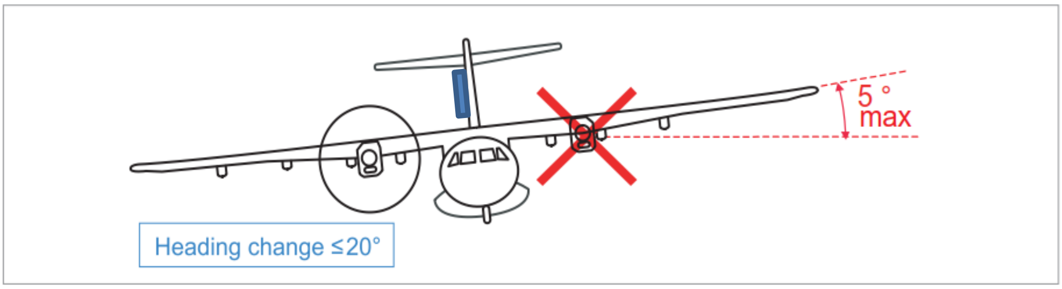


Figure B3: Minimum Control speed in the Air: V_{MCA}

3.3.4.2. **Remarks.** As stated in the previous paragraph**,** CS/FAR 25.149 is for airplane design engineers. It provides the requirements and the conditions for sizing the vertical tail with rudder and the ailerons, and is also used by experimental test pilots and flight test engineers for conducting experimental and certification flights while an engine fails and/or is inoperative. Refer to the theory in § 2 above. Manufacturers should provide a V_{MCA} definition that is more adapted for operational use by pilots; a suggestion is presented in § 2.1.5.2 above.

3.3.4.3. "*Critical engine"* is used during design and flight testing, because V_{MCA} after failure of that engine is a little higher than V_{MCA} after failure of the other engine. However, when the non-critical engine fails the published V_{MCA} also applies! In addition, V_{MCA} not only applies after a *sudden* failure, but also when an engine failed during takeoff and is inoperative during the remainder of a flight. Pilots do not need to know about the *"critical engine"* (§ 2.2 above). Only one V_{MCA} applies, as well as only one engine emergency and/or abnormal procedure after either engine failure.

3.3.4.4. *Straight flight with an angle of bank of not more than 5°*. A bank angle of max. 5°, as shown in Figure B3 above, refers to the maximum steady bank angle that airplane design engineers are allowed to use for sizing the vertical tail and analyzing the controllability while an engine is inoperative, and for experimental test pilots during determining V_{MCA} in-flight. While applying the steady, constant selected bank angle for the conditions under (c), the sideslip is minimal (§ 2.1.3 above), hence the climb performance maximal, and the actual V_{MCA} is lower than with the wings level. V_{MCA} is the lowest airspeed at which the heading can just be maintained[12] (for the conditions under (c).
"*5° max*" is definitely not meant for airline pilots, on the contrary, airline pilots need to maintain the exact same small bank angle away from the failed or inoperative engine that was used by the tail design engineer for sizing the vertical tail, which is usually but not necessarily 5° into the good engine when the thrust is maximal and the airspeed is V_{MCA} or close to V_{MCA}. As shown in § 2.1.3 above, keeping the wings level of the sample airplane increases V_{MCA} by some 8 – 10 kt and increases the drag affecting the Rate Of Climb. V_{MCA} is defined and determined for straight flight, definitely not for turns. This V_{MCA} is also called the static V_{MCA} and applies from takeoff to approach.

3.3.4.5. The line *"to prevent a heading change of more than 20°"* is also for experimental test pilots. During dynamic V_{MCA} testing (sudden engine failure), that is conducted at several airspeeds, the heading change may not exceed 20°, etc. The highest of static and dynamic V_{MCA} will be published as the V_{MCA} of the airplane. Usually, the static V_{MCA} is the highest, the worst case.

3.3.4.6. V_{MCA} only warrants pilots to being able to regain control after a sudden engine failure and thereafter maintain straight flight while banking 5° {or as determined by the

[12] Dr. Jan Roskam (Kansas University, DAR Corporation) wrote in his college book *Airplane Design: Preliminary sizing of airplanes* on tail design: *"The $V_{MC(A)}$ value ultimately used ties takeoff performance to engine-out controllability"*.

manufacturer) away from the failed engine while an engine is inoperative. The published V_{MCA} is not valid for wings-level flight or during turns. The manufacturer should therefore publish the bank angle that was used for sizing the vertical tail and for which the sideslip in minimal and hence, the published V_{MCA} is valid in the legend of the V_{MCA} data charts in the Airplane Manuals, and also emphasize that V_{MCA} is valid only during straight flight, definitely not during turns. Also to emphasize is that at V_{MCA}, the rudder needs to remain deflected up to maximal or to a rudder pressure of 667 N (150 lbf) as long as the asymmetrical thrust is maximal (and rudder trim is not yet adjusted).

3.3.4.7. *"$V_{MC[A]}$ may not exceed 1.13 V_{SR}".* This is not a limit of importance to pilots, but is also for airplane design engineers. They would like to design a vertical tail as small as possible to reduce weight and manufacturing cost. But a smaller tail requires a higher airspeed for producing the (horizontal) lift of the fin, the side force required to counteract the asymmetrical thrust yawing moment when one of the engines fails. By imposing a speed limit on V_{MCA} (1.13 V_{SR}), the certifying authorities ensure the tail will not be too small. Hence, pilots do not need to know this maximum limit, it is included in the published V_{MCA}. See also § 2.1.2 above.

3.3.4.8. *"Maximum available take-off power or thrust on the engine".* This is also a condition that applies to design engineers for sizing the vertical tail, but could also serve as reassurance for pilots that the published V_{MCA} and the therewith derived takeoff speeds warrant protection against the loss of control when an engine fails.
V_{MCA} must be determined at the maximum (asymmetrical) thrust a pilot can set from the cockpit, meaning max. PLA and/or related power buttons or (assumed/flexible) temperature settings, and with the propeller of the inoperative engine feathered, if feathering is automatic. After reviewing the AFM, it is not quite sure that the *"Maximum available take-off power or thrust on the engine"* was indeed used to determine V_{MCA}. Refer also to § 4.4 below.

3.3.4.9. "*the most unfavorable center of gravity*", which is the aft center of gravity for ATR airplanes. With an *aft cg*, the moment arm to the rudder is shortest, and V_{MCA} is highest – is worst-case. The effect of cg location is included in the published V_{MCA}. When the cg is more forward, the actual V_{MCA} might be a little lower, which is safer.

3.3.4.10. "*maximum sea-level take-off weight or less to show $V_{MC(A)}$*" is indeed stated in the Regulation for determining V_{MCA}, but CS/FAR Flight Test Guides (Footnotes 5 and 6 on page 6) require minimum weight, because then the V_{MCA} is highest when the small bank angle into the good engine for zero drag is maintained. In other words, minimum weight is the worst-case weight for V_{MCA} when the small favorable bank angle into the good engine is being maintained for minimum drag (refer to Figures 2 and 3 in § 2.1.3 above). Increasing the bank angle into the good engine, increases the sideslip, and leads to a fin stall. A higher speed is required to avoid this stall (V_{MCA} is higher). To maintain equilibrium of forces and moments, the rudder needs reversed, refer to the figures in § 2.1.3 above.
When banking to the other side, into the inoperative engine, V_{MCA} increases not only with bank angle, but also with weight, refer to Figures 2 and 3 in § 2.1.3.

3.3.4.11. A *"heading change ≤ 20°"* after engine failure, as shown in Figure B3, is a maximum that is allowed during flight-testing the dynamic V_{MCA}, being the V_{MCA} following a sudden engine failure (i.e. *"suddenly made inoperative*" during the test flight). If the heading change during flight-testing is larger, V_{MCA} will have to be increased. Heading change is not a criterion/guarantee for airline pilots. If a pilot does not apply adequate rudder and bank angle into the good engine immediately following the engine failure when the airspeed is as low as V_{MCA} and the asymmetrical thrust is maximal, then the heading change will increase larger than 20°, as Flight Data Recorder data in many accident investigation reports show. Heading and bank changes at V_{MCA} are not always rapid, so pilots do not consider these a danger. But as they allow the bank angle to increase, they will not be able to return to the favorable bank angle, because control is lost. Only a temporary small reduction of asymmetrical thrust can be a remedy.

3.3.4.12. *"The aeroplane airborne and the ground effect negligible"*. When is an ATR airplane out of ground effect? At height > half wingspan?
In addition, a V_{MCA} applies during the whole flight, all the time, not only after an engine failure but also in anticipation of an engine failure, from liftoff to landing.

3.3.4.13. **Conclusion and Recommendation**. V_{MCA} warrants pilots to being able to regain control after a sudden engine failure and thereafter maintain straight flight only. The published V_{MCA} is not valid for wings-level flight or during turns. The Rate of Climb will decrease and control might be lost if a pilot does not maintain the small bank angle that the manufacturer used for sizing the vertical tail and during determining V_{MCA}. It is therefore strongly recommended to replace the V_{MCA} definition in this paragraph and in the Airplane Manuals with an improved definition for pilots, for instance:

> V_{MCA} is the minimum speed for maintaining straight flight when an engine fails or is inoperative and the opposite engine is set to provide maximum thrust (ATR: "*Wall*"), provided a bank angle is being maintained of 3 – 5 degrees [exact number to be provided by the manufacturer] away from the inoperative engine.
>
> Banking away from this bank angle increases the sideslip (drag) and increases V_{MCA} and the probability of a fin stall and the loss of control.

and not include all of the conditions out of CS/FAR 25.149 that do not apply to pilots.

3.3.5. ATR Performance Guide Chapter B § 1.3.3. Minimum Control Speed during Approach and Landing: V_{MCL}

3.3.5.1. The definition of V_{MCL} is also copied out of CS/FAR 25.149 (b) into this ATR Manual.

> *" (f) V_{MCL}, the minimum control speed during approach and landing with all engines operating, is the calibrated airspeed at which, when the critical engine is suddenly made inoperative, it is possible to maintain control of the aeroplane with that engine still inoperative, and maintain straight flight with an angle of bank of not more than 5°. V_{MCL} must be established with:*
>
> > *(1) The aeroplane in the most critical configuration (or, at the option of the applicant, each configuration) for approach and landing with all engines operating;*
> >
> > *(2) The most unfavorable center of gravity;*
> >
> > *(3) The aeroplane trimmed for approach with all engines operating;*
> >
> > *(4) The most unfavorable weight, or, at the option of the applicant, as a function of weight (...)*
> >
> > *(6) Go-around thrust setting on the operating engines*
>
> *(h) In demonstrations of V_{MCL} (...)*
>
> > *(3) Lateral control must be sufficient to roll the aeroplane from an initial condition of steady straight flight, through an angle of 20 degrees in the direction necessary to initiate a turn away from the inoperative engine(s) in not more than 5 seconds."*

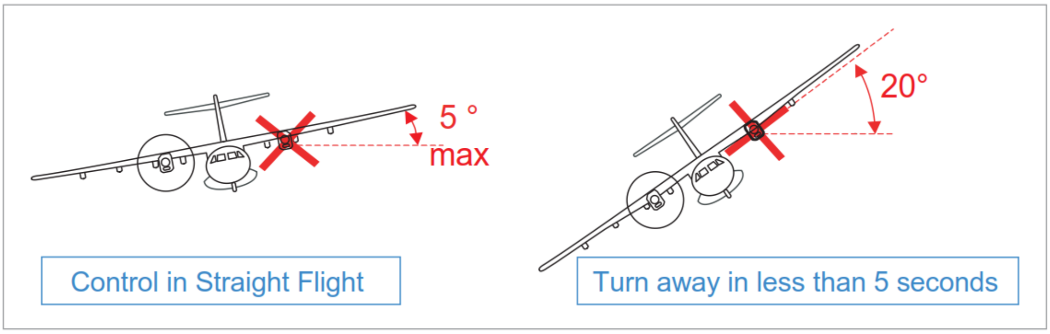


Figure B4: *Minimum Control speed during approach and Landing: V_{MCL}*

3.3.5.2. **Remarks**. Refer to § 2.1.3 above for remarks on the use of "*5° max*" as bank angle limitation for airline pilots.

3.3.5.3. It is unclear what the manual writer wants to say by including these figures. These are based on CS/FAR 25, which is for certification and for flight-testing only.

- *Figure B4 left*: The bank angle at V_{MCL} for airline pilots must be a fixed small bank angle; might be 5°, can also be less than 5° but is certainly not 0°. The manufacturer should have presented the exact bank angle here for maintaining straight flight at airspeed V_{MCL} and max. asymmetrical thrust. By the way, when the thrust is less than maximal, the thrust yawing moment is less, as are the required rudder deflection, the sideslip and bank angle.
- *Figure B4 right*: A quote out of AMC 25.149(h)(3): "*The 20° lateral control demonstration maneuver may be flown as a bank-to-bank roll through wings level*". This is also a flight-test maneuver. For an airline pilot it would be sufficient to understand that V_{MCL} allows some bank angle excursions although flight-test experts will doubt that, since V_{MCL} is determined with a (fixed) bank angle of not more than 5°, just like V_{MCA}.

3.3.5.4. Because V_{MCL} is also determined with a bank angle of max. 5° into the good engine set at go-around power, an additional "*20° turn away"* into the good engine results in a considerable increase of sideslip which might cause the vertical tail to stall (rudder is fully deflected at V_{MCL}), resulting in the lateral loss of control (and a catastrophic accident). V_{MCL} is not a requirement in Military Flying Qualities Specifications and is not taught at military Test Pilot Schools.
V_{MCL} is only of relevance if and whenever maximum power is set during the approach. Usually the power setting will not have to be maximal, so the actual V_{MCL} is very low, and not a factor for controllability. When full throttle is required for a go-around and flaps are up (one notch), V_{MCA} applies, not V_{MCL} anymore.

3.4. ATR Performance Guide Chapter C. Takeoff

3.4.1. ATR Performance Guide Chapter C § 2.2.2 (page 42). Decision Speed: V_1

3.4.1.1. Takeoff Decision speed V_1 is defined in CS/FAR 25.107(a)(2):

> *"V_1, in terms of calibrated airspeed, is selected by the applicant; however, V_1 may not be less than V_{EF} plus the speed gained with the critical engine inoperative during the time interval between the instant at which the critical engine is failed, and the instant at which the pilot recognises and reacts to the engine failure …".*

3.4.1.2. The V_1 definition is copied to § 2.2.2 and followed by the following line:

"*V_1 can be selected by the applicant, assuming that an engine failure has occurred at V_{EF}. The time which is considered between the critical engine failure at V_{EF}, and the pilot recognition at V_1, is 1 second. The following relation is thus verified: $V_{MCG} \le V_{EF} \le V_1$*".

