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Pilot's Operating Handbook Beechcraft Super King Air B200 & B200C, Raytheon Aircraft, Dec. 1994, Change May, 2000

Limited Review

for commentary and teaching purposes

Including Recaps of Pitot-Static System, Calibrated and Indicated Airspeeds and Minimum Control Speed

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– Committed to Improve Aviation Safety –

Pilot's Operating Handbook Beechcraft Super King Air B200 & B200C, Raytheon Aircraft, Dec. 1994, Change May, 2000[1] **–** Limited Review

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Harry Horlings has been appointed Officer in the Order of Orange-Nassau by the King of the Netherlands in 2022 for rendering outstanding service of national and international importance concerning airplane accident prevention and investigations.

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It is recommended to download the most recent version with working links from website: www.avioconsult.com/downloads.htm (#17).

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[1] Retrieved from the internet July 2025. https://pdfcoffee.com/beech-super-king-air-b200-amp-b200c-poh-5-pdf-free.html.

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1.   Introduction

1.1.   After reviewing more than 500 accident investigation reports, it was noticed that there are huge differences in the interpretation and the use of the air minimum control speed V_{MC} (or V_{MCA}) and of takeoff speeds (decision speed V_1, rotation speed V_R and takeoff safety speed V_2) of a multi-engine airplane, between airplane manufacturers and experimental test pilots on one side and airline pilots as well as accident investigators on the other side. These differences in interpretation have led to the many catastrophic accidents during the past 25 years caused by the loss of control and/ or performance after engine failure and to incorrect conclusions in the accident investigation reports.

1.2.   The sources of the inappropriate interpretation of important safety speeds by pilots are the Airplane Flight Manual (AFM), the Pilot Operating Handbook (POH), and pilot training manuals in which these speeds are incorrectly defined and explained, and inadequate guidance is presented for pilots in understanding and using these speeds.

1.3.   Beechcraft (Textron Aviation) is a member of the General Aviation Manufacturers Association (GAMA) and obviously used *GAMA Specification No. 1 for Pilot Operating Handbooks (POH)*[2] for preparing the B200 POH. The use of calibrated and indicated airspeeds (CAS, IAS) and the definitions thereof, including of the minimum control speed V_{MCA} and the accompanying maneuver limitations in the Specification, are incorrect and not in compliance with Federal Aviation Regulations (FAR) 23, which must have led to fatal accidents.
The GAMA-proposed definition of the minimum control speed, and the engine emergency procedures do not include the most important limitation that pilots should observe to prevent the loss of control after engine failure, especially during take-off, approach for landing, and go-around. The consequence is that pilots, without realizing, maneuver their airplane after engine failure in a way for which it was not designed and flight tested, and subsequently lose control and get killed, taking their crew and passengers with them.
GAMA Specification No. 1 was regrettably not written with a high level of aeronautical expertise, while the FAA inappropriately concluded that it meets the requirements in FAR 23, which is definitely not the case. The reviewing FAA office did not consult appropriate expertise either. The Specification was reviewed by Avio*Consult*. The *Limited Review of GAMA Specification No.1 for Pilot's Operating Handbook* is available for download[3].

1.4.   Included as an important notice in Section I of the POH is: *"all limits, procedures, safety practices, time limits, servicing, and maintenance requirements contained in this handbook are considered mandatory for continued airworthiness and to maintain the airplane in a condition equal to that of its original manufacture"*. These subjects then need to be perfect, but they are not, which is the reason that the POH of the Beechcraft Super King Air B200/B200C is critically reviewed in this paper. Remarks are made and clarified. The review is limited; not all pages are scrutinized.

1.5.   Another objective of this review is to explain certain lifesaving limitations that originate from aeronautical airplane design and engineering and of experimental flight-test principles and practices and from Federal Aviation Regulations, which are usually not very well understood and explained in multi-engine rating course books and by Certified Flight Instructors, and neither by accident investigators following accidents.
Pilots have the right to be well informed about the real value of the limitations of the airplane, and understand emergency procedures, rather than only apply them, for getting home safely when an emergency, or something less urgent occurs.

1.6.   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 required to conduct experimental flight-tests. The entrance level was an

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[2] GAMA Specification No. 1, *Specification for Pilot's Operating Handbook*, Rev. No. 2, 1996, https://gama.aero/facts-and-statistics/consensus-standards/publications/gama-and-industry-technical-publications-and-specifications/.
[3] Harry Horlings, Avio*Consult, Limited Review of GAMA Specification No.1 for POH's,* https://www.avioconsult.com/downloads/GAMA%20Specification%20No.1%20for%20Pilot's%20Operating%20Handbook,%20Limited%20Review.pdf

MSc degree in engineering or a BSc and an entrance exam. Test pilot schools teach aircraft performance, flying qualities, and airborne systems. During the one-year course, students receive in 50% of the time theory on the subjects mentioned and conduct some 120 flight hours of flight-training and -testing in 24 different types of airplanes: gliders, single, twin and 4-engine propeller and turbojet/fan transports, fighter jets, helicopters, and simulators. They have to pass 32 exams, write 32 reports, and undergo frequent test rides.

Pitot-static system calibration, and flying qualities testing of multi-engine airplanes while an engine is inoperative including determining the Minimum Control Speed in the Air (V_{MCA}) are part of the curriculum. The FAA Flight Test Guide[4] describe and explain the flight-test techniques. The courses on Flying Qualities of the USAF Test Pilot School can be downloaded from the USArchives[5], and of another test pilot school via the Links page of the website of Avio*Consult*[6]. A link to the Pitot-static course follows.

1.7.   In an attempt to increase the level of knowledge on the subject of flight with an inoperative engine, Avio*Consult* published during the past 20 years several reviews and accident analyses, wrote several papers and courses, and published these on the Downloads and Accidents pages of his website[7]. A video lecture was uploaded on YouTube[8].