3.4.1.3. **Remarks**. In a definition for pilots it is not relevant to talk about the critical engine. V_1 applies after failure of either engine. See also § 3.3.4.3 above. Another reason is the crosswind during a takeoff that influences the answer of the question which engine is the critical engine (refer to § 2.2.7 above).

3.4.1.4. The first part of the *"verified"* relation $V_{MCG} \le V_{EF}$ is correct; V_{EF} must be selected by the applicant and may not be less than V_{MCG}. The second part $V_{EF} \le V_1$ is not quite in accordance with CS/FAR 25.107 (a)(2): V_1 must be ≥ (V_{EF} + the speed gained with one engine inoperative in one second reaction time (two seconds for distance at V_1, FAR post-amendment 25-42)). If this speed increase was not applied by ATR in calculating V_1, the V_1 data presented in the ATR pilot manuals are too low; the *"verified relation"* cannot have been approved by EASA.

3.4.2. ATR Performance Guide Chapter C § 2.2.3. Rotation Speed: V_R

V_R is the speed at which the pilot initiates the rotation, at the appropriate rate of about 3° per second, to reach V_2 not lat~~t~~er than 35 ft.

3.4.2.1. Several requirements in CS/FAR 107 apply to determining V_R; the most important (subparagraph (e)) being that *"V_R may not be less than V_1 or 105% of V_{MCA}"*.

3.4.2.2. **Remarks**. This requirement should result in an airspeed safety margin of at least 5% above V_{MCA}. However, during rotation the wings of the airplane are level (bank angle 0°) while the AFM-published V_{MCA} is measured while banking (max.) 5° away from the inoperative engine. When keeping the wings level, the actual V_{MCA} is higher and might even be higher than 1.05 times the published V_{MCA}. Hence, the 5% safety margin is not included in V_R when the wings are kept level (refer to the charts in § 2.1 above).

3.4.2.3. It is recommended that the manufacturer increases V_R to a value 5% higher than the wings-level V_{MCA} or increases the percentage to meet the safety margin requirement for a wings-level takeoff path.

3.4.3. ATR Performance Guide Chapter C § 2.2.5. Take-off Climb Speed: V_2

3.4.3.1. This procedural speed is usually called Takeoff Safety Speed V_2. The definitions of V_{2MIN} and V_2 are also copied from CS/FAR 25.107 into this Performance Guide:

"(b) V_{2MIN}, in terms of calibrated airspeed, may not be less than:

(1) 1.13 V_{SR} [EASA] or 1.2 V_S [FAA] for two-engined turbo-propeller powered aeroplanes (1);

(3) 1.10 V_{MCA}.

(c) V_2, in terms of calibrated airspeed, must be selected by the applicant to provide at least the gradient of climb required by CS 25.121(b)(2) but may not be less than –

(1) V_{2MIN};

(2) V_R plus the speed increment attained (in accordance with CS 25.111(c)(2)) before reaching a height of 11 m (35 ft) above the take-off surface; and"

3.4.3.2. Not included in this paragraph, yet applicable:

"(3) A speed that provides the manoeuvring capability specified in CS 25.143(h)".

3.4.3.3. The following notes are added in this paragraph:

"[(1)] 1.2 V_S limit is considered for ATR 42-300 and 1.13 V_{S1G} for all other ATR.

[(2)] 2.4% climb gradient in the take-off configuration with the landing gear fully retracted".

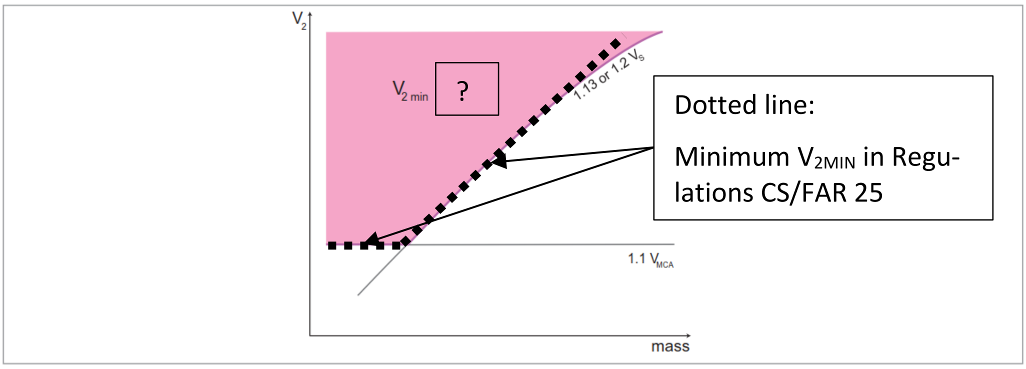


Figure C3: V_{2min} versus aircraft mass

3.4.3.4. The following line is added to this paragraph:

"V_{MCA} depends on the OAT and Pressure altitude of the departure airport, whereas V_S depends only on the aircraft mass. At low weights, V_{MCA} is generally more limiting."

3.4.3.5. **Remarks**. In the remarks below, not all applicable requirements of CS/FAR 25 are discussed.

3.4.3.6. Figure C3 is included in the V_2 paragraph, but it is unclear what the red shaded area represents. Is it V_{2MIN} plus increment, since V_2 is on the vertical axis? It looks like V_{2MIN} covers a large area with weight and airspeed, while the requirement is that V_{2MIN} is the max. of 1.1 V_{MCA} and 1.13 V_{SR}, i.e. the minimum V_{2MIN} should follow the added dashed line (by example). The red shaded area might represent V_2, i.e. V_{2MIN} + an increment, which seems very large for lower weights and reduces to zero at high weights. This Figure cannot be correct.

3.4.3.7. It is unknown whether the requirements of CS 25.121(b) and CS 25.107 (c) (2) and (3) are met by the V_{2MIN} as presented in Figure C3: V_2 may not be less than V_{2MIN}. This requirement should result in a safety margin of at least 10% above V_{MCA}. However, if the wings of the airplane are kept level (bank angle 0°) after lift-off, the actual V_{MCA} is higher than the AFM-published V_{MCA} and might even be higher than V_{2MIN}, if V_{2MIN} is 1.1 times the AFM-published V_{MCA}. Hence, the 10 % safety margin of V_{2MIN} above published V_{MCA} is not high enough when the wings are kept level. After all, the AFM-published V_{MCA} is measured while banking 5° (or less as the manufacturer should have published) away from the inoperative engine. A speed increment above V_{2MIN} might be required for V_2 to be a safe takeoff safety speed.

3.4.3.8. Not included in this ATR paragraph is CS/FAR 25.107 (c)(3): *"A speed that provides the manoeuvring capability specified in CS 25.143(h)"*. CS 25.143(h) states in a table: "*At V_2 the manoeuvring bank angle in a coordinated turn of 30 degrees with power setting Asymmetric WAT-Limited (= A combination of weight, altitude and temperature (WAT)) such that the thrust or power setting produces the minimum climb gradient specified in CS 25.121 for the flight condition.*" The question can be raised whether V_{2MIN} is high enough to provide for the required maneuvering capability without losing control of the airplane, because of the increase of V_{MCA} to some higher actual value (§ 2.1.3 above). This increased actual V_{MCA} might be higher than V_{2MIN} and/or V_2. Many accidents happened during turns while maintaining published V_2. V_2 is not a safe takeoff safety speed when it is equal to V_{2MIN}. An increment is not only desirable.

3.4.3.9. Remarks to the last line in ATR Performance Guide Chapter C § 2.2.5 that is quoted in § 3.4.3.4 above. The actual V_{MCA} is indeed lower than the standardized V_{MCA} at higher OAT and higher altitudes because the engine thrust decreases under these conditions. Then the thrust yawing moment is smaller, hence the airspeed (V_{MCA}) to counteract the asymmetrical thrust yawing moment can be lower with maximum rudder. The lower actual V_{MCA} results in lower takeoff speeds V_1, V_R and V_2, enabling the airplane to takeoff from shorter runways or at higher takeoff weights. This last line suggests that the writer knows about the effect of weight on V_{MCA} and the bank angle required for V_{MCA} to be the valid, because at low weights, V_{MCA} is indeed higher than at high weights, provided a small bank angle is being maintained; a consequence of the side force $W \cdot \sin(\phi)$. Refer to § 2.1.3.3 above; Figure 3 also shows that at high weights, V_{MCA} is more limiting (i.e. increases considerable) when banking away from the operative engine. A $V_2 \geq 1.1\ V_{MCA}$ will not be adequate during maneuvering.

3.4.4. **ATR Performance Guide Chapter C § 3.2.1. Take-off distance.**

3.4.4.1. In this paragraph, CS/FAR 25.113 is copied. This paragraph is a requirement for airplane manufacturers to publish the correct, safe takeoff data in their manuals. Data that always apply, whichever engine fails, critical or non. Failure of the critical engine might cause a little more drag than failure of the other engine but is considered negligible during flight testing (§ 2.1 above). There are no separate tables with takeoff data for critical engine failure. Refer to § 2.2.5 above to learn that during the takeoff run both engines are equally critical (angle of attack is zero).

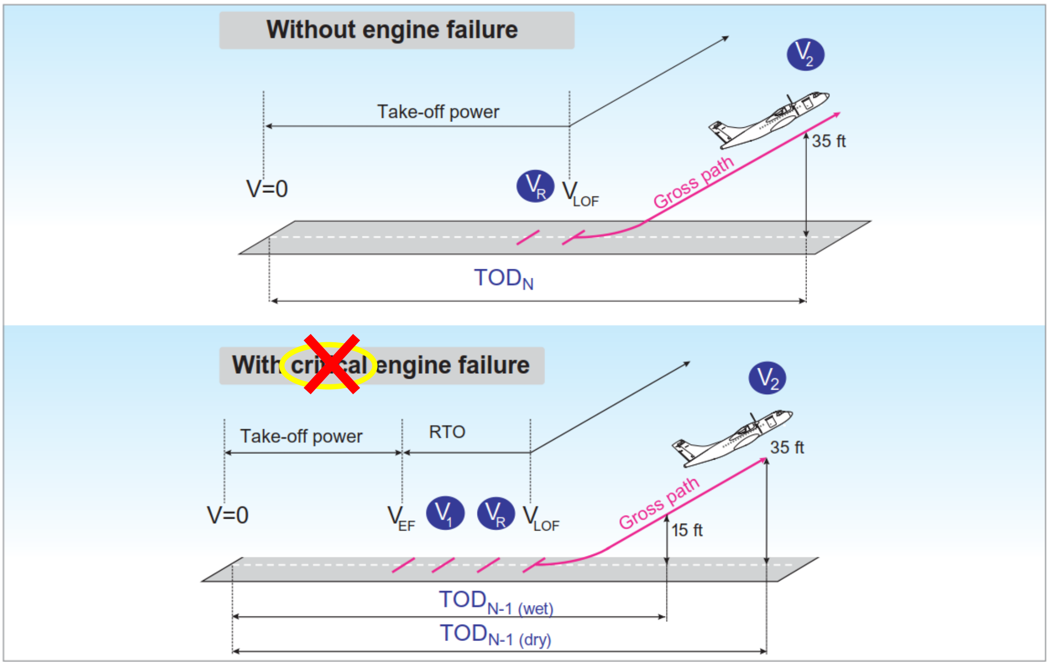


Figure C10: Take-Off Distances

3.4.4.2. For an airline pilot, it does not make any difference for takeoff performance whether the failing engine is the critical engine or the non-critical engine. The AFM-published takeoff data are worst case data, i.e. determined with the critical engine inoperative; the pilot will achieve the published takeoff performance, whichever engine fails.

The term "*critical*" (in Figure C10 above) does therefore not belong in a pilot's manual; it might be confusing, and pilots might ask what data apply in case the non-critical engine fails, or even neglect the data because 'it seems not to apply after failure of the non-critical engine'. There is also only one engine emergency procedure that applies after either engine failure.

3.4.5. ATR Performance Guide Chapter C § 3.2.2. Take-off Runs

3.4.5.1. The same as presented in the previous paragraphs applies to Figure C11 below.

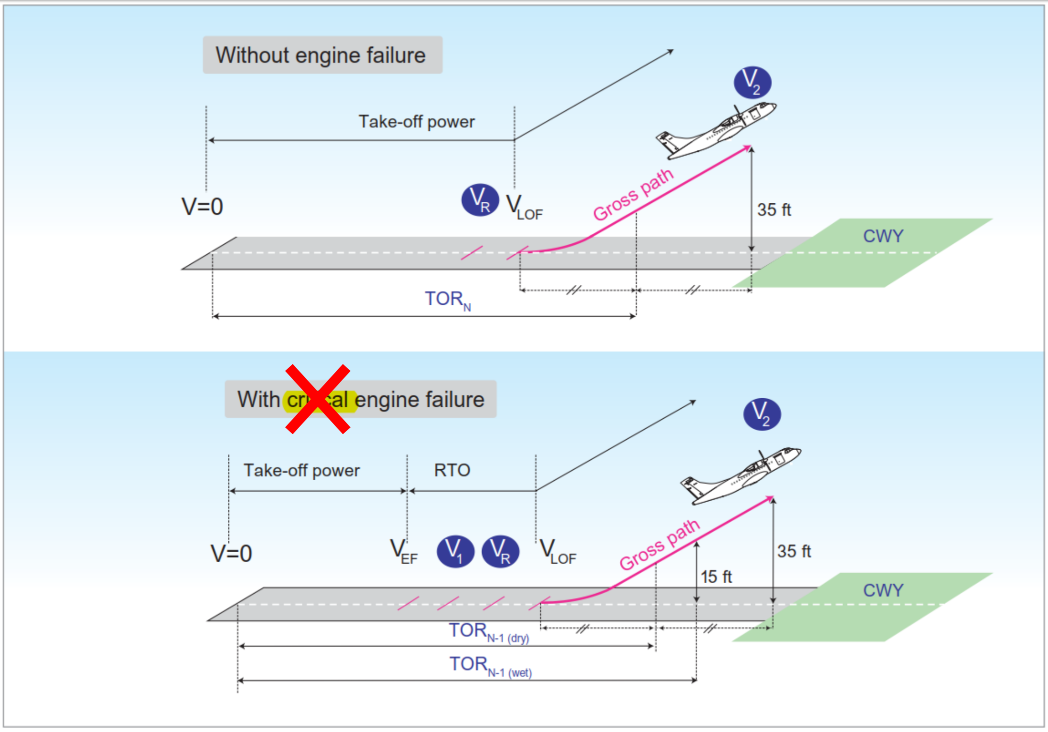


Figure C11: Take-Off Runs with a Clearway

3.4.6. ATR Performance Guide Chapter C § 3.2.3. Accelerate-Stop Distance

3.4.6.1. Again, a separate figure (in Figure C12 below) for critical engine failure. This figure is for airplane design engineers and for experimental test pilots. Critical is not for use by airline pilots. What would be the difference with the non-critical engine failure?

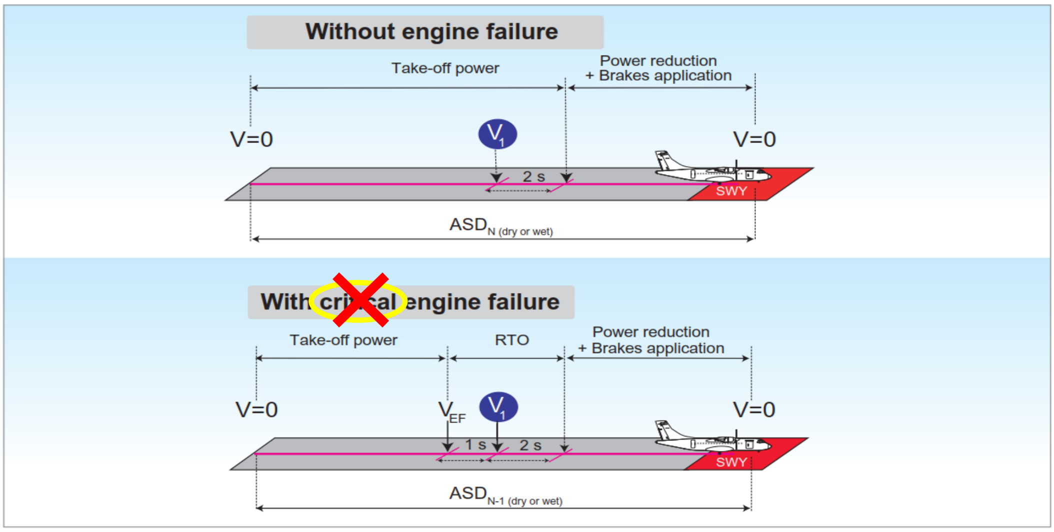


Figure C12: Acceleration-Stop Distances

3.4.6.2. In addition, the question is whether there is any difference in takeoff distance between failure of the critical and the non-critical engine. It is not the relative wind that determines which engine is the critical engine, because the airplane is on the runway, the angle of attack is zero, hence there is no influence of P-factor, no difference between the thrust yawing moments of both engines, besides the yaw direction.

3.4.6.3. Crosswind might have a larger effect but is not discussed (see § 2.2.7 above).

3.4.6.4. V_{EF} is copied out of CS 25.111(a)(3) which is for airplane design, for the manufacturers' flight test department to determine and publish takeoff speeds. It is not an airspeed for operational use; no need to mention for pilots here.

3.4.7. ATR Performance Guide Chapter C § 4.3. Take-off path summary

3.4.7.1. **Remarks.** The table in this paragraph should be reviewed using the information presented above and be limited to the airspeeds that are of use to airline pilots. V_{LOF} is not a procedural takeoff airspeed for pilots; instead, "accel to V_2" should be used here. Reference should be made to reducing the drag and to actual V_{MCA} by banking a few degrees away from the inoperative engine and maintain straight flight. Further, an airplane is in or out of ground effect (when higher than a half wing span), not without.

3.4.8. ATR Performance Guide Chapter C § 4.4. Take-off turn Procedure

3.4.8.1. Above 50 ft and below 400 ft, a turn with max. 15° of bank might be required for obstacle clearance or noise abatement, according to EU-OPS 1495.

3.4.8.2. **Remark**. In order to meet requirements for turns with bank angles of 15° or 25°, takeoff safety speed V_2 might have to be increased to be higher than the actual V_{MCA} that would apply during the turns. The flight-test measured and published V_{MCA}, as was explained above, is only valid during straight flight while banking a few degrees away from the inoperative engine. Actual V_{MCA} increases considerable when banking (refer to § 2.1 above). Refer to the YouTube lecture of *AvioConsult* in which a takeoff accident with an EMB-120 is analyzed; V_2 turned out to be not a safe takeoff speed.

3.4.8.3. The last line in this paragraph is:

> *"The loss of single-engine climb gradient versus the aircraft bank angle, depending on the V_2, is provided in the AFM 6.03.04, Altitude speed – bank angle – turn radius: relationships."*

3.4.8.4. **Remark.** Refer to § 4.18.1.1.

3.4.8.5. The remainder of this Chapter was not reviewed.

3.5. ATR Performance Guide Appendix 2. Takeoff optimization, p. 140

3.5.1. ATR Performance Guide Appendix 2 § 2.1.1 (p. 140). V_1/V_R Range

3.5.1.1. § 2 Takeoff Speeds begins with the following statement:

> *"Take-off speeds represent the most important source of optimisation and TOW gain."*

3.5.1.2. **Remark**. Takeoff speeds have to be made available to pilots for them to be able to conduct a takeoff, i.e. getting the airplane off the ground and climb safely initially, even if an engine fails. CS/FAR 25.105 requires that takeoff speeds, accelerate-stop distance, the takeoff path, takeoff distance, takeoff run and takeoff path must be determined in the selected configuration for takeoff at the actual weight, altitude and temperature. Although Regulations allow some speed variations, takeoff speeds V_1, V_R and V_2 are to comply with authoritative requirements for safe operation with unchangeable runway and outside condition parameters. Above 400 ft after takeoff, climb speeds can be varied to optimize the aerodynamic performance, for instance for achieving a maximum rate of climb or maximum angle if climb, whatever required. So, ground phase takeoff speeds V_1 and V_R do not *"represent the most important source of optimisation and TOW gain"*, don't you agree?

§ 2.1.1 continues:

> *"The decision speed V_1 must not be higher than the rotation speed V_R. As V_R depends on weight, the maximum V_1 value is not fixed, whereas the maximum V_1/V_R ratio is equal to one (regulatory value).*
> *Besides, it has been demonstrated that a V_1 speed less than 84% V_R induces too long take-off distances and does not, therefore, present any take-off performance advantages. Consequently, the minimum V_1/V_R ratio is equal to 0.84 (manufacturer value)."*

3.5.1.3. **Remark**. CS/FAR 25.107 indeed requires that V_R may not be less than V_1. But this is not the only requirement for V_R; other quite important ones are: $V_R \geq 1.05\ V_{MCA}$, and V_R is not less than the speed that allows reaching V_2 before reaching 35 ft; refer to CS/FAR 25.107 (e) for details, and (2): "*For any given set of conditions (such as weight, configuration, and temperature), a single value of V_R, obtained in accordance with this paragraph (CS/FAR 25.107 (e)), must be used to show compliance with both the one engine-inoperative and the all-engines-operating take-off provisions*".
V_R does not depend on weight only. Will a V_1/V_R ratio of 0.84 provide the take-off safety that is intended by CS/FAR, keeping in mind the actual values V_{MCG} and of V_{MCA} when the wings are kept level during rotation, as explained in § 2.1? Not for low takeoff weights.

3.5.2. ATR Performance Guide Appendix 2 § 2.2.1 (p. 143). V_2/V_S Range

3.5.2.1. Paragraph 2.2 is titled: *"Take-off climb speed V_2"*, while V_2 is defined as takeoff safety speed in all other applicable documents.

§ 2.2.1 V_2/V_S Range continuous with:

> *"The minimum V_2 speed is defined by regulations, and limited by the stall speed (V_S) and the minimum control speed in the air (V_{MCA}). The stall speed depends on the weight and the minimum V_2/V_S ratio is known for a given aircraft type. The minimum control speed in the air depends on the atmospheric conditions (OAT and Pressure Altitude), and is generally limiting when the aircraft is light.*
> *Above $(V_2/V_S)_{opt}$ where the maximum gradient is reached, there is no interest of increasing V_2 because the take-off distances are increased and the climb gradient decreased."*

3.5.2.2. **Remarks**. The effect of bank angle for reducing drag and minimizing V_{MCA} after engine failure is not discussed in the Performance Guide, neither is its effect on procedural takeoff speeds that are calculated using V_{MCA}.

3.5.2.3. V_{2MIN} is defined by CS/FAR 25.107 and is limited by the highest of 1.13 V_S and 1.1 V_{MCA}, not by V_S and V_{MCA}. CS/FAR 25.107 (c) requires the applicant (= manufacturer) to select V_2, not V_{2MIN}. V_{2MIN} is not intended to be used as procedural minimum, the lowest V_2 but is intended to be used as one of the factors for calculating the take-off safety speed V_2 (CS/FAR 25.107 (b)).
V_2 must be selected by the applicant to provide the climb gradient (2.4 %) up to 400 ft above takeoff height as required by CS/FAR 25.121(b) but may not be less than V_{2MIN}, V_R plus increments for reaching 35 ft and a speed that provides the specified maneuvering capability. Above 400 ft, V_{FTO} applies; the minimum gradient of climb is 1.2%.
V_{2MIN} is a speed within CS/FAR 25, that is for certification, and is not to be used as minimum, the lowest take-off safety speed (inappropriately called take-off climb speed in

the Guide). V_{2MIN} without applicability restriction (such as a small bank angle while maintaining straight flight) is neither a safe takeoff safety speed nor a safe take-off climb speed following an engine failure. V_{2MIN} is not intended for use by airline pilots; they only should use V_2 which should be higher than V_{2MIN}. The use of V_{2MIN} is even more critical because the ATR Manuals do not provide a single standardized V_{MCA}, but require pilots to lookup a V_{MCA} in the AFM using the actual pressure altitude and OAT, for calculating V_{2MIN}. Such a V_{MCA} will hardly provide any safety margin, even a negative margin if the small favorable bank angle is not maintained. The use of a V_{2MIN} that is only 10% above the actual V_{MCA} is not safe without banking a few degrees away from the inoperative engine. Loss of Control after liftoff then is imminent when an engine fails and other parameters that have effect on V_{MCA} happen to be at their worst case values. The minimum V_2/V_S ratio and $(V_2/V_S)_{opt}$ cannot be explained referring to CS/FAR 25. V_2 seems to be used here as an airspeed for maximum angle of climb, for obstacle clearance, while V_2 is defined by Authorities to be a takeoff safety speed for the first 400 ft climb, not a takeoff climb performance speed.

3.5.2.4. The sideslip, hence the drag reduction by applying a small bank angle into the good engine is not mentioned at all, therefore this chapter falls short and is not further reviewed; no further remarks are presented.

3.6. Conclusions Limited Review ATR Performance Guide

3.6.1. Writers of the Performance Guide were obviously and regrettably not made aware of the real meaning and value of Minimum Control Speed V_{MCA} and of the flight restrictions that apply for the published V_{MCA} to be valid. The effect of bank angle on V_{MCA}, and hence on V_R and V_2, and in general on the climb performance was not included, while the unfamiliarity with this effect is the real cause of most fatal accidents after engine failure.

3.6.2. The definitions of V_{MCG}, V_{MCA} and V_{MCL} presented in this (and the other) manuals are definitions that are for airplane design engineers, not for pilots. The published V_{MCA} is valid for straight flight only while maintaining a favorable bank angle that should have been determined – and published – by the manufacturer, because V_{MCA} increases considerably with bank angles other than the favorable bank angle that was used to determine V_{MCA}, which is regrettably not discussed.

3.6.3. ATR introduces optimization of takeoff speeds for takeoff weight gain by introducing ratio's (V_1/V_R and V_2/V_{SR}) for use and change by pilots, but forgets the influence of V_{MCA} on these speeds. The calculation of takeoff speeds is defined in CS/FAR 25.107 and cannot be fooled around with by pilots. The optimization process is the reduction of takeoff weight for a given runway at an also given altitude and OAT, and/or a minimum required climb performance after takeoff, if applicable. Takeoff speeds are a result of TOW optimization, not a source.

3.6.4. V_{2MIN} is obviously used as takeoff safety speed V_2, which is not in agreement with the applicable CS/FAR. While reviewing this Manual, doubts arose about the real safety of the takeoff speeds as calculated and explained, and about the correctness of performance data. This will become more obvious during the review of the AFM in the next chapter.

4. ATR 72 Airplane Flight Manual, Rev. 29.0, Jun 21

4.1. In this chapter, remarks that are already presented above will be repeated if applicable, to enable this chapter to be separately used.

4.2. AFM LIM.3 page n°09. Speed Definitions

4.2.1. This Section presents the Definitions of Speeds, a few of which are quoted here.

4.2.2. **§ 1.1 AFM definition V_1:**

"V_1 is the maximum speed at which the flight crew can decide to reject the takeoff and is ensured to stop the aircraft within the limits of runway".

4.2.2.1. **Remarks**. The words reject and abort are both used in this manual to recommend interrupting the takeoff. For instance, in PRO.NNO.ABN § 99.2, Rejected takeoff is used, while on the next page in § 99.3 Aborted takeoff is used. To reject is to refuse to accept or make use of, to abort is to terminate an operation or procedure. You reject a takeoff during flight planning, or even before you enter the runway, you abort a takeoff when it already began when equipment fails or something else happens that will endanger the takeoff. Regrettably, more manufacturers made this error.

4.2.2.2. V_1 only applies to the accelerate/ stop distances; it is the maximum speed at which it is possible to stop the airplane before reaching the end of the runway, the longitudinal limit. V_{MCG} is the minimum speed for being able to keep the airplane within the lateral limits of the runway when an engine fails and the other engine(s) operating at max. thrust. Equipment failure at takeoff speeds below V_1, indicated by an uncommanded yaw or alerts, should definitely result in an abort at once, by closing the throttles immediately to avoid vacating the runway laterally. It is recommended to rewrite this definition and add this requirement to the definition as a reminder.