Papers were also presented during seminars of the European Chapter of the Flight Safety Foundation[9], the EuroControl Safety Forum in Brussels[10], Dutch ALPA and other organizations, such as FAA, LBA and universities. Many concerned pilots, who noticed that the explanation of flight with an inoperative engine in their flight and training manuals does not agree with the published papers of Avio*Consult* (and hence, with the formal certification and flight-test regulations), asked Avio*Consult* for advice on the subject. Many manufacturers, including Beechcraft (Textron), authorities and Transport Safety Boards were asked to improve their manuals and investigations, but these organizations obviously also suffer from poverty of knowledge, because they did not change anything and regrettably did not appreciate the competency of a Test Pilot School graduate either. Fatal accidents continue to happen…

1.8.   This review presents flight-test based facts, and is not to apportion blame or liability to anybody, but to alert, make aware, teach, and learn from, which is necessary because appropriate knowledge obviously just faded away during the past 50 years or so, and fatal accidents with multi-engine airplanes, not only with Textron airplanes, continue to occur every month. For this reason, explanations are included as well as some recommendations for improvement. Although presented for the Beechcraft 200 POH, the remarks made below not only apply to this POH, but also to POH/AFMs of most multi-engine airplanes. Reviewing this POH was considered an indispensable obligation of a flight-test expert who has become aware of improper guidance to pilots, as contribution to preventing fatal accidents in the future.

2.   Airspeeds Explained

2.1.   During reviewing the Beech 200 POH (and other POH/AFMs prepared using GAMA Specification No.1), the use of Calibrated Air Speeds (CAS) and Indicated Air Speeds (IAS) was found to be neither in compliance with the way these airspeeds are defined and used in Airworthiness Standard

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[4] FAA Flight Test Guide AC-23-8C: http://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_23-8C.pdf

[5] - Flying Qualities Textbook, Volume II, Part 1, 1986,
    https://ia800107.us.archive.org/32/items/DTIC_ADA170959/DTIC_ADA170959.pdf,
  - Flying Qualities Textbook, Volume II, Part 2, 1986 (Chapter 11, Asymmetrical power),
    https://ia801001.us.archive.org/17/items/DTIC_ADA170960/DTIC_ADA170960.pdf.

[6] Website Avio*Consult*, Links page with links to USArchives downloads: https://www.avioconsult.com/links.htm.

[7] Website Avio*Consult*: https://www.avioconsult.com.

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

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

[10] 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 Forum slides AvioConsult June 2019 - video links.ppsm.

14 CFR FAR 23[11] and equivalent, nor as used during airplane design as taught at aeronautical universities[12], and nor as taught at test pilot schools for experimental flight testing, including the calibration of pitot-static systems. POH/AFM-writers, approving authorities, and pilots seem to struggle with understanding why these airspeeds exist and what their function is. Therefore, a few general remarks are presented prior to reviewing the POH to become aware of the real values of the used airspeeds. Misuse of the CAS and IAS in a POH led and still leads to fatal accidents, as will become clear in this review. Reference is made to the applicable aviation and other regulations; the source of the remarks below is the *Pitot-Statics and the Standard Atmosphere* course book of the USAF Test Pilot School[13] that is approved for public release and available for download from the US Archives. Instructors of test pilot schools teach and conduct pitot-static system testing, i.e. airspeed system calibrations, at least 50 times each year to and with the students; they know what they are talking about, and share their knowledge to learn from.

2.2. The True, Calibrated, and Indicated Airspeeds of an Airplane

2.2.1.   Pilots need to know what the airspeed of their airplane is, not only for navigation purposes, but also for the piloting task, for using operational and limiting speeds. Complicating is that the airplane operates in a moving atmosphere at altitudes between ground level and the maximum operating altitude of the airplane. The temperature and air pressure in the atmosphere, also called density, change during the day and with altitude, and have effect on the performance of engines, on the aerodynamic (control) surfaces of the airplane, and on measuring the airspeed (and altitude).

Four speeds that are in use today are briefly explained, and in addition also the Minimum Control Speed $V_{MC(A)}$, because this limiting speed, that applies in anticipation of and following an engine failure, is misunderstood by most pilots, leading to accidents.

2.2.2.   **True Air Speed** (TAS, or V_t) is the airspeed (velocity) at which the airplane is plowing the air mass which is not yet disturbed and influenced by the airplane (e.g. its bow wave), and which generates the aerodynamic lift and control power with respect to the ambient temperature (density ρ_a[14]) and pressure P_a at the flying altitude (Figure 1).

$$V_t = \sqrt{\left(\frac{1}{\rho_a}\right) 7 P_a \left(\left(\frac{P_T - P_a}{P_a} + 1\right)^{\frac{2}{7}} - 1\right)}$$

Figure 1. True Airspeed (TAS, V_t) equation.

TAS is not useful for the piloting task, i.e. for control and performance, because of the influence of both ambient temperature and altitude. The use of TAS would require computing different speeds for each combination of ambient temperature and altitude. In addition, it is quite complicated to build an accurate mechanical TAS indicator to account for the temperature and altitude effects, which was the reason to introduce the **Calibrated Air Speed** (CAS), for which the *standard atmospheric pressure and temperature at sea level* are used as a reference, rather than the ambient pressure and temperature at flight altitude. CAS makes the piloting task and the use of pre-determined and flight-test acquired performance data, operational, and limiting speeds more convenient.

TAS is the airspeed used by pilots for the navigation task, for calculating the speed and time enroute and is calculated from CAS using both the actual ambient pressure altitude and the outside air temperature, using a flight computer (E6-B), or by an on-board computer.

A proper definition of True Airspeed (TAS) is:

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[11] Code of Federal Regulations, Title 14, Chapter I, FAR 23, 1–1–10 Edition was used in this review. Link to 2017 version: https://www.ecfr.gov/on/2017-01-03/title-14/chapter-I/subchapter-C/part-23/subpart-B.

[12] *Stability and Control during Steady Straight Flight*, Airplane Design Part VII, Dr. Jan Roskam, DAR Corporation, Kansas: https://shop.darcorp.com/index.php?route=product/category&path=60

[13] *Pitot-Statics and the Standard Atmosphere*, 4th edition (July 2020), Russell E. Erb, USAF Test Pilot School, https://apps.dtic.mil/sti/pdfs/AD1115005.pdf.

[14] ρ is pressure P divided by (R (gas constant) times T (temperature)). Is the Equation of State $P = \rho RT$.

> **TAS is the true airspeed of the airplane in an undisturbed airstream
> with respect to the ambient pressure and temperature**

As the standard atmospheric pressure and density (temperature) at sea level were used as references for the CAS, TAS is equal to CAS at sea level in a standard atmosphere.