4.2.3. **§ 1.1 AFM definition V_2:**

"Take off, safety speed reached before 35 ft height with one engine failed and providing second segment climb gradient not less than the minimum (2.4 %)".

4.2.3.1. CS 25.107 (c) defines V_2 as follows:

"V_2, in terms of calibrated airspeed, must be selected by the applicant to provide at least the gradient of climb required by CS 25.121(b) but may not be less than –

(1) V_{2MIN};

(2) V_R plus the speed increment attained (in accordance with CS 25.111(c)(2)) before reaching a height of 11 m (35 ft) above the take-off surface; and

(3) A speed that provides the maneuvering capability specified in CS 25.143(h)."

4.2.3.2. **Remarks**. Although it is a requirement to reach V_2 before the airplane is 35 ft above takeoff surface (CS 25.111(c)(2)), it is not sure that this indeed happens. The initial rate of climb, while the landing gear is not yet retracted, only needs to be positive, not 2.4% (CS 25.121(c) and CS 25.121(a) for OEI); a power setting is not specified, though. V_2 must be maintained until the airplane is 400 ft above the takeoff surface. Above 400 ft, the climb gradient may not be less than 1.2% (two-engine airplanes). The net takeoff flight path may even be reduced by 0.8% (CS 25.115(b)(1)).

4.2.3.3. Takeoff Safety Speed V_2 is listed on the takeoff data card and/or bugged on airspeed indicators, for use by pilots. V_2 is not only supposed to provide a certain climb gradient and some maneuver capability, but is in the first place an airspeed that provides a safe speed margin above V_{MCA} and V_{SR}.

4.2.3.4. It seems that ATR recommends to use V_{2MIN}, rather than a takeoff safety speed that has a higher safety margin above V_{MCA}. As explained in § 2.3 above, V_{2MIN} might only be 10% higher than standardized V_{MCA} (measured while maintaining a small bank angle) and might even be lower than the wings-level V_{MCA} when the variables that affect V_{MCA} happen to be at their worst-case values (§ 2.1.3 and § 2.3.1 above).
By using V_{MCA} data out of the charts with actual OAT and altitude, rather than a worst-

case sea level V_{MCA}, the safety margin decreases even more. When a pilot keeps the wings level after engine failure, an increment is recommended above $V_{2(MIN)}$ for being able to maintain straight flight, and not lose control (at low weight and high power setting).

4.2.3.5. During banking V_{MCA} increases, and might increase above the published V_2, rendering the airplane out of control. Turning at V_2 (which must be higher than V_{2MIN}) is not recommended, but if a turn at low altitude is needed, the airspeed must be increased first to avoid the loss of control.
The AFM definition of V_2 should be improved. An improved definition of V_2 would be:

> "V_2 is the takeoff speed that provides a safe margin above V_{MCA} and a positive gradient of climb after failure of one of the engines, provided straight flight is being maintained". [A small favorable bank angle might be required].

4.2.3.6. AFM § 1.1 correctly defines V_2 as takeoff safety speed, while in the Performance Guide it was called a take-off climb speed (refer to § 3.4.3 above). V_2 as used by ATR seems V_{2MIN} that does not include the increments required by CS 25.107 (c) (2), (3).

4.2.4. **§ 1.1 Other AFM definitions**

4.2.4.1. Since this review is limited, not all definitions are reviewed. It is recommended to also carefully review the other definitions in this section. The definitions of V_R, V_{REF} and V_{APP} must also be improved in any case.

4.2.5. **§ 1.2. AFM definition Limit Speed V_{MCG}:**

> *"Minimum Control speed on the Ground from which a sudden failure of the critical engine can be controlled by use of primary flight controls only, with the other engine operating at RTO power".*

4.2.5.1. **Remarks**. The engine which is the critical engine of the ATR-72 is not defined in the AFM. Even in LIM.5 Page n°35 under head Propellers, the rotating direction of each propeller is not presented. How will a reader know which engine is the critical engine?

4.2.5.2. *"A sudden failure"* is used by test pilots to determine V_{MCG} because it is the worst case failure. They approach V_{MCG} from a higher speed. V_{MCG} will also be a factor for airline pilots when either engine fails gradually. It is recommended to replace *"from which"* with 'above which', and delete the word *"sudden"* from this definition.

4.2.5.3. The failure *"of the critical engine"* is required by Aviation Regulations for airplane (systems) design and flight-testing to determine V_{MCG} because failure of the critical engine results in the highest V_{MCG}. This worst case V_{MCG} is to be published in the AFM and is used for calculating V_1. Although the V_{MCG} after failure of a non-critical engine might be a little lower, the published V_{MCG} and the therewith derived V_1 definitely also apply after failure of the non-critical engine. There are no separate procedures and no separate V_1's for any engine failure, #1 or #2, to avoid critical decision making in the cockpit at the instant an engine actually fails. The deviation from the pre-engine-cut projected ground track after failure of a non-critical engine might be a little less than 30 ft though (§ 3.3.1 above).

4.2.5.4. During a takeoff in a strong crosswind, the actual critical engine is the upwind engine and might not be the standard critical engine, the reason being that partial rudder already is required during the early phase of the takeoff run for counteracting the yaw due to crosswind (weather cock) leaving less rudder available for counteracting the asymmetrical thrust yawing moment after engine failure.

4.2.5.5. Therefore, the use of the term *"the critical engine"* in a manual for airline pilots is a 'critical' error, is not at all necessary to mention, is misleading and should be replaced by "either engine" or "an engine". It is not the failure of an engine that can be controlled, but the control of the airplane that can be maintained. The lateral deviation on the runway might be up to 30 ft (§ 3.3.1 above).

4.2.5.6. *"with the other engine operating at RTO power".* RTO power means Reserve Takeoff power in this manual; in EASA CS 25, RTO means Rejected Takeoff. The term Reserve power in English means power that is kept back or saved for future use, or for a special purpose.
Regulations require V_{MCL} and also V_{MCA} to be determined with the other engine operating at the maximum power a pilot can set from the cockpit, because then the minimum control speeds are highest, most unsafe. Is RTO power the max. power a pilot can set from the cockpit? Not according to the FCOM, the max. torque is 115% (*"Wall"*). V_{MCL} and also V_{MCA} and V_{MCL} should be based on this max. torque setting.

4.2.6. **§ 1.2. AFM definition V_{MCA}:**

> *"Minimum Control speed in flight at which the aircraft can be controlled with 5° bank, in case of failure of the critical engine with the other engine at RTO power (take off flaps setting and gear retracted.)"*

4.2.6.1. **Remark**. This V_{MCA} definition is a definition for airplane design engineers to ensure that they design a large enough vertical tail, but is not a definition for pilots, see also § 2.1.2 above. The published V_{MCA} should be high enough to recover/ maintain control after a sudden failure, and thereafter to maintain straight flight with 5° of bank (away from the inoperative engine), not only after failure of the critical engine, but after failure of either engine. The definition suggests that 5° of bank was indeed used by ATR engineering for designing the vertical tail and by ATR test pilots to determine V_{MCA}. The conditions for which the V_{MCA} in the ATR manual is valid are regrettably neither included nor clarified in this definition, nor in the legend of the V_{MCA} data plot on LIM.3 page n°15. Both the actual V_{MCA} and the sideslip, hence drag, increase considerable when the favorable 5° bank angle is not being maintained, such as during turns.

4.2.6.2. Therefore, as for V_{MCG} above, the use of the term *"the critical engine"* in a manual for airline pilots is a 'critical' error, is not at all necessary to mention, is misleading and should be replaced by *"either engine"* or *"an engine"*.
The manufacturer should include the requirement for maintaining straight flight with the exact bank angle for which the listed V_{MCA} is valid with the definition and in the legend of the V_{MCA} data, to avoid pilots from initiating turns at too low a speed and altitude.

4.2.6.3. Refer to § 4.2.5.6 above for a remark on the use of *"RTO power"* and to § 2.1.5.2 above for an improved V_{MCA} definition for pilots.

4.2.7. **§ 1.2. AFM definition V_{MCL}:**

> *"Minimum flight speed at which aircraft can be controlled with 5° bank in case of failure of the critical engine, the other being set at GA power (landing flaps setting, gear extended) and which provides rolling capability specified by regulations."*

4.2.7.1. In LIM.3 page n°16, § 4.3, Landing V_{MCL} is presented as 98 kt CAS for both Flaps 30 and 15.

4.2.7.2. **Remarks**. V_{MCL}, as defined in CS 25.149(f), is the speed at which it is possible to maintain control of the airplane, while an engine is inoperative, and maintain straight flight with an angle of bank of not more than 5° away from the inoperative engine.

4.2.7.3. Like in the V_{MCA} definition, V_{MCL} seems only valid in case of failure of the critical engine. What is the V_{MCL} in case of failure of the non-critical engine? It is just a little, a few knots lower, safer. For airline pilots, it is the same, no analyzing required in the cockpit after engine failure. It is recommended to replace "*the critical*" with "either". Refer also to § 2.2 above.

4.3. AFM LIM.3 page nº 14. Minimum Control Speeds

4.3.1. The header and titles on this page are shown in this figure:

AFM	LIMITATIONS SPEEDS MINIMUM CONTROL SPEEDS	LIM.3 Page n°14

4 MINIMUM CONTROL SPEEDS

4.1 TAKEOFF V1 LIMITED BY VMCG

1 Flaps 15

Flaps 15

50707c0a-63a6-45d7-882d-7a0599a4c981		**0.1**
		ALL
		APPROVED

V1 LIMITED BY VMCG (FLAPS 15)

PW127F / PW127M / PW127N – BOOST OFF

4.3.1.1. **Remarks**. Many cluttering and redundant terms and lines on this (and many more) page(s). § 4 has the same title as already presented in the page header. V_1 is located under the head *"minimum control speeds"*, but V_1 is not a minimum control speed, it is one of the takeoff (performance) speeds as defined in CS 25.107, and should be placed under an appropriate paragraph head. V_{MCA} is not a takeoff speed, is a control speed; a V_{MCA} applies during the whole flight, all the time, not only after an engine failure but also in anticipation of an engine failure, from liftoff to landing.

4.3.1.2. The head of § 4.1 in the figure above and the title of the chart are *"Takeoff V_1 limited by V_{MCG}"*. This suggests that there is a another V_1 limited by some other factor. Only *"V_1 limited by MAX brake energy"* on DEV.2 Page n°16 under *"Dispatch With Flaps Retracted"*, was found but no data (after searching using this term). A data chart was ultimately found in AFM PRO.SPO Page n°31, but is there called *"Decision Speed Limited by maximum brake energy"*. Why not used just V_1 in this title as on other pages? Three terms for the same speed, confusing, don't you agree?

4.3.1.3. *CS 25.107(a) Takeoff speeds* requires a V_1 to be established. $V_1 = V_{EF}$ selected by the applicant ($V_{EF} \geq V_{MCG}$) + the speed gained in one second engine failure recognition and reaction time of the pilot. V_{EF} is the lower limit for V_1, not V_{MCG}, unless V_{EF} was selected by ATR to be equal to V_{MCG}.
Takeoff speed V_1 is never limited by V_{MCG} (or V_{EF}), because the minimum V_1 is always the speed gained in one second pilot reaction time after the sudden failure of an engine higher than V_{EF} or V_{MCG} (if V_{EF} is selected to be equal to V_{MCG} by ATR).
The use of *"limited by VMCG"* in the titles is not quite correct, not in agreement with CS 25.107(a) and unnecessary complicating, don't you agree? The question whether ATR indeed used the speed increase during 1 second after engine failure to calculate V_1 is also justified, isn't it? Or is this included in the chart?

4.3.1.4. The subparagraph *"1 Flaps 15"* suggests that there are more paragraphs with different flap settings, but there aren't. Either this or the second sub head *"Flaps 15"* is redundant, unnecessary. It seems that, throughout the manual, there are a lot of superfluous, hence redundant headers. This clutters the pages unnecessarily.

4.3.1.5. This chart is not accompanied by a legend with details on propeller feathering, thrust level operative engine (*"Notch, Ramp, Wall"*), crosswind, etc. for which the presented data are valid. *"OUTSIDE TEMPERATURE"* should be *"OUTSIDE AIR TEMPERATURE"* as used elsewhere in this AFM.

4.4. AFM LIM.3 page n°15. Takeoff V_{MCA}

4.4.1. This Section presents a chart containing V_{MCA} data, with OAT and Pressure Altitude as entry variables for three engine types (boost off) and flaps 15.

4.4.1.1. **Remarks.** The paragraph title is *"Takeoff V_{MCA}"*, while the title of the chart is *"Minimum control speed in flight – V_{MCA} (flaps 15)"*. The latter is best, because V_{MCA} not only applies during takeoff, but during the whole flight, from takeoff to approach, while an engine is inoperative, or in anticipation of an engine failure.

4.4.1.2. This chart provides a multiple of V_{MCA} graphs, but is not accompanied by a legend with the conditions for which the presented data are valid, like the thrust setting of the operative engine, the required bank angle (into the good engine, § 2.1.3 above), propeller feathering, airplane weight (low), center of gravity (aft), and the data source (flight-test or analysis), etc.

4.4.1.3. The V_{MCA} of multi-engine airplanes got underestimated during the past 50 years because many flight-instructors, accident investigators and manual writers were obviously not made aware anymore of the real value of V_{MCA} for the safety of flight with an inoperative engine and of the flight restrictions that come with it (straight flight with a small bank into the good engine). Test Pilot Schools though, still teach and demonstrate airplane control after engine failure as they always did and their students conduct engine-out and V_{MCA} testing in-flight in accordance with the EASA and FAA Flight Test Guides. Refer to the courses on flight with asymmetrical power of two Test Pilot Schools and to EASA and FAA Flight Test Guides for which links are provided on the Downloads and Links pages of the website of Avio*Consult*[13].

4.4.1.4. The bank angle for zero sideslip, i.e. for best performance, and also for V_{MCA} in the charts to be valid is not included in the legend, neither in this chart nor in the other One Engine Inoperative Performance charts. Is it 5°? Or is the V_{MCA} presented in this chart the wings-level V_{MCA} of the airplane? Refer to § 4.2.6 above for other remarks.

4.4.1.5. The data obviously applies to three engine types (refer to the figure in § 4.3.1 above); ALL is printed in the Data Module. However, PW127M offers 5% more power than its predecessor PW127F, and PW127N provides a 4.5% power increase. If more powerful engines are installed, either a larger vertical tail is required to be able to counteract the increased thrust yawing moment or all minimum control speeds (and all associated takeoff speeds) need to be higher. Or were the PW127F or PW127N, if installed on the ATR-72, derated to the power level of PW127M since the V_{MCA} data are identical? Propeller types are not mentioned. The published V_{MCA} must be the V_{MCA} that applies when the pilot sets the maximum thrust that can be set, with the power handles and/or other power affecting controls or assumed/flexible temperatures, from the cockpit.

[13] https://www.avioconsult.com.

4.4.1.6. Using *"Boost off"* in the legend and in many more titles of charts suggests that some boost can also be engaged, increasing (asymmetrical) engine thrust and therewith increasing V_{MCA}, but no *"Boost on"* data are presented in the AFM. It seems that the Auto Takeoff Power Control System (ATPCS) automatically increases the torque of the operative engine to 100% when the torque of the failing engine decreases below 19%. This increases the asymmetrical thrust yawing moment. In addition, pilots have the option to increase the power levers (to PLA 100°) for a torque of 115%, called *"Wall"*. This power setting is obviously the maximum thrust setting a pilot can set from the cockpit, reason why this setting should have been used for determining V_{MCA}. The consequence is that while moving the throttles fully forward to the *"Wall"*, to PLA 100°/ 115% torque, when an engine fails or is inoperative, the actual V_{MCA} increases above the V_R and V_2 that were calculated with a V_{MCA} for a lower torque setting, rendering the airplane out of control at once. The use of a lower thrust level than the level that a pilot can set from the cockpit for determining V_{MCA} is not in agreement with CS and FAR 25.149.
The *"boost off"* V_{MCA} for three different engine types as presented in the AFM must be too low, as will be takeoff speeds V_R and V_2 that are calculated using this V_{MCA}. This is favorable for takeoff distance and required runway length (and for sales), but not for the safety when an engine fails during takeoff.

4.4.1.7. In the Data Module strip, *"ALL"* is printed meaning for all engine configurations, and *"APPROVED"* by the authority (EASA?), which cannot be true. A well-educated manufacturer will not present similar V_{MCA} data for engines with different power output, and a cognizant authority will never approve such a V_{MCA} chart. This chart is not in agreement with CS/FAR. This remark also applies to the V_1 chart above.
Takeoff and go-around safety after engine failure is not at a level that is required by the Regulations.

4.5. AFM LIM.3 page n°16. Minimum Maneuver Operating Speeds

4.5.1. Paragraph 5.1 presents the minimum maneuver operating speeds.

> *"Minimum maneuver/ operating speeds are defined in order to provide sufficient margin against stall."*

4.5.2. **Remarks**. Stall seems the only concern for specifying the minimum maneuver/ operating speeds, while V_{MCA}, or better the actual V_{MCA} that a pilot would experience in-flight during banking away from the small constant bank angle into the operative engine that was used to determine V_{MCA}, increases considerable and is by far more dangerous (refer to § 2.1.3.3 above).

4.5.2.1. With zero flaps, VmLB (ϕ max. 15°) is to be 1.18 V_{SR}; the actual flaps-up V_{MCA} at low weight might become very close to or even exceed VmLB during Low Bank maneuvering.

4.5.2.2. With 15° flaps VmLB is to be V_2, or is this V_{2MIN} (1.1 V_{MCA})? In this case, the actual V_{MCA} at low weights may also exceed VmLB during Low Bank maneuvering.

4.5.3. The same can be said about VmHB.

4.5.4. It took a while to learn what is meant by HB and LB. Bank at high altitude, low altitude? A bank angle is small or large, not low or high; a wing can be high or low during banking.

4.5.5. By now the reader of this review should realize that V_{MCA}, that also increases considerably during banking, is regrettably not included in VmLB and VmHB. It is strongly recommended to not only mention the margin against stall, but also include a statement on the increase of (actual) V_{MCA} while banking when one engine is inoperative (and the thrust is max.), in order to increase awareness and prevent the loss of control while maneuvering, and provide sufficient margin against the loss of control. Refer to § 2.1 above.

4.6. AFM PRO.NNO.EMR page n°01. TOC Emergency procedures

4.6.1. The procedures are organized to ATA chapter system number.

4.6.1.1. **Remarks**. Pilots do not need to be familiar with ATA numbering. The consequence is also that quite important emergency procedures are hidden in chapter *EMR.99 Miscellaneous* and do not show up in the TOC. An AFM is a pilot manual, not an engineering manual.

4.6.2. The same remarks apply to the Abnormal procedures section.

4.6.3. The lack of remarks on the remainder of this section does not mean there are none; this review is limited.

4.7. AFM PRO.NNO.ABN page n°57. Flying with OEI

4.7.1. This section presents the procedures for flying with one engine inoperative.

4.7.1.1. **Remarks**. This procedure seems misplaced under non normal operations/ abnormal procedures and is considered a miscellaneous procedure under ATA n°. 99. Don't you agree this is not the right place?

4.7.1.2. The title fortunately does not describe Flying with Single Engine but OEI, as discussed in § 4.18.1.2 below.

4.7.1.3. Sub procedures are for *"Engine Flame Out"*. Are there procedures for any other kind of propulsion system malfunction, like propeller failure or engine turbine failure? Or just call this 'Engine failure' rather than *"Engine Flame Out"*.

4.7.2. The procedure continues:

"With a positive vertical speed:

Use rudder and control wheel to control aircraft heading maintaining aircraft wings essentially levelled"

Climb at V_2".

4.7.2.1. **Remark**. As explained in § 2.1 above, keeping the wings level increases V_{MCA} by approximately 10 kt. Climb speed V_2 in this manual is V_{2MIN}, and might be lower than the actual V_{MCA} when the wings are kept level. Loss of control is very close. In addition, a turn increases V_{MCA} as well, hence straight flight should be recommended for V_{MCA} and V_2 to be valid, until reaching a safe altitude. It is strongly recommended to improve this procedure.

4.8. AFM PRO.SPO page no°13, § 4.1.1. Operation on Narrow Runways

4.8.1. Under two paragraph heads, both called Applicability:

Runway width < 30 m (98 ft)

NOT APPLICABLE

4.8.1.1. **Remark**. This suggests that operations on runways less than 30 m wide are not approved. However, in the same paragraph, just below a second Data Module strip, the applicability is obviously changed:

This appendix applies to aircraft operated according to the provisions of the DGAC "Condition Spéciale B11" relative to operations on narrow runways : width < 30 m (98 ft).

Narrow runways operation reflects the capability of the aircraft as evaluated in terms of airworthiness but that not constitute approval for operations, in case such operational approval was required by the National Authorities to the Operators.

4.8.1.2. It seems that the first Data Module strip in this paragraph was not deleted.

4.8.2. In the Performance Guide § 1.3.1, on the bottom of p. 32:

V_{MCG} is increased in case of narrow runway. ATR aircraft are certified to operate normally on runways whose widths are at least 30m (98ft). However a specific modification allows to operate on runways down to 14-meter (46ft) wide, please refer to AFM 7.01.09 or FCOM 3.11.10, Operations on narrow runways. In this case, the V_{MCG} is increased, and as a consequence V_1 (please refer to Paragraph C.2.2.2, Decision Speed.)

4.8.2.1. **Remark**. This is confusing, leaves pilots with questions such as: is my airplane yes or no approved for operations on narrow runways. The AFM should have the certificated answer, don't you agree?

4.9. AFM PRO.SPO page n°19. § 10.3 Performance

4.9.1. Two headers *"V1 LIMITED BY VMCG"* under PERFORMANCES, and 100% Torque.

4.9.1.1. **Remark**. Again too many headers, is cluttering, don't you agree? Refer to § 4.3.1 above. Performances = Performance.

4.10. AFM PRO.SPO page n°21 - 29. Performance Takeoff with 100% Torque

4.10.1. This section begins with a chart showing the takeoff run data on a dry runway for OEI.

4.10.1.1. **Remarks**. The paragraph heads do not include that this chart is for OEI, while in the heads of the next chart is included *"All Engines Operating"*. On the OEI charts, *"Dry Runway"* is included in the legend but not on the All Engines Operating charts. Why this difference? Although these charts are in paragraph 10.3.2 Dry Runway, this paragraph is not repeated as prefix to the sub numbers on the remainder of the paragraphs, which makes it more difficult to determine whether the user is using the correct chart.

4.10.1.2. In the charts, the V_1/V_R and V_2/V_{SR} ratios are used. Refer to § 3.5.2 above and § 4.14.1.1 below for remarks. The pilot obviously has the option to amend safety margins, while CS/FAR 25.107 does not allow this.

4.11. AFM PRO.SPO page n°31. Decision Speed Limited by Max. Brake Energy

4.11.1. These charts present the Decision Speed Limited by Max. Brake Energy (Flaps 15).

4.11.1.1. **Remark.** This chart is about decision speed limited by max. brake energy. Why not use V_1 in the paragraph head, like on LIM.3 page n°14? Also refer to § 4.3.1.2 above.

4.11.1.2. On the right-hand side of the chart, both CAS and IAS are presented. How can you present IAS when you don't know the airspeed indicator instrument correction (V_{ic}) of an installed individual airspeed indicator (but only the pressure lag and position errors, V_{icl} and V_{pc})? And what about the ground effect? In manuals that apply to a type of airplane (not a single tail number), only CAS should and can be used, don't you agree?

4.12. AFM PRO.SPO page n°147. Approach Climb Gradient

4.12.1. This and the next page present the approach climb limiting weight (flaps 15), one engine inoperative, V = 1.13 V_{SR}.

4.12.1.1. **Remarks**. At low weight (15 ton) during the go-around, after the flaps are up to 15°, 1.13 V_{SR} is 93 kt and V_{MCA}, while the bank angle is 5° away from the inoperative engine, is 98 kt (SL, OAT 15°), and even (≈10 kt) higher when the wings are kept level (refer to § 2.1.3 above). The margin to avoid the Loss of control is then negative, or at best, very small. A go-around speed of 1.13 V_{SR} is too low, don't you agree?

4.13. AFM PER.3 page n°16. Takeoff Flight Path in Case of Engine Failure

4.13.1. This page presents a chart with the Takeoff Flight Path in Case of Engine Failure.

4.13.1.1. **Remarks**. The speed in the 1st and 2nd segment must be V_2 with flaps 15. V_2 in this manual is actually as low as V_{2MIN}, without increments that make it V_2 (as described in § 3.5.2.3 above). V_{2MIN} must be the higher of 1.1 V_{MCA} and 1.13 V_{SR}. At a low weight of 15 ton, 1.13 V_{SR} = 93 kt (flaps and gear up); V_{MCA} = 98 kt (SL, 15°C), hence 1.1 V_{MCA} = 108 kt. V_{2MIN} is then 108 kt, the safety margin above V_{MCA} is 10 kt, but only when a small favorable bank angle is being maintained. When the wings are kept level, the actual V_{MCA} increases to 98 + ≈10 = 108 kt (§ 2.1.3 above) and equals V_{2MIN}, the safety margin above V_{MCA} is then zero.
If the V_{MCA} data in LIM.3 Page no. 15 are valid for the power setting used during the 1st and 2nd segment, the recommended V_2 in this chart is too low for a safe initial climb when an engine fails, if not a small bank angle is maintained into the operative engine, which decreases actual V_{MCA} and the drag. If boost is on, or the torque is even higher, V_{MCA} is higher too, and V_2 needs to be increased as well.
In the legend of the chart is regrettably not included that it is required to maintain a small bank angle away from the failed engine to keep both the actual V_{MCA} and the drag as low as possible, and ensure an adequate safety margin above V_{MCA}.

4.13.1.2. The required airspeed during the 3rd and final takeoff segments is 1.18 V_{SR}. A few numbers: if at a low weight of 15 ton, V_{SR} = 96.5 kt (flaps and gear up), hence V = 1.18 V_{SR} = 114 kt. This is a safe 16 kt above standardized V_{MCA} (98 kt at SL, OAT 15°) but only approximately 6 kt above the actual V_{MCA} when the wings are kept level (98 + ≈10 kt), assuming that flaps-up have no effect on V_{MCA}. When turning, the margin will be even smaller, refer to § 2.1.3 above. Not only bank angle has a large effect on V_{MCA}, also the power setting. As V_{MCA} is determined with *"boost off"*, increasing the torque for whatever reason, manually or automatically to a higher level also increases the actual V_{MCA} at once and might render the airplane out of control if 1.18 V_{SR} is being maintained. To increase the safety margin of the second and final takeoff segment speed above V_{MCA}, not only a V_{MCA} for the *"Ramp"* and *"Wall"* torque settings is required and should be used to calculate a safe 2nd and final takeoff segment speed, but also a small bank angle into the operative engine needs to be maintained, hence straight flight, and should be recommended in the legend of this chart and in takeoff procedures. As already mentioned above, V_{MCA} should have been determined with the maximum asymmetrical thrust a pilot can set from the cockpit. If turns are required in the departure procedure, a much higher airspeed than 1.18 V_{SR} might be required when an engine is inoperative.

4.13.1.3. Don't you agree that a legend should be included in this chart with a caution that the data are valid for straight flight only, while maintaining a small bank angle (to be determined by the manufacturer) into the good engine? When the bank angle deviates from the small bank angle used to determine V_{MCA}, the actual V_{MCA} increases considerable, and loss of control might occur if a turn is initiated. Refer to § 2.1.3 above.

4.14. AFM PER.3 page n°19. Determination of MTOW for a Given Runway

4.14.1. This page presents a large diagram for the Determination of Max. Takeoff Weight for a Given Runway.

4.14.1.1. **Remarks**. In the legend is printed: "FOR A GIVEN V2/VSR", but where is this ratio given? Also *"FOR DIFFERENT~~S~~ V1/VR RATIOS, …".* These ratios also appear in other sections, and must already be known when entering the graphs for Takeoff Run, Takeoff Distance and Accelerate Stop Distance. Where are these ratios defined and explained? What is the source and who determines? Where is this diagram explained in the AFM? See also § 3.5.2 and § 3.5.1 above and § 4.15.1.1 below.