2.2.3.   **Calibrated Air Speed** (CAS, or V_C) is the airspeed (velocity) of the airplane in the undisturbed free airstream with reference to standard atmospheric pressure and temperature at sea level, as explained in the previous paragraph. The air pressures that are representative of the speed should be sensed by a long pitot-static boom that sticks out in front of the bow wave, which is not always practical. Therefore, the total pressure (P_T) is sensed by a pitot tube mounted on fuselage or wings in disturbed air and the ambient (static) pressure (P_a or P_S) by one or two flush ports, as shown in Figure 2 below. Both air pressures are fed into an Air Speed Indicator
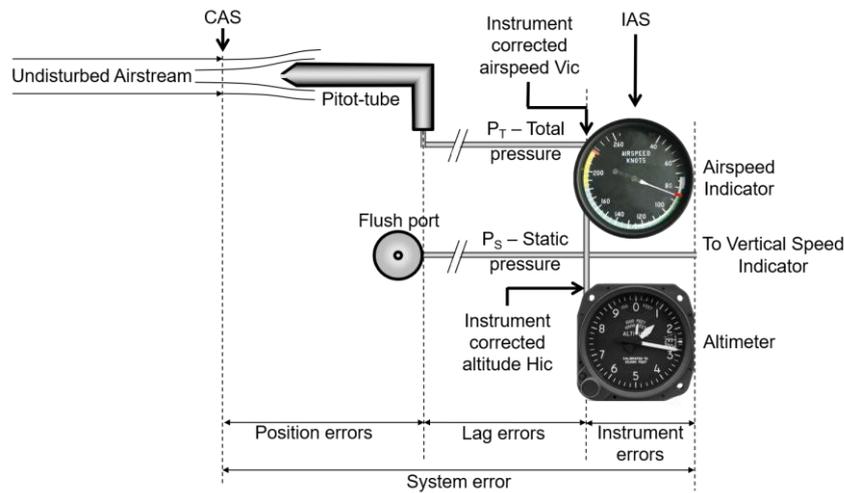
Figure 2. A common pitot-static system and its errors; from CAS in undisturbed airstream to IAS on the ASI.

$$V_c = \sqrt{\left(\frac{1}{\rho_{SL}}\right) 7 P_{SL} \left(\left(\frac{P_T - P_a}{P_{SL}} + 1\right)^{\frac{2}{7}} - 1\right)}$$

Figure 3. Calibrated Airspeed (CAS, Vc) equation.

(ASI) which is constructed to sense the differential pressure $P_T - P_a$ and indicate the corresponding calibrated airspeed (which occurs when the errors are zero) with respect to the standard atmospheric pressure and density at sea level (P_{SL} respectively ρ_{SL} in Figure 3), which are the references for CAS. The only variable is the differential pressure $P_T - P_a$.

At a constant differential pressure, the CAS will always be the same. Changes in sea level pressure and temperature will not affect CAS. Hence, CAS on one day is CAS on another day. Therefore, CAS is convenient for the piloting task (as compared to TAS); the POH-published speed limitations such as V_S, V_{MC}, and V_{MO}, and operational speeds such as V_1, V_R, V_2 and V_{REF} are proportional to CAS for a given gross weight. CAS is also used to present performance data in an POH. CAS in one airplane is CAS in another airplane of the same type. The CAS of two airplanes flying in formation should be equal. CAS is often inappropriately explained as being the abbreviation of Computed Air Speed, even by accident investigators.

2.2.4.   The definition of CAS in a POH is almost always how to calculate CAS from IAS, like GAMA inappropriately recommends in Specification No.1: *"Calibrated Airspeed means the indicated airspeed of an airplane corrected for position and instrument error"*. CAS is indeed IAS corrected for *instrument and position errors,* in this order though when the pilot needs CAS, but CAS *"means"* much more. CAS is the origin of the other airspeeds. CAS is used during flight-testing to determine and report limiting and operational speeds, and performance data. The use of CAS allows the manufacturer or operator to use (copies of) the same POH/AFM for a series of airplanes of

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the same type that have identical pitot-static systems (position errors); the FAA or equivalent authority then must approve only one AFM. Therefore, CAS deserves a better, appropriate, and explaining definition, rather than being a corrected IAS.

The proper definition of Calibrated Airspeed (CAS) should be:

> **CAS is the calibrated airspeed in undisturbed air with respect to the standard atmospheric pressure and temperature at sea level**

2.2.5.   **Errors in the Pitot-static system.** Prior to explaining Indicated Airspeed, the pitot-static system errors (Figure 2) need some clarification. The system errors consist of position, lag, and instrument errors which will be discussed briefly.

2.2.5.1.   *Position Error*. The consequences of positioning the pressure sensors in disturbed air and flush on the fuselage are errors in the pressure measurements, called position errors. The error due to angle of attack and angle of sideslip in the normal flight range is usually close to zero. FAR § 23.1323 (b) determines: "*the pitot-static system error, <u>excluding</u> the ASI calibration error, to not exceed the maximum of 3% of CAS or 5 kt*". Position errors are determined during in-flight calibration for several configurations (flaps, gear, weight) over a range of airspeeds and altitudes and are furnished in graphs in the AFM for use by pilots.

2.2.5.2.   *Instrument Errors*. An ASI has errors too, called instrument errors, as shown in Figure 2 and requires **calibration** as well. Calibration of both the pitot-static system and the ASI gave the calibrated airspeed its name; CAS is the airspeed with maximum obtainable accuracy (for subsonic flight). The expansion of the aneroid (diaphragm or bellows) within a mechanical ASI due to the difference between P_T and P_S (= P_a) is translated by mechanical parts to the pointer of the ASI which rotates above an airspeed scale indicating the IAS. The mechanism in the ASI is designed and constructed to indicate the airspeed with respect to the standard atmospheric pressure and temperature (ISA) at sea level (CAS equation in Figure 3).