4.14.1.2. The final check on this diagram after selecting, determining and computing is the check whether the calculated $V_2 \geq 1.1\ V_{MCA}$. V_2 determined here seems to be V_{2MIN}, but there are two increments above V_{2MIN} that seem not included (CS/FAR 25.107 (c)): V_2 may not be less than V_{2MIN}, V_R + a speed increase and a speed that provides the maneuvering capability. These requirements other than V_{2MIN} seem not included in this diagram. The calculated V_2 might be too low.

4.14.1.3. Is a pilot authorized to vary the ratios, to bend the rules for calculating takeoff speeds? This cannot be the case and is not in agreement with the Regulations in CS/FAR 25.107. Don't you agree that this chart encourages pilots to use 'illegal' ratios and incomplete checks. Pilots should be protected against the use of inappropriately obtained performance data, don't you agree?

4.14.1.4. All takeoff performance data in the ATR AFM and in derived publications, such as the FCOM and QRH, needs to be carefully reviewed and brought in line with the legal requirements in CS/FAR 25.107. Legends must inform users of limitations.

4.15. AFM PER.3 page n°21 – 25. Performance Charts

4.15.1. These pages present Performance Charts, including charts for one engine inoperative and one propeller feathered.

4.15.1.1. **Remarks**. The performance charts on these pages include pilot selectable ratio V_2/V_{SR} or V/V_{SR}. As already mentioned in the previous paragraph, no note is presented for the use of these ratios and where to find guidance; nowhere in the AFM these ratios are discussed. What ratio does a pilot have to use to comply with Regulations? Is the V_2 referenced here in accordance with the requirements of CS/FAR 25.107? Does the speed include the maneuvering capability specified in CS 25.143(h)? No reference is made to a small bank angle that is required for minimum drag while this must be required when the CAS is as low as V_2.

4.15.1.2. In the Determination of MTOW for a Given Runway in PER.3 Page n°19, the final check is whether the calculated V_2 is $\geq 1.1\ V_{MCA}$ but the large effect of bank angle on V_{MCA} is not included. As explained in this review, V_{MCA}, although determined with a maximum thrust level and a small bank angle, varies considerable with these parameters. A V_2 of $1.1\ V_{MCA}$ might not be a safe takeoff safety speed.

4.16. AFM PER.3 page n°71. Take-off Speed – V_2 (Flaps 15)

4.16.1. This chart presents Take-off Speed – V_2 (Flaps 15) with one propulsion system inoperative.

4.16.1.1. **Remarks**. The title should be Take-off Safety Speed – V_2, because that is how V_2 is defined. First subparagraph is for Flaps 15, but there are no further paragraphs, so delete unnecessary paragraph heads to avoid cluttering a page.

4.16.1.2. Here again V_2/V_{SR} is included as pilot-selectable ratio from 1.13 to 1.35. CS/FAR 25.107 (b) requires V_{2MIN} to be not less than 1.13 V_{SR} and 1.1 V_{MCA} (determined at the maximum thrust a pilot can set from the cockpit). The V_2 in the ratio V_2/V_{SR} might be V_{2MIN} of CS/FAR 25.107. V_{2MIN} is not the lowest, the minimum V_2 for use during takeoffs, but is one of three factors to calculate takeoff safety speed V_2. Again, V_2 may not be less than (1) V_{2MIN}, (2) V_R + speed increment and (3) a speed that provides the maneuvering speed (CS/FAR 25.107 (c)). A V_2 range of 1.13 – 1.35 V_{SR} is not defined, its source is unclear. A clear instruction on how to use the V_2/V_{SR} ratio was not found in the AFM. See also next paragraph.

4.16.1.3. Refer to § 4.11.1.2 on remarks on the use of IAS in charts.

4.17. AFM PER.3 pages n°75 - 89. Obstacle Clearance T.O. Flight Path

4.17.1. The charts in this section present obstacle clearance takeoff flight paths for different V_2 takeoff speeds, that is for V_2/V_{SR} ratios: 1.13, 1.20, 1.27, 1.35, all for flaps 15 and for close and remote (nearby and distant) obstacles. For icing conditions, only V_2/V_{SR} = 1.22 data are presented.

4.17.1.1. **Remarks.** V_2 speeds are only required and are used as a target speed for heights between 35 ft and 400 ft above the takeoff surface. V_2 is a takeoff safety speed, not a speed for obstacle clearance. The charts are for flaps 15, but as presented in the chart on AFM PER.3 Page n°16 it looks like the flaps need to be retracted during the 3rd segment at 400 ft or above and the speed increased to 1.18 V_{SR}.
For obstacle clearance at and above 400 ft the takeoff safety speed V_2 doesn't apply anymore and the airplane is accelerated to V_{FTO}. V_{FTO} might be optimized for obstacle clearance, such as the minimum required or the best angle of climb. So why does ATR present V_2 data for 400 ft and above? The titles are not correct, don't you agree?
In addition, V_{MCA} seems not considered to be a factor for obstacle clearance, nor is the bank angle for zero drag, hence max. climb performance, which is of importance to obstacle clearance when an engine fails. The check $V_2 \geq 1.1\ V_{MCA}$ does not take into consideration that keeping the wings level increases V_{MCA} by approximately 10 % and also increases the drag because the sideslip is not minimal.

4.17.1.2. The same remarks apply to the charts for takeoff in icing conditions in PER.3 from page n°93. Icing conditions are not at all mentioned in the title or legend of the charts; the chart is not readable very well.

4.17.1.3. Climb performance is usually determined from an airspeed schedule during experimental flight testing. The airspeeds for best angle of climb and for the maximum rate of climb are both determined for several conditions and weights (and engine power). While maintaining either of these speeds, a small favorable bank angle may still be required to minimize sideslip, hence drag when an engine is inoperative, and improve obstacle clearance.

4.17.1.4. CS 25.107 (g) requires:

> *"V_{FTO}, in terms of calibrated airspeed, must be selected by the applicant to provide at least the gradient of climb required by CS 25.121(c), but may not be less than –*
>
> *(1) 1.18 V_{SR}*
>
> *(2) A speed that provides the maneuvering capability specified in CS 25.143(h)".*

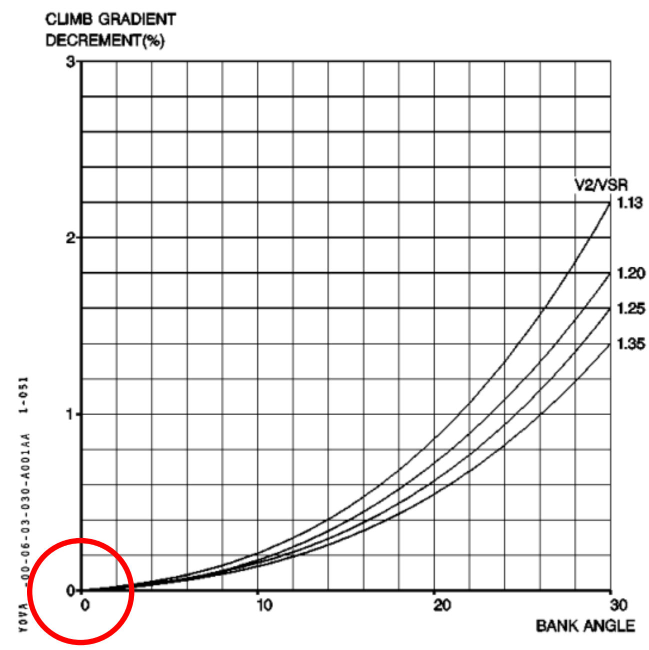
At low weight (<15t), V_{FTO} is equal to or very close to V_2 (§ 4.2.3 and § 4.13.1.2 above). When such a low V_{FTO} is used, Loss of Control will occur during turns if an engine fails

and the other variables that have influence on V_{MCA} are at their worst case value.
The reason for *"maneuvering capability"* is that an increasing V_{MCA} during banking is always a factor to consider when the airspeed is V_{FTO}, especially at low weights.

4.18. AFM PER.3 page n°99. Bank Angle Effect on SE Climb Gradient

4.18.1. The following chart is presented on this page:

BANK ANGLE EFFECT ON SINGLE ENGINE CLIMB GRADIENT
(FLAPS 15)



4.18.1.1. **Remark**. Rudder is required to counteract the asymmetrical thrust yawing moment when one engine is inoperative; its side force also causes a lateral acceleration, hence a sideslip, which increases until the opposite side force due to sideslip equals the rudder side force and an equilibrium of side forces is attained. Normally, a small bank angle (<5°) is used to reduce this sideslip using the side force component of the Weight ($W \cdot \sin \phi$) (refer to § 2.1.3 above). When the wings are kept level (bank angle $\phi = 0°$), while an engine is inoperative, there is no side force component of the Weight to counteract the rudder side force. Hence the sideslip cannot be zero and neither can the climb gradient decrement.
Hence, a climb gradient decrement of zero % at bank angle zero (red circle) is unattainable. This chart cannot be correct for asymmetrical flight. The thrust level of the operating engine should have been mentioned in the legend, as well as a statement on validity of these data; analysis or flight test? The suggested allowable bank angle of up to 30° is misleading. A turn while an engine is inoperative is never a coordinated turn. Can this bank angle be achieved without losing control? At what speed?
It seems that the effect of bank angle on V_{MCA} and on climb performance while an engine is inoperative is unknown to the AFM writers. Refer to Footnote 12 on page 16.

4.18.1.2. In the title of this chart and in this manual, the term *"Single Engine"* is often used, while the term 'one engine inoperative (or OEI)' is also used, as in PRO.NNO.ABN page n°57. Wouldn't be it preferable to use the same terms throughout?

4.19. AFM PER.4 page n°100. Single Engine Cruise, Introduction

4.19.1. This section presents performance data for single engine cruise. The first line under the three times repeated head *"Introduction"* is: *"The* "En route" *gradient given in this chapter are established by decreasing the available gradient at each point with a margin of 1.1 %"*.

4.19.1.1. **Remarks**. This line is not clear. The chart on page n°101 shows dotted lines that suggest the way to use the chart. But a gradient is not established, the arrows in the dotted line end at the weight on the right side. The 1.1 % margin is not at all obvious.

4.19.1.2. This chart was announced and referred to on PRO.SPO page n°08: *"Refer to SINGLE ENGINE CRUISE of this manual to determine the en route net gradient at the drift down speed"*. Why is this separated from PRO.SPO page n°08 which is for ETOPS with OEI? Do pilots not need a drift down altitude, the OEI ceiling, rather than a gradient?

4.19.2. On page n°101 the En-route Strategy / en-route net gradient for normal Conditions is presented. The speed to be maintained is 1.18 V_{SR} (flaps 0) and on the next page for icing conditions V/V_{SR} = 1.30 (flaps 15), both for one propeller feathered and one engine MCT power.

4.19.2.1. **Remarks**. A *"Strategy"* is not presented in this chart, unless it is used to determine the maximum weight at a certain altitude after engine failure. This is not an appropriate title. The chart itself has no title either.

4.19.2.2. If used during preflight, the chart provides, as indicated by the arrows, the weight for entry variables OAT, altitude and required gradient. But the OAT at the point en-route when an engine might fail is not known. As also stated above, do pilots not need a drift down altitude, the OEI ceiling, rather than a gradient (which is 50 fpm)?

4.19.2.3. Are the data valid for wings level or while maintaining a small bank angle for maximum performance? This is not mentioned in the legend (on page 498), nor is 'Inop. Propeller feathered'.

4.19.2.4. Is this a strategy as printed in the page head? Is V/V_{SR} = 1.18 the speed for maximum range (glide distance) for all weights? To minimize the drag due to asymmetrical thrust and maximize the range, a small bank angle of a few degrees might still be required. This requirement should be included in the legend of the charts.

4.20. AFM PER.5 page n°111. Approach Climb Gradient

4.20.1. This page presents charts with the Approach Climb Gradient - one engine.

4.20.1.1. **Remarks**. One of the paragraph heads is *"Normal Conditions"*, but what are these normal conditions? Why not use *"Non-icing conditions"* instead. One Engine Inoperative is not a normal condition.

4.20.1.2. Are the data valid for wings level? Or for flight with a bank angle of a few degrees into the good engine for minimum drag? Not mentioned in the legend.

4.20.1.3. It again seems up to the pilot to determine the safety margin, given the variable V/V_{SR} ratio between 1.13 to 1.4. A clear and legally correct instruction of how to use this ratio was not found, which is definitely inappropriate. An airspeed of 1.13 V_{SR} (one of the parameters to calculate V_{2MIN}) might be lower than V_{MCA}. Again, no reference is made to a required bank angle into the good engine for minimizing the sideslip/drag and the actual V_{MCA}. Refer to § 2.1 and § 4.19.2 above.

4.21. AFM PER.5 page n°114. Final Approach Speed Chart

4.21.1. § 2.2 presents the final approach speed charts preceded by the following text.

> "*The approach speed is at least 1.23 V_{SR} in the configurations:*
> *- FLAPS 15*
> *- FLAPS 30*
> *Or V_{MCL}, whichever is higher.*
> *The regulation authorizes to take approach speed up to 1.4 V_{SR}.*
> *The minimum final approach speed is the speed at 50 ft height taken into account for landing distance computation.*
> *It is equal to 1.23 V_{SR} in the landing configuration or V_{MCL}, whichever is higher*".

4.21.1.1. **Remarks**. In the definitions of the Limitations Section, LIM.3 Page n°09, the definitions for approach speeds V_{REF} and V_{APP} are presented:

- **V_{REF}**: "*Final approach reference speed for the determination of the certified landing distance", and*
- **V_{APP}**: *"Final Approach speed is the operational speed used during landing taking into account corrections (Wind/Gust/Failure)".*

"Final approach" and *"landing"* are used in both definitions. So, what is the difference between the two approach speeds?
V_{REF}, in EASA CS-Definitions, is the 'reference landing speed' and was called the threshold speed (at 50 ft AGL) years ago. V_{REF} is the target airspeed for crossing the threshold at 50 ft AGL; thereafter the throttles are closed (to a schedule) to enable touchdown. In accordance with CS 25.125 (b)(2), V_{REF} in non-icing conditions may not be less than 1.23 V_{SR}, V_{MCL} and a speed that provides maneuvering capability (as defined in CS/FAR 25.143(h)).
V_{APP} is the (stabilized) approach speed not less than V_{REF} to be maintained during the whole final approach (from 2000 ft) down to 50 ft above the threshold (CS 25.125 (b)(2)), and is not necessarily *"used during landing"* (touchdown) as the definition above suggests. V_{APP} is V_{REF} plus a wind additive plus other additions, if applicable. In the AFM, the only other addition found is +10 kt in case of certain failures.
On many airplanes, V_{APP} is at least 5 kt higher than V_{REF} for increasing the safety during the approach.

4.21.1.2. When § 2.2 states *"The approach speed is at least 1.23 V_{SR} …"*, the reader might believe that V_{APP} is meant. But the second last line is: *"The minimum final approach speed is the speed at 50 ft height taken into account for landing distance computation"*, which is referring to V_{REF}. V_{REF}, being a control speed, does not include wind and other additives (except in case of icing conditions). The ATC-reported wind is already included in the landing distance calculations, usually made at the top of descent. V_{REF} is not a factor in the calculation of the landing distance (refer to the landing distance charts in PER.5 from Page n°117).
These definitions are not very clear and are not quite correct and complete either, don't you agree? Why are *"V_{REF}"* and "V_{APP}" not used on this page? Is this page really approved by EASA? The chart on the next page of § 2.2 does not have a legend. Is this chart indeed showing V_{REF}?

4.21.1.3. No guidance on the required approach speed wind additive for a safe approach is presented on this page and in this paragraph for a normal approach and landing. It seems that the wind additive only applies to Cat. 2 approaches because it is only found on PRO.SPO Page n°136: *"The wind correction is equal to the highest of 1/3 of the reported headwind or the gust in full, with a maximum correction of 15 kt".*

4.21.1.4. On this page under Approach speed also the following line is printed: *"When the aircraft is stabilized on GLIDE slope the selected approach speed V_{APP} is 1.23 V_{SR} (FLAPS 30) + wind correction and not less than V_{MCL}"*. The two factors 1.23 V_{SR} and V_{MCL} are both already included in V_{REF}, refer to § 4.21.1.1 under V_{REF} above. The quoted line should therefore be: "*When … the selected approach speed V_{APP} is* V_{REF} + wind additive + other additive (in case of malfunctions)", don't you agree? The same remark applies to V_{APP} in § 21.2.2.1 on PRO.SPO Page n°138.

4.21.1.5. In a few procedures, *"V_{APP} … not less than VmHB +10 kt" is used.* On LIM.3 Page n°16 in § 5.2, V_{mHB} is determined to be 1.23 V_{SR} and not less than V_{MCL} during approach with either flap setting. So, during approach V_{mHB} is the same as V_{REF}. Then why not use V_{REF} + 10 kt rather than V_{mHB} + 10 kt in procedures? And what about wind additives? See also § 4.5 on V_{mHB} and V_{mLB} above.

4.21.1.6. **Magnitude of approach and landing speeds**. An example of approach and landing speeds for non-icing conditions. If the landing weight is 15 ton and flaps are 30, V_{REF} = the highest of 1,23 V_{SR} (= 1,23 x 75 = 92 kt), V_{MCL} (= 98 kt) and a maneuver speed (which is unknown, not given), hence V_{REF} is at least 98 kt. V_{APP} = V_{REF} + wind and other additives. When no wind and other additives, V_{APP} is also 98 kt. This is quite low; this V_{APP} provides no safety margin at all above V_{MCL}. V_{MCL} is determined while maintaining a small bank angle away from the inoperative engine. When the thrust is increased to maximal for whatever reason during the approach and the wings are kept level, control will be lost. This V_{APP} should not be recommended, is too low.

4.21.1.7. If a headwind of 20 kt gusts 30 is reported by ATC, then V_{APP} is still 98 kt, because wind additions are not presented in this paragraph. An omission? If the highest of 1/3 of the headwind or all of the gust is used as for Cat. 2 landings, V_{APP} would have to be 98 + (max 1/3 x 20; 10) = 108 kt. Then there still is no adequate safety margin above the actual V_{MCL} when keeping the wings level.

4.21.1.8. In the QRH on PER 3 Page n°03, with ops data for a landing weight of 15 ton, the listed Final Approach speed VmHB (Flaps 30) is 95 kt, not 98 kt (V_{MCL}). This recommended final approach speed (assumed V_{APP} is meant) is less than V_{MCL}, is definitely too low! In addition, why is *"V_{REF}"* not used here rather than VmHB? Then it will also be clear that wind additives might have to be added to calculate V_{APP}.

4.21.1.9. What is the source of the line: *"The regulation authorizes to take approach speed up to 1.4 V_{SR}"*? Which regulation? Do pilots need to know this? V_{APP} is not used in Regulation CS 25.

4.21.1.10. The V_{APP} and V_{REF} definitions should be improved, and data on calculating V_{APP} should be added to this page, because these also apply to normal approaches.

4.22. AFM PRO.NNO.ABN page n°57. Flying with One Engine Inoperative

4.22.1. *§ 99.2.01 Takeoff* presents the takeoff procedures with engine flame out before and between V_1 and V_2, that is also referred to from the Missed Approach procedure 99.2.04 on the next page.

4.22.2. In the procedure *"Takeoff with Engine Flame Out Between V_1 and V_2"* the following is included:

► LDG … Retract

"*Use rudder and control wheel to control aircraft heading maintaining aircraft wings essentially levelled".*

► *Climb at V_2*

4.22.2.1. **Remarks**. The rudder need not be used to control aircraft heading, but should be deflected large enough to maintain the heading, to maintain straight flight (CS 25.149). A slow yawing might give the impression that the heading is controlled, but is in fact the indication that directional control is lost with the current rudder position.

4.22.2.2. The wings need not be *"essentially leveled"*, but a bank angle of 5° or a little less should be attained away from the inoperative engine for the actual V_{MCA} to be as low as possible, and for the smallest sideslip, hence drag. Refer to § 2.1.3 above.

4.22.2.3. The landing gear is down or up, rather than *"Retract"* as used elsewhere in the AFM (or "*Order*" as on PRO.NOP.NOR Page n°08 and elsewhere). The indentation of *"Climb at V_2"* is incorrect, is printed too far to the left.

4.22.3. **Missed Approach/Go-around procedure**

4.22.3.1. The Missed Approach procedure § 99.2.04 (PRO.NNO.ABN Page n°58) refers with a link (1) to the Go-Around procedure (PRO.NOP.NOR Page n°10) in which power is increased to go-around power and flaps are selected up one notch to 15°. Back in the Missed Approach procedure (without being able to use a link) the pilots, *"at acceleration altitude"*, must *"Proceed as for takeoff with engine flame out between V_1 and V_2"*. In this procedure 99.2.01 Takeoff on the preceding page, the airplane should be accelerated *"up to 1.18 V_{SR} flaps 0"*, which is 1.18 x 96.5 = 114 kt for a weight of 15 ton (=V_{FTO}). For a landing weight of 13 ton, 1.18 V_{SR} = 106 kt.
If the go-around thrust is maximal, as used to determine V_{MCA}, then the margin of the V_{FTO} speeds above V_{MCA} with the wings level (SL, 15°C) is not very large ($V_{MCA\ \phi = 0}$ ≈ 98 + 10 ≈ 108 kt, assuming V_{MCA} with flaps-up is equal to V_{MCA} with flaps 15, because flaps-up V_{MCA} data are not provided). Turning at these speeds will even further increase the actual V_{MCA} leading to the loss of control (and loss of performance).

4.22.3.2. The approach climb limit weight data on page PRO.SPO Page n°147 in § 21.3.1 is presented for OEI, the other engine at go-around power, flaps 15 and V = 1.13 V_{SR}. The resulting speed for a weight of 15 ton is 1.13 x 82.5 = 93 kt, which is below both V_{MCL} and V_{MCA} (both 98 kt at SL, 15°C). At a weight of 20 ton, 1.13 V_{SR} is only 108.5 kt. If the thrust is increased to maximum, and the wings are kept level, the actual V_{MCA} increases by ≈ 10 kt and hence, the loss of control cannot be prevented (§ 2.1.3 above). If the throttles are (inadvertently) advanced to the *"Wall"* setting, V_{MCA} increases even more. It is not clear what power level is to be set for a go-around, just like it is not clear what power level was used to determine V_{MCA} – refer to § 4.4.1.6 above.

4.22.3.3. An approach climb speed of 1.13 V_{SR} is way too low. To avoid the loss of control when a go-around is (to be) initiated, either in anticipation of an engine failure or while an engine is already inoperative, the airplane should be accelerated down the glide path first (altitude permitting) to – in this example – at least 108 kt (wings-level V_{MCA} for the power setting used to determine V_{MCA}). It is obviously much more safe to increase V_{APP} for all approaches to V_{MCA} + 10 kt, in anticipation of an engine failure during the approach or go-around. It seems that V_{GA} is only given for Cat. 2 approach climb gradient because it is only found in the AFM on PRO.SPO Page n°149, Specials Operations, Cat 2 approach, normal conditions.

4.22.3.4. By the way, why is this procedure in 99 Miscellaneous? Is a go-around procedure really a miscellaneous procedure?

4.23. Additional General Remarks on the AFM

4.23.1. A general remark is that the AFM should be intended for pilots, not for the engineering staff. An AFM should support pilots for safely operating the airplane. Pilots need not be engineers, need not have engineering degrees, don't have to know engineering abbreviations, annoying abbreviations, etc. The use of such abbreviations already begins in the Table of Content (TOC) with six generally unknown abbreviations (LTR, LNR, etc.). What is ATR trying to prove by using these? Why are these terms not fully written out? These items in the TOC are presented at the same level as the Limitations Section, Procedures, Performance, etc. while these items are only part of the introduction to the manual and its organization, and should be moved into a separate Introduction section as required by CS AMC 25.1581 6a. CS 25.1581 requires a TOC because of the complexity of the manual.

4.23.2. Obviously, several people worked on the AFM and were using different terms for the same item or issue. A lead editor who is tasked with standardizing the contributions would improve the readability of the manual.

4.23.3. On several pages, a condition for a step in a procedure is printed below the step, like in this example on page PRO.NNO.ABN Page n°57:

► PWR MGT selector...MCT
On expiry of RTO power limiting time

Usually, the condition precedes the action, otherwise a pilot will execute a step and only then reads the condition, too late; in this case power might be reduced too early.

4.23.4. The items in the TOC Page n°01 refer to either page 01 or page 03, which are bookmarks, that don't work when the AFM is printed on paper. An example out of TOC Page n°01:

CRT.. page 01
GENERAL INFORMATION.. page 03
LIMITATIONS.. page 03

These bookmarks do not refer to the TOC of the individual sections. If the item Procedures in the TOC is clicked, a user expects to find a TOC of the whole Procedures section, including subsections, but he doesn't; only after scrolling down a few pages he'll find the TOC of Emergency procedures. Where are the other procedures, the normal and abnormal procedures? The TOC of subsections are difficult to find, or do not exist. This is not the EASA intention of accessibility by means of a TOC.
The accessibility of the AFM is very poor, which is unacceptable, is in fact a major deficiency. The AFM is made without consideration for the future users. The required information might be all there, but don't ask how and where.

4.23.5. ATR elected to use a section and chapter numbering system and an order of data and procedures that deviates considerable from other manufacturers' AFMs. Why did ATR not use the order and layout that is commonly used in all Flight Manuals, and that pilots transitioning from other types of airplanes are used to? Pilots transitioning to an ATR type have to learn a new (aviation) language, and new abbreviations, acronyms and a new manual format that do not always make sense. This is not favorable to aviation safety.

4.23.6. AMC 25.1581 5b(1) requires that each page of the approved portion of the AFM should bear the notation "EASA Approved", besides other identifying information. ATR however, has not provided each page, but each paragraph with a so-called data module strip with approval data. These do not show "EASA approved" though, but only "approved", which is not in accordance with CS 25 (see sample page below). A reader might ask the justified question: approved by whom? Just stating "approved" does not show the AFM to be the authoritative source as required by CS AMC 25.1581 1. The many Data Module strips on many pages clutters the pages, are distracting, cause confusion and require time to find the needed data in between the strips and are therewith affecting the safety. In the sample AFM page above, six Data Module strips are printed. Don't you agree this is distracting? What do they add for the purpose of this manual?

AFM	LIMITATIONS GENERAL LIMITATIONS	LIM.1 Page n°03

1 Introduction

_3e920159-6867-4bdb-809a-5059f15e96e7		0.1
		ALL
		APPROVED

Law requires the observance of th

When operating in accordance witn an approved appendix or supplement to this AFM, these limitations apply, unless amended by such appendix or supplement.

2 Kinds of Operation

_39c36470-bd17-4491-9888-80a05bc67d9a		0.1
		ALL
		APPROVED

The aircraft is certified in the transport category for day and night operations, in the following conditions when the appropriate equipment and instruments required by the airworthiness and operating regulations are approved, installed and in an operable condition:

- VFR and IFR
- Flight in icing conditions
- Reverse thrust taxi (single or twin engine).

3 Minimum Flight Crew

_4e716386-fd2a-4057-8be2-86720ae8d222		0.1
		ALL
		APPROVED

2 Pilots.

4 Performance Configuration

_a6294274-7351-4b3c-aec2-be2f9c726bcd		1.1
		ALL
		APPROVED

Refer to PER.1.2.01 Performance Configuration for aircraft configuration associated with certified performances.

5 Maximum Operating Altitude

_5e0f199b-a433-4e46-8d33-496abde00c11		0.1
		ALL
		APPROVED

Maximum Operating Altitude....................25 000 ft

6 Maneuvering Limit Load Factors

_50f667d9-e2a5-4754-b6ff-2f59e971a16f		0.1
		ALL
		APPROVED

Gear and flaps retracted.................... +2.5 g to -1 g
Gear and/or flaps extended.................... +2 g to 0 g

4.23.7. Many abbreviations defined in the Glossary of Standard Nomenclature, usually called List of Abbreviations (from GEN.3 Page n°07), are not at all used in the manual, for instance ABV,

meaning Above, ACCU for Accumulator, ANN for Annunciator, APC for Active Phase Control, etc. etc. There are also abbreviations used in the manual that are not defined, for instance APCH, Z, and mn.
Symbols of the Système International d'unités (SI) are often misused, such as KG and Kg should be kg, M should be m, etc. Similarly, English units NM and Nm should be nm, kts and KT should be kt, Ft – ft, and Lb and LB – lb. Mini is used for minimum.
Many abbreviations and acronyms are also different from those commonly used in aviation. which takes time for pilots to learn and get used to, and which might become confusing when the workload in the cockpit becomes high, such as during incidents. Terminology used in cockpits should be standardized. Doesn't ATR consider experienced pilots who transition from other airplane types?