The errors between the air pressures P_T and P_a at the entrance ports of the ASI and the eyes of the pilot(s), caused by the mechanical parts within the ASI, such as manufacturing discrepancies, magnetic fields, hysteresis or friction, altitude, temperature changes, vibration, inertia of moving parts, and the parallax, contribute to the total instrument error. The instrument error of each individual ASI over a range of airspeeds is determined in an instrument laboratory during calibration at sea level in a standard atmosphere, as required by FAR § 23.1323(a). SAE AS 8019 presents detailed ASI specifications, but this document is not freely accessible. In another POH, the permissible instrument error is mentioned to be ± 4 kt at speeds above 50 kt. In addition, the friction of the pointer *"must not produce an error exceeding 3 kt".*

Hence, in a worst-case situation, the difference between the IAS indicated on two ASIs connected to the same pitot-static system is allowed to be up to 8 kt (if one error happens to be – 4 kt and the other + 4 kt) while the CASs, calculated after adding the known instrument correction of each ASI and the (common) position error correction of the pitot-static system are equal.

2.2.5.3.   The pressure difference P_T minus P_a (or P_S) at the entrance of the ASI is a measure of the IAS plus or minus the instrument error, and is also called the *instrument corrected airspeed* Vic (Figure 2), which is to be used as the entry variable for the position error chart in the POH when calculating CAS from IAS.

2.2.5.4.   *Lag errors.* The pressure lag errors are caused by the friction, the pressure drop, and the inertia of the air mass in the air tubes causing a small delay, but are considered not to have influence except when changing airspeed or altitude. These errors will not be further discussed.

2.2.5.5.   ***Errors in Electronic Air Data systems and displays.*** Modern air data systems do not have a mechanical ASI anymore (except for a backup/ alternate). Such a system however, still has the errors as shown in Figure 2. Pressure transducers in the air data system convert the analog air pressures P_T and P_S into digital output data for further processing and display. Besides analog to digital conversion errors, also drifting of the output can occur over time; fluctuations of electrical power supply voltage and equipment temperature might affect the output data as well. Such an air data system would require calibration, which might include both pitot-static position and "instrument" calibrations, of which the result could be entered in the computerized air data system for correcting the errors. Then the airspeed indicated on the ASI (speed tape) has become the CAS of the airplane, the only relevant, accurate speed for the piloting task which is also the only airspeed that should be used in the POH/AFM. The piloting task becomes easier and faster. Less failures will be made if the pilot only works with CAS. In most older airplanes though, the pilot must still work with both the position and instrument errors and hence with both CAS and IAS.

2.2.5.6.   ***Total system error***. The sum of both position and instrument errors comprises the relationship between CAS and IAS. FAR § 23.1587(d)(10) requires this relationship to be furnished to the pilot for commuter category airplanes. The maximum regulations-approved airspeed error, being the sum of the approved instrument and position errors, is in a worst case allowed to be as high as (4 + 5 =) 9 kt (FAR § 23.1323(b) and SAE AS 8019). An additional friction error of up to 3 kt might occur during acceleration (takeoff) or deceleration. These are numbers that a pilot needs to be made aware of for being able to plan and conduct the takeoff, approach, and landing safely, and for handling the airplane, including in case one engine fails or is inoperative.

2.2.5.7.   Hence, the airspeed indicated by the pointer of the (mechanical) ASI is not the CAS anymore; the inherent system errors (Figure 2) affect the air pressures P_T and P_a enroute from the undisturbed air ahead of the airplane to the ASI, and the conversion of the air pressures within the ASI up to the airspeed indicated by the pointer. Hence, CAS cannot be directly indicated in the cockpit but must be calculated by the pilot by adding both the pitot-static position error and the ASI instrument error to the airspeed indicated by the Airspeed Indicator (ASI), and the results written on a Takeoff and Landing Data card, or by positioning bugs on the ASI. The errors can be positive, zero or negative. Backwards, when the pilot needs performance data out of the POH/AFM while in-flight, IAS values read from the ASI need to be corrected with the instrument error (=Vic), which is then used to find the position error to be added to calculate the CAS required to enter the performance graphs in the POH/AFM.

2.2.6.   **The Indicated airspeed** (IAS) is the speed indicated or displayed on an Airspeed Indicator (ASI), which is the CAS including the inherent pitot-static position and instrument errors (Figure 2), and hence is not the airspeed anymore at which the airplane moves through the air. IAS is a speed that is not directly useful for pilots, however, it is the only speed that the pilot can work with, but it needs corrections to be a valuable airspeed.
IAS exists because an ASI is simple in design and construction and is easy to calibrate, but also has unavoidable manufacturing and other errors, which were already mentioned in § 2.2.5.2 above. The errors of individual ASIs differ from each other, reason why each ASI needs to be calibrated individually in a laboratory and its error published in a calibration report (small table) and furnished to the pilot (FAR 23.1323). The IAS indicated by two ASI's in one cockpit may disagree with ± 4 kt (total of 8 kt) due to different instrument errors. The differences of instrument errors between ASIs in the same cockpit and in the fleet of airplanes of the same type for which a single POH/AFM applies, and changes in instrument errors due to future maintenance replacements of ASIs, are the reasons that limiting and operational airspeeds cannot be furnished as IAS in a single AFM that applies to a series of airplanes. The indicated airspeed IAS is not accurate enough to be of direct value to pilots. The IAS of two airplanes flying in formation are most probably not

equal, while their CASs should be.

As noticed during reviews of manuals, many if not all AFMs consider the instrument error to be zero, which is not in compliance with FAR 23. It makes the IAS less accurate (± 4 kt). IAS is not really the airspeed of the airplane, but an airspeed comprising errors; IAS is only of value after applying corrections. IAS could also mean InAccurate Speed.
A proper definition of Indicated Airspeed (IAS) is:

> **IAS is the airspeed indicated on an airspeed indicator and is CAS including the error due to the position of the pitot tube and the ASI instrument error**

2.2.7. **Ground Speed (GS).** The flow of the airmass through the atmosphere, such as the wind, also has influence on navigation. The speed of the airplane relative to the ground, called the Ground Speed, is the TAS plus or minus a tail- or headwind component. Ground speed allows calculating the distance travelled in a period.
Finally, the definition of Ground speed (GS) is:

> **GS is the airspeed relative to the ground, and is the TAS corrected for the wind**

2.2.8. **Equivalent Airspeed** (EAS) is still taught at Test Pilot Schools and universities, and was used by pilots before World War II, but the difference with Calibrated Airspeed is small and within acceptable tolerances for Part 23 airplanes.

2.2.9. **Further reading**. Refer to the (free) book *Pitot-Statics and the Standard Atmosphere* in footnote 13 on page 6 for a complete course at MSc level on pitot-statics, airspeeds, altitudes, and the standard atmosphere.

2.2.10. This paper is about airspeeds, the altimeter errors were not mentioned but are addressed in FAR 23. The calibration is required in FAR § 23.1325(e).

2.3.   Calibrated and Indicated Air Speeds in Federal Aviation Regulations (and equivalent)

2.3.1.   FAR 23 "*prescribes airworthiness standards for the issue of type certificates, and changes to those certificates, for airplanes in the normal, utility, acrobatic, and commuter categories. Each person who applies under Part 21 for such a certificate or change must show compliance with the applicable requirements of this part*".
Hence, FAR 23 is intended to be used by airplane design engineers for designing airplanes (including sizing the vertical tail); and for the certification of the airworthiness of the airplanes. Non-compliance with FAR 23 renders the type certificate and hence, the certificate of airworthiness of an individual airplane invalid. Below, a few relevant FAR paragraphs are described and explained that are needed during this review.

2.3.2.   GAMA Specification is originally intended for Normal Category Airplanes, but it is also used for Commuter Class POH/AFM. Therefore, several Regulatory paragraphs of FAR 23 (1-1-10 Edition) for normal category (< 9 pax), commuter category (< 19 pax and MTOW < 19,000 lb), and SFAR No. 23 (> 10 occupants/Part 135), about airspeeds are partly copied below with some remarks added. This chapter was originally written for an FAA certified airplane, which is the reason for references to FAR § 23. The review also applies to EASA CS 23 paragraphs.

2.3.3. **FAR § 23.1581**

> **"(c)** *The units used in the Airplane Flight Manual must be the same as those marked on the appropriate instruments and placards*".
> **"(d)** *All Airplane Flight Manual operational airspeeds, unless otherwise specified, must be presented as indicated airspeeds*".

These requirements did not yet exist in the 1970 edition of FAR 23, and must have been included after the issue of GAMA Specification No. 1, which was regrettably not written with a high level

of aeronautical expertise, as described in the *Limited Review of GAMA Specification No.1 for Pilot's Operating Handbook[3]*.

"Units" refers to mph or knots, not to KCAS or KIAS. Since the word *"marking"* is used in the same sentence, the writer might mean that the markings on the ASI must be in KIAS (of course), but that KIAS must also be used in the AFM, which is not possible.

Presenting all operational airspeeds as IAS requires a single POH/AFM for each and every airplane of the same series/type because the errors of the installed ASI's might differ, unless the instrument error is neglected (is assumed zero), which introduces unacceptable inaccuracies that affect the safety of flight, and which is not in compliance with other FAR 23 and Advisory Circular requirements.

2.3.4. **FAA Flight Test Guide AC 23-8C**[4] in Section 2, § 3 d specifies for commuter category airplanes: *"(1) Takeoff Speeds. The following speed definitions are given in terms of calibrated airspeed"*.

The "*following speed definitions*" are those of: V_{EF}, V_1, V_R, V_{LOF} and V_2. Not included are V_S and V_{MC}, although both are used to calculate V_R and V_2. Limiting speeds V_S and V_{MC} should therefore also be specified here as calibrated airspeeds, like they are in FAR § 23.51 and § 23.149.

These operational airspeeds are determined and/or calculated following (experimental) flight tests, and usually presented as CAS for reasons described in the paragraphs above and in § 2.4 below. These do not need to be presented in IAS in a POH/AFM.

AC 23-8C continues with: *"The AFM presentations are required, by 23.1581(d), in indicated airspeed (IAS)",* except for the *"following"* operational and limiting airspeeds, that were mentioned above. POH/AFM presentations cannot be (accurate) in IAS in an AFM that applies to a series of airplanes, and of which the instrument errors are assumed zero. This requirement must have been included following the issue of GAMA Specification No. 1 which, as will be shown in this review, is not written with competence at a high aeronautical level of knowledge. What a pilot must do is find the appropriate and needed operational and limiting airspeeds as CAS for a particular flight in the POH/AFM data tables and/or graphs, and correct these to IAS by applying both the position error in the POH/AFM and the instrument error found in the calibration report of the ASI (a small table) installed in the particular airplane during preflight and present these IAS values on the Takeoff and Landing Data (TOLD) card for use in the cockpit, one for each ASI. Presenting IAS in a POH/AFM that is issued for a series of airplanes is intolerable and asking for fatal accidents, and is not in compliance with FAR 23 either. See further § 2.4 below.

2.3.5. **Pt. 23, SFAR No. 23, § 5(b)(1)** requires decision speed V_1 to be in CAS. V_1 is calculated using V_S and V_{MCG}, so these speeds must also be provided in CAS (FAR § 23.51 and § 23.149).

2.3.6. **Pt. 23, SFAR No. 23, § 7** and FAR § 23.73 also require the landing approach speed V_{REF} in CAS, because the source speeds V_{MC} and V_S are in CAS (FAR § 23.51 and § 23.149).

2.3.7. **Pt. 23, SFAR No. 23, § 20 (f)** determines that the performance information in the POH/AFM must include*: "Airspeeds, as indicated airspeeds, corresponding to those determined for takeoff in accordance with section 5(b)".* Section 5(b) defines takeoff speeds V_1 and V_R in CAS, because V_S and V_{MC} are also determined in CAS (FAR § 23.51 and § 23.149). The instrument errors between airplanes differ, hence the takeoff speeds in IAS (as required here) will not be accurate in an AFM that applies to a series of airplanes of the same type. This is not in compliance with other paragraphs in FAR 23 either, such as § 23.51.

2.3.8. **FAR § 23.51(a)** requires rotation speed V_R for normal category airplanes to be not less than 1.05 V_{MC} or 1.1 V_{S1}. As V_{MC} and V_S are determined in CAS, V_R will also be in CAS (see also the Flight Test Guide quote in § 2.3.4 above). For commuter category airplanes (§ 23.51(c)), V_1, V_R, and V_2 must be established/selected in terms of CAS as well.