4.23.8. Why use abbreviations and not full text. A few abbreviations were already mentioned above. Another is DSC, meaning description. Whoever uses that abbreviation? DSC and other 'abbreviations' such as NNO are not in the list of abbreviations, but appear in many page headers. NNO obviously means Non Normal (for Procedures and Operations), but on the Procedure pages 'Abnormal' is used instead, even under the head Non Normal Operations. EMER is defined as emergency in the List of Abbreviations, but is in page headers EMR (elsewhere known as Electro-Magnetic Radiation). Many used abbreviations and acronyms are not common in flight operations, making the manual unnecessarily difficult to access and read. There is a reason why AFM's use a simple numbering system, rather than an ill-defined combination of letters/ abbreviations. Why not make it easy on pilots? The AFM Is not written with care for the population it is intended for.

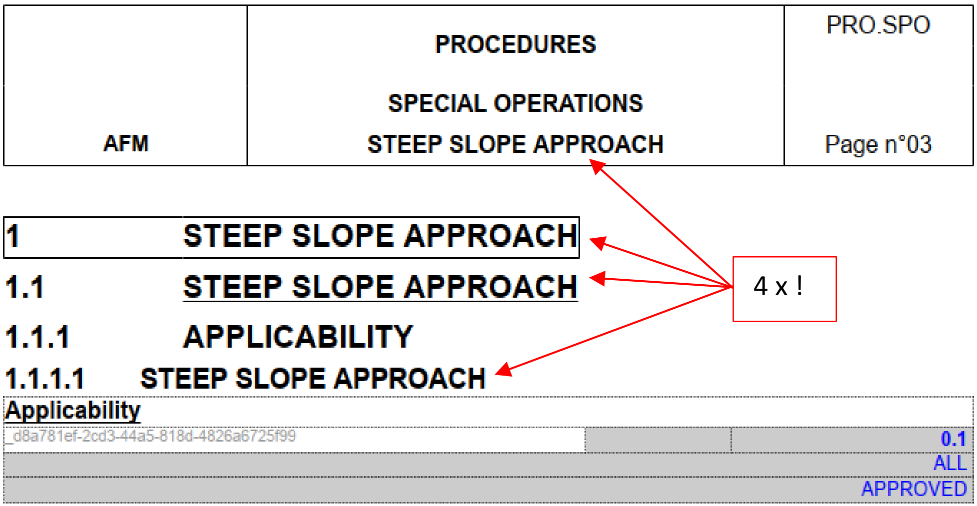
4.23.9. Often black letters on dark shaded text boxes are used which are difficult to read and takes time. An example (part of table on AFM LIM.5 Page n°30):

ICING CONDITIONS			
CONFIGURATION		RA CLIMB	RA INCREASE CLIMB
FLAPS 0	Z < 20 000 ft	AUTHORIZED	INHIBITED
	Z >20 000 ft	INHIBITED	INHIBITED

4.23.10. The letter Z in the figure above obviously refers to some kind of altitude, but is not explained in the List of Abbreviations. It is not even a symbol for altitude in aeronautical engineering (which is H), so why is Z used in the ATR AFM? Z is the axis of the Earth axis system that points to the center of the Earth. Z is also used in the manual as prefix for Radio Altitude (ZRA), for Cabin Altitude (Z CAB) and for Pressure Altitude (ZP). These abbreviations are not normally used by pilots for expressing and reporting altitudes.
Pilots use several altitudes, such as pressure altitude and flight level above 1013,2 hPa (QNE), altitude above MSL (QNH), above ground level (QFE) and density altitude. Why not just used 'above' and 'below' 20 000 ft in this table? Simple and understandable.

On many pages, paragraph heads are repeated quite a few times, like in the example head below. The head 'Steep Slope Approach' appears four times just below each other; 'Applicability' shows up twice. Furthermore there is no paragraph 1.1.1.2, so why use this paragraph level? There are very many unnecessary paragraph heads in the AFM. This unnecessarily clutters pages. This format proves that care was not taken while assembling this manual.

4.23.11. Subscripts in defined abbreviations, such as in V2, VSR, VMCA, VMCL, etc. are not used in page and paragraph heads. In addition, V_{REF}, V_{ref} and Vref are used to denote the same speed. This, and the use of upper case letters in heads and in bookmarks does not improve readability, don't you agree?



AFM	PROCEDURES SPECIAL OPERATIONS STEEP SLOPE APPROACH	PRO.SPO Page n°03

1 STEEP SLOPE APPROACH

1.1 STEEP SLOPE APPROACH

1.1.1 APPLICABILITY

1.1.1.1 STEEP SLOPE APPROACH

4 x !

Applicability

_d8a781ef-2cd3-44a5-818d-4826a6725f99 0.1

ALL

APPROVED

4.23.12. Although not reviewed, most of the remarks will also apply to the FCOM and QRH.

4.24. Conclusions Limited Review AFM

4.24.1. Content

4.24.1.1. The definitions of V_R, V_2, V_{MCA} and V_{MCL} in the AFM are the definitions that were just copied out of CS/FAR 25. These however, apply to airplane design engineers and experimental test pilots; they are incorrect and incomplete for use by pilots and should have been amended for use in the AFM. The flight restrictions that come with these speeds and that definitely apply to pilots when an engine is inoperative, are not included in or with the definitions. Inappropriate definitions lead to misinterpretation and therewith to catastrophic accidents (§ 4.2).

4.24.1.2. The take-off safety margins used in the Performance Section seem pilot selectable (by offering to use V_2/V_{SR} and V_1/V_R ratio's), which is not the intention of CS/FAR 25. The presented margins are very small in engine-out cases. The control and performance restrictions and the flight-limitations that apply following a (sudden) propulsion system malfunction and during the remainder of a flight, when a propulsion system is inoperative, are not discussed. The charts and tables in the AFM seem to allow pilots to apply their own safety margins, which is not in accordance with CS/FAR required safety margins; the objective of the level of safety that is established by the aeroplane's certification basis is not met. A clear instruction on how to use the ratio's was not found in the AFM. This leads to the conclusion that the safety margins required in CS/FAR 25 can easily be undermined by applying the current takeoff data charts with self-determined ratio's, rendering the aeroplane not airworthy (an AFM is integral part of the Certificate of Airworthiness). Takeoff speeds seem adjustable for meeting performance requirements, while Takeoff speeds should be adjusted for meeting speed criteria (§ 3.5).

4.24.1.3. Pilots need to be protected by their manuals for not making catastrophic mistakes when planning and executing flight operations; they need not be (performance) engineers. The AFM seems to be a manual made by engineers who don't care about flight operations, who forgot that they should make manuals that are easy to use when things run out of hands in the cockpit, when there are malfunctions, smoke, heavy turbulence, darkness. Under normal, abnormal and emergency conditions.

4.24.1.4. It became clear that the manual writers – and their supervisors – fall short of appropriate aeronautical knowledge at a high enough level. To be more specific, engineering and/or experimental flight-test knowledge on engine-out flight, especially of the flying qualities and the consequences for the magnitude of the safety speeds, was regrettably not applied. The effect of bank angle and weight on the minimum control speeds, which are used to calculate take off and go-around speeds, seem not known to the writers; most pilots do not know that either. The consequence is that most takeoff speeds in the AFM are too low and that emergency procedures are incomplete.

4.24.2. **Layout of the AFM**

4.24.2.1. Most pages in the AFM are cluttered with superfluous information. Every paragraph has its own so-called data module strip, while CS 25.1581 requires only a simple *"EASA approved"*, a revision number and an identification number on every approved page (refer to AMC 25.1581 5b(1)). The required STC applicant's name (ATR) and aeroplane type or model designation are not presented either on all (approved) pages.
There are pages in the AFM that are nearly filled with data module strips, making the real required procedure or data difficult to find by pilots. Easy for engineers to assemble a manual from a common database, but an embarrassment for pilots who use the manuals.
The layout is not as most experienced pilots are used to from other airplane types and manufacture, which requires additional time to learn to use the manuals.

5. Conclusions and Recommendations

5.1. Conclusions

5.1.1. Conclusions of each of the reviewed manuals are presented in the respective paragraphs above (§ 3.6, § 4.24).

5.1.2. The most important conclusions are:

5.1.2.1. Manuals are written without care. The AFM looks like an engineering manual, while it is for pilots who are not required to be an engineer.

5.1.2.2. It is hard to believe that EASA approved the AFM. If they did, then they didn't pay close attention, or the approvers suffer from poverty of aviation knowledge.

5.1.2.3. Incorrect engine out theory and procedures are presented in the ATR Performance Guide, which might also be caused by poverty of aviation knowledge, because high – academic – level knowledge and high level educated pilots were obviously not consulted. This was also the reason for writing the paper referenced in Footnote 4 on page 5.

5.1.2.4. Data is not in sections as experienced pilots, who are transitioning from other types, are used to and would expect, including emergency and abnormal procedures. Many procedures are organized to ATA chapter system number, which pilots don't (have to) know. Some abnormal/ emergency procedures are given number ATA number *"99 miscellaneous"*. Is flight with one engine inoperative (99.2) really an abnormal miscellaneous procedure? Not a real emergency? The emergency procedure is: Land ASAP. Should this procedure not be in the emergency procedures, rather than in abnormal? The organization of the manual is disappointing.

5.1.2.5. Experienced pilots transitioning to ATR airplanes must also get used to terminology and abbreviations that are different from what they learned and are used to in manuals of other manufacturers. This affects the safety and efficiency of operations with the airplane (§ 4.23 above).

5.1.2.6. The layout of many pages in the reviewed ATR manuals, including identification and approval status (AMC 25.1581 4k) data, is very much 'overdone'. All paragraphs are provided with identification data in page-wide text boxes called Data Module strips, that do not apply to pilots. The approval data could also be reduced to one per page in header or footer, if applicable, as required by EASA CS. The pages are way too cluttered with unnecessary information for pilots. No great care was taken to make a helpful, easy to read manual for pilots. ATR manual writers should keep in mind that their manuals are not only used at a desk, but also in an small cockpit that might, during emergencies that requires review of the manuals, be engulfed in smoke, in heavy turbulence, with oxygen masks donned, panic in the cabin, etc. For such circumstances, clean and easily accessible and readable manuals are required because of their influence on the safety. The ATR manuals, as reviewed, look more like manuals by engineers who want to show off to pilots. Unnecessary complicated and containing cluttering information that a pilot doesn't need for operating the airplane (§ 4.24.2 above).

5.1.2.7. The briefly reviewed manuals, especially the Performance Guide, seem engineering manuals while they should be manuals written for pilots, using pilot language and abbreviations/ acronyms that all pilots around the globe understand and know from their initial training or from other airplane type manuals and procedures. This will enhance the safety after transitioning to ATR airplanes.

5.1.2.8. The Minimum Control Speeds seem underestimated in ATR manuals, while many multi-engine airplanes crash following the loss of control after engine failure. The definitions of limiting speeds are the definitions copied from Certification Specifications that are intended for airplane design engineers and test pilots. In a manual for pilots the definitions should be adapted for use by pilots (§ 2.1.5.2 and § 3.3.4.13 above).
The flight-restrictions that come with and apply with minimum control speeds are not included. (§ 3.6.2 above). The V_{MCA} data presented in the chart on LIM.3 Page n°15 seems valid for three types of engine with different power output. This is impossible; engine power affects V_{MCA}, as does bank angle, the large effect of which is not mentioned at all. The data cannot be reliable; takeoff safety is at stake.

5.1.2.9. The use of speed ratios, such as V_1/V_R and V_2/V_{SR}, suggests that pilots may select their own safety margin while this is a responsibility of both manufacturer and operator as determined in CS/FAR. Pilots should be protected from making mistakes with take-off speeds by providing them with safe, easy to find and use take-off data, as CS and FAR require. ATR uses V_2, but the V_2 presented is really V_{2MIN}, which is too low a take-off safety speed, and is not in accordance with CS/FAR 25.107, because V_R plus the speed increment attained , and the speed that provides the specified maneuvering capability seem not included (CS/FAR 25.107 (c)). V_2 is also used for obstacle clearance, while CS/FAR use V_{FTO}, because V_2 applies up to 400 ft or another acceleration height only.

5.2. Recommendations

5.2.1. The takeoff speeds presented in the Airplane Flight Manual are too low. Recommended is to increase takeoff, approach, landing and go-around speeds with a margin that exceeds wings-level V_{MCA}. The used check $V_2 \geq 1.1\ V_{MCA}$ is not safe for engine-out flight when the wings are kept level or during turns.

5.2.2. It is strongly recommended to use the remarks and recommendations in this Review to improve the manuals to make it manuals that support pilots and present information they need for the safe operation of their airplane. Papers[14] on the subject and on the concepts of checklists and their objectives and on recommended typography, might be a source of inspiration.

5.2.3. It is strongly recommended to have not only the Performance Manual and the AFM, but all ATR manuals for pilots reviewed by competent, high (both flight and MSc aeronautical engineering) level experts to correct the many errors and therewith improve the ATR Manuals.

5.2.4. It is strongly recommended to replace the V_{MCG}, V_{MCA} and V_{MCL} definitions in these manuals, that currently are definitions for airplane design engineers, with improved definitions that are applicable to pilots and include with the definitions the flight restrictions that come with the speeds. This is also recommended for the derived takeoff speeds. ■

[14] *Designing Flightdeck Procedures*, NASA/TM—2016–219421, Oct. 2016, (https://ntrs.nasa.gov/api/citations/20160013263/downloads/20160013263.pdf), Immanuel Barshi, et.al.;
On the Design of Flight-Deck Procedures, NASA Contractor Report 177642, June 1994, (https://rosap.ntl.bts.gov/view/dot/12832), Asaf Degani and Earl L. Wiener;
Human Factors of Flight-Deck Checklists: The Normal Checklist, NASA Contractor Report 177549, May 1990, (https://ti.arc.nasa.gov/m/profile/adegani/Flight-Deck_Checklists.pdf), Asaf Degani and Earl L. Wiener;
On *The Typography of Flight-Deck Documentation*, Nasa Contractor Report # 177605, Dec. 1992, (https://ti.arc.nasa.gov/m/profile/adegani/Flight-Deck_Documentation.pdf), Asaf Degani.