Hence, FAR § 23.51 specifies the operational takeoff speeds V_1, V_R, and V_2 and stall speed V_S to be presented as CAS in the AFM. FAR § 23.73 specifies the landing approach speed V_{REF} as CAS, and FAR § 23.149 specifies both V_{MC} and V_{MCG} as CAS. Hence, these are the operational and limiting airspeeds that are *"otherwise specified"* (§ 2.3.3 above) and hence, should not be presented

as indicated airspeeds in an AFM, the reason being that these speeds are critical to flight safety and need to be quite accurate and reliable. As mentioned in § 2.3.4 above, the pilot must calculate the corresponding IAS values of the operational and limiting speeds by adding both the position error and the instrument error of the installed ASI to the CAS values and present these on a Takeoff and Landing Data card for use in the cockpit

2.3.9. **FAR § 23.1323(a) and Pt. 23, SFAR No. 23, § 13(a)** require: "*Each airspeed indicating instrument must be calibrated to indicate true airspeed (at sea level with a standard atmosphere) with a minimum practicable instrument calibration error when the corresponding pitot and static pressures are applied*".
Each ASI is calibrated in a laboratory to determine its instrument error, being the error between the air pressures at the entrance ports (P_T and P_a) and the airspeed indicated by the pointer on the dial of the ASI. The IAS + the instrument error is also called Vic (§ 2.2.5.3).
There is no requirement for ASI calibration at higher altitudes, only for a range of speeds at sea level, because the reference airspeed and temperature used in the ASI are standard atmospheric sea level pressure and density (Figure 2).

2.3.10. **FAR § 23.1323 (b)** requires: "*Each airspeed system must be calibrated in flight to determine the system error. The system error, including position error, but excluding the airspeed indicator instrument calibration error, may not exceed three percent of the calibrated airspeed or five knots, whichever is greater, throughout the following speed ranges: …*"
A similar requirement in **Pt. 23, SFAR No. 23, § 13(b)**: "*The airspeed indicating system must be calibrated to determine the system error, i.e., the relation between IAS and CAS, in flight and during the accelerate takeoff ground run*", **and in § 13(d)**): "*information showing the relationship between IAS and CAS must be shown in the Airplane Flight Manual*".
The system error is the position error plus the lag error (Figure 2 above), but excluding the instrument error. The lag error is often neglected because it has effect only during pressure changes, which do not occur during steady flight.
Hence, the relationship between IAS and CAS is the sum of the instrument error of the ASI and the position error of the pitot-static system: CAS = IAS + instrument error + position error. The instrument error cannot be presented in a POH/AFM for a series of airplanes of the same type, as explained above, only the position error must be provided in a chart or table. The instrument error should be mentioned though in the POH/AFM, certainly in the legend of the position error chart, because the pilot must read the airspeed instrument correction from an instrument error correction table and add this to the IAS to calculate the instrument corrected airspeed (Vic) which is then used to enter the position error chart to read the position error or CAS. An IAS to Vic conversion table is to be made and be available for each individual ASI (for each serial number).

2.3.11. So, **FAR § 23.1323** requires both the pitot-static system and the airspeed indicator instrument to be calibrated separately. The calibration data of both must be made available to the pilot to be able to calculate the CAS from the IAS during flight, and to calculate pre-flight determined performance data and takeoff speeds from CAS in the POH/AFM to IAS for use in the cockpit (on the Take Off and Landing Data (TOLD) card). The GAMA Specification No. 1 seems not to mention the instrument calibration error, on the contrary, GAMA assumes and recommends zero instrument error and therefore does not comply with several FAR 23 paragraphs. It should not have been approved by the aviation authority.

2.3.12. **FAR 23.1581**. "*An Airplane Flight Manual must be furnished with each airplane, and it must contain the following:*

   (1) Information required by §§23.1583 through 23.1589.
   (2) Other information that is necessary for safe operation because of design, operating, or handling characteristics."

§§ 23.1583 and 23.1587 are copied in the next paragraph. Not only minimum control speed V_{MC} must be furnished as number, but also other information necessary for safe operation after

engine failure. V_{MC} and its associated conditions will be explained in § 2.5 below.

2.3.13. **FAR 23.1583** requires that "*the AFM must contain operating limitations*", including:
"*(a)(1) Information necessary for the marking of the airspeed limits on the indicator as required in §23.1545, and the significance of each of those limits and of the color coding used on the indicator.*
(2) The speeds V_{MO}, V_O, V_{LE}, and V_{LO}, if established, and their significance".
Hence, the airspeed limits that require marking on the indicator must be furnished in the AFM, these are in CAS. The marks must be located at the corresponding indicated airspeeds, meaning at CAS plus the position error of the pitot-static system and plus the instrument error of the to be marked airspeed indicator. The errors can be positive or negative. If the instrument error is considered zero in the POH/AFM, then the markings are on a wrong location on the indicator. The error can be up to ± 4 kt, a range of 8 knots.
In addition to the markings, the significance of the speeds in (2) must be contained in the POH/AFM.

2.3.14. **In FAR § 23.1587(d):** "*In addition to paragraph (a) of this section, for commuter category airplanes, the following information must be furnished— (10): The relationship between IAS and CAS determined in accordance with §23.1323 (b) and (c)*"; (is an error, must be (a) and (b)).
The relationship between IAS and CAS is the sum of the position error (≤ 5 kt) and the instrument error (≤ 4 kt), i.e. is between 0 and 9 kt depending on the airspeed, and can be 3 kt higher due to the approved friction error when the airspeed decreases or increases.
This FAR paragraph requires both the position error and the instrument error to be furnished. The position error is usually published in a chart in the POH/AFM, but the separately to be provided instrument error seems forgotten, while it can be larger than the position error. Not furnishing instrument errors, or assuming instrument errors to be zero is not in compliance with this FAR paragraph.

2.3.15. **Summary IAS and CAS in FAR**. The use of IAS and CAS in Regulations is confusing and, given the GAMA Specification No. 1, is not understood either, is even misinterpreted. The impression is that several paragraphs were changed to match GAMA Specification No.1, while other paragraphs are not, causing inconsistencies (§ 2.3.3). The GAMA Specification No. 1 is indeed mentioned in the FAA Flight Test Guide (page 163 and more). The consequences of changing airspeeds from CAS to IAS in POHs/AFMs might not have been obvious to the rule makers, because of lack of proper high-level knowledge of pitot-static systems and its errors, and of the effect of small airspeed errors on the controllability of airplanes (§ 2.4.4 below).

2.3.16. The (improper) FAR requirement for the use of IAS in POH/AFMs can only be met if, besides the position error, also the instrument errors of each individual ASI in all airplanes of the same type, for which the POH/AFM applies, are known to the POH/AFM-writer, including the errors of a second or third (alternate) ASI in the same cockpit. This would lead to a large data table, the use of which would be prone to errors. Requiring presenting IASs in a POH/AFM requires a separate POH/AFM for each individual ASI (due to its instrument errors), and not just one POH/AFM for a series of airplanes of the same type. This is expensive, and not acceptable for controlling the manuals.
A maintenance replacement of a defective ASI would lead to a change of all IASs published in the AFM of the airplane. Changing limiting or operational indicated airspeeds in the FAA approved part of an AFM requires approval of the FAA and printing new manuals, which takes quite some time during which the airplane is grounded, unless the instrument error of the new ASI is the same as of the replaced ASI.
In addition to the amendment of the POH/AFM of the specific tail number, the required red radial line indicating V_{MC} on the ASI (FAR § 23.1545(b)(6)), or for airplanes >6000 lb and turbine engine-powered airplanes the placard in the cockpit (FAR § 23.1563(c)) with airspeed limitations also needs to be amended and/or replaced. If the instrument error is considered zero, then the POH/AFM will not include the instrument error with the consequence that the markings on the

new ASI and/or placard will not be at the correct location (§ 2.3.13, FAR § 23.1583). Safety is at stake.

This cannot be the intention of these GAMA-amended and -added FAR requirements; they obviously are unworkable, and must be in error (or are misunderstood). An ASI must be accompanied by an instrument correction table for a range of airspeeds on the instrument panel, for the pilot to be able to calculate the indicated airspeed that corresponds with the CAS value, and the markings must be at the right location. When the author of this review started flying Part 23 airplanes in the early seventies, such a table could still be found on the instrument panel.

It seems that many manufacturers avoid the use of the instrument error by prescribing a zero-knot instrument error in their POH/AFM, unaware of the consequences for flight safety. The relationship between CAS and IAS is then only the pitot-static position error, but this is not in compliance with FAR 23, and leads to inaccurate indication of limiting and operational speeds, and to fatal accidents.

2.4.   Calibrated and Indicated Air Speeds in a POH/AFM

2.4.1.   The takeoff, stall, minimum control, cruise and landing approach speeds, and the handling qualities of the airplane were determined during experimental flight tests with a calibrated airspeed measuring system, and were reported as CAS for a given gross weight (mass). These, for flight operations important speeds are usually also published as CAS in a POH/AFM because then they are valid for all airplanes of the same series/type, for which the POH/AFM applies. As also mentioned above, another reason for publishing airspeeds as CAS is that the POH/AFM-writer does not know the instrument error of each individual ASI installed in any production airplane (at any one time, now or in the future). The position error of the pitot-static system must be published for a range of airspeeds in a chart in the POH/AFM, and an airspeed instrument error correction table should be available showing the airspeed correction for each individual installed ASI, except for a few categories of airplanes, unless the errors are compensated for in a computerized air data system (§ 2.2.5.5 above). The airspeed instrument correction table should be mentioned in the POH/AFM, like all required placards are. With this table and with the position error chart in the AFM, the pilot can determine the Indicated Airspeeds that correspond to the Calibrated Airspeeds (that are published in the AFM as limitation, operational, or performance speeds) and write these on the Take Off and Landing Data card.

2.4.2.   GAMA Specification No. 1 requires airspeeds to be published in IAS, because *"the pilot exclusively works with IAS" (Preface)*. The pilot who wrote this, or who approved this on behalf of all GAMA members is not a competent pilot, and probably never studied pitot-statics at a higher level. It is also incomprehensible that GAMA members approved this; none of them obviously consulted a graduate of one of the test pilot schools or an aeronautical engineer. They might not even employ one, which proves incompetence, leading to the question whether their airplanes are well developed and flight-tested.

In addition to the quote in the Preface of GAMA Specification No. 1, § 2.3 requires to *"Provide airspeed limitations and the operational significance of such limitations. The name, symbol, value in knots, CAS, and LAS (assuming zero instrument error) and the significance of each airspeed, shall also be provided"*. The requirement to provide IAS data might cause confusion, and certainly also errors because the instrument errors of all individual airspeed indicators are and cannot be included in a POH/AFM that applies to a series of airplanes of the same type, only the position error in the relationship between IAS and CAS can (§ 2.3.10 above).

This IAS requirement is not in compliance with FAR 23. A recommended instrument error of zero knot might lead to controllability problems, while the pilot believes to be safe when reading the ASI, as an example will show.

2.4.3.   *An example*: The minimum control speed V_{MC}, determined during experimental flight-tests, is 91 KCAS. With a position error CAS to IAS of −5 kt, and an instrument error of +4 kt, the V_{MC} on the ASI is 91 − 5 + 4 = 90 KIAS. In a POH/AFM that publishes indicated airspeeds with a zero instrument error, as GAMA recommends, the measured V_{MC} of 91 KCAS is indicated on the

ASI as 91 KCAS minus only the 5 kt position error, 91 – 5 = 86 KIAS, which speed might also be the POH/AFM published, red-lined, or placarded V_{MCA}. When maintaining this 86 KIAS, the pilot believes to be safe, but his airspeed is 4 kt, the magnitude of this instrument error, below the flight-test determined V_{MC} (90 KIAS), and he will lose control when an engine fails, the other engine is set at maximum thrust, and the small favorable bank angle is not being maintained. The takeoff speeds (in IAS), if calculated using V_{MC} in IAS with zero instrument error, will also be too low. If the V_{MC} marking on the ASI of normal category Part 23 airplanes is positioned using both the position and the instrument errors, then the pilot will notice the pointer is below the published V_{MC} as IAS and he needs to accelerate.

These data are for straight flight only, while maintaining a small 5° bank angle away from the inoperative engine.

The increase of V_{MC} with the wings level or during a turn is not included and will be discussed below (§ 2.5.23). CAS and both errors are required to provide safe indicated V_{MC} and other limiting and operational speeds to the pilot.

2.4.4.   Readers, like the writers of the GAMA Specification No. 1 and the reviewers of the FAA, might believe 1, 2 or even 4 kt is not that big of an (instrument) error, so why all the fuzz. But it is not about the few knots, it's all about physics, about the forces and moments generated by the freestream air at the calibrated airspeed around the wings and the aerodynamic control surfaces that produce the lift and the control forces which are required to maintain the equilibrium of forces and moments, i.e. to maintain control of the airplane. The aerodynamic forces are proportional to the square of the airspeed (V^2), as shown in the lift equation: Lift = C_L ½ρV^2 S. A few knots difference at a higher speed has a larger influence on the generated control forces, which decreases with decreasing airspeed (V^2). V_{MC} testing proves that a speed of only one knot below V_{MC} results in the loss of control when an engine fails; rudder and/or ailerons lost the control power required to maintain the equilibrium of forces and moments. On the other higher speed side, a rudder ratio changer in large airplanes prevents overloading the vertical fin, by reducing the rudder deflection per degree of rudder pedal travel with an inverse quadratic function of the increasing airspeed rather than with a few knots.

2.4.5.   FAR 23 requires airspeeds to be provided accurately; rules were made many years ago with competence and should not be amended or neglected by ignorance, because **physics has no mercy**.
Pilots have the right to be made aware of the errors in the pitot-static systems for them to be able to apply the correct speed corrections and hence, apply the correct and safe operational and limiting airspeeds, which were determined in CAS, to conduct a flight and return home safely, including after engine failure. Pilots cannot be allowed to *"exclusively work with IAS"*. If they do, their airplane is not airworthy as required by FAR 23. Pilots must work with CAS in graphs and tables in a type generic POH/AFM, and must add the position error in the POH/AFM and the instrument error of the particular ASI in the airplane to the CAS to obtain IAS to be able to relate to, to work with, airspeed indications and markings on the ASI in that specific airplane (tail number) that indeed correspond to the CASs in the AFM.

2.4.6.   In GAMA Specification No. 1 many more statements are found that are not in agreement with FAR 23 and FAA Flight Test Guide. The writers and/or advisors of the Specification obviously had a disappointing low-level understanding of airplane speeds, performance, and control, and of FAR 23. A POH/AFM prepared with their Specification No. 1 did not contribute to preventing the many fatal accidents referred to in § 1.1 above. GAMA made a huge mistake by not hiring aeronautical expertise at MSc or test pilot school level. It is also incomprehensible that the FAA approved GAMA Specification No. 1 and the many POH/AFMs for different airplanes that were prepared using the Specification.

2.4.7.   An AFM is designated by number in the Type Certificate Data Sheet of the airplane, and is mandatory for the airplane to be operated airworthy. Many accidents occurred and were investigated by TSBs around the globe, but obviously none of these boards reported errors in the

POH/AFM and recommended or mandated improvements during the past 50 years. Aviation is drifting into failure due to incompetence of key-personnel that the public relies on.

2.5.   Minimum Control Speed V$_{MC}$ or V$_{MCA}$

2.5.1.   When an engine of a multi-engine airplane fails or is inoperative, the pilot needs to counteract the asymmetrical thrust yawing and rolling forces and moments using the rudder and ailerons continuously. Therefore, a flight with asymmetrical thrust is not a coordinated flight. The forces and moments generated by the aerodynamic controls rudder and aileron are proportional to the square of the airspeed (V^2). So, whatever the attitude or configuration of the airplane, there always is an airspeed below which the asymmetrical thrust, the gravity induced forces, and other forces and moments can no longer be counteracted with rudder and ailerons, and an equilibrium of forces and moments can no longer be maintained. This airspeed is called the minimum control speed.
FAR 23 defines minimum control speed as V$_{MC}$ for the takeoff configuration which is to be published in the AFM. Other publications also use V$_{MCA}$, for V$_{MC}$ *"in the Air, or Airborne"*. Both refer to the same speed. This review uses both abbreviations separately or combined as V$_{MC(A)}$, but in addition also *"actual V$_{MCA}$"*, which is the V$_{MC}$ when the configuration, flap setting, bank angle, etc. are not as prescribed in FAR 23.149 for the takeoff configuration, and a higher airspeed is required to maintain the equilibrium of forces and moments during actual circumstances, such as a larger bank angle, a non-feathered propeller, or other asymmetrical drag. A minimum control speed applies always in-flight in anticipation of, and following an engine failure, not only during takeoff. The *actual* V$_{MCA}$ increases to a value higher than the published V$_{MC}$ with bank angle, i.e. during turns, as will be explained below.

2.5.2.   During reviewing the GAMA Specification No. 1, several AFMs, and many investigation reports of accidents after engine failure, it was noticed that the AFM-writers, the mishap pilots, and accident investigators were not aware of the real value of V$_{MC}$, and of the associated conditions for V$_{MC}$ to be valid. Therefore below, in addition to the papers presented on the website of Avio*Consult*, a few highlights of V$_{MC}$ are explained in this paper below using FAR/EASA CS 23, the FAA Flight Test Guide AC 23-8C, and courses of a test pilot school, one of which is for the prediction of V$_{MC}$ prior to conducting V$_{MC}$ testing. Copies of the applicable Regulatory paragraphs, Flight Test Guide and course manuals are brought together in one *Background V$_{MCA}$ Info* pdf file[15] for the reader to be able to verify what is written below.

2.5.3.   V$_{MC}$ is defined in FAR § 23.149(a) (and equivalent) as follows: *"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"*.

2.5.4.   This definition, although intended for the design and certification of airplanes for which FAR and CS 23 apply, is also often copied into Airplane Flight Manuals (AFM) but is usually misunderstood by pilots and accident investigators. To improve the understanding of V$_{MC}$, this paragraph briefly explains the sizing of the vertical tail, the effect of bank angle on V$_{MC}$, and the flight test techniques used to determine V$_{MC}$. Readers will be become familiar with the real value of the V$_{MC}$ that is published in the of multi-engine airplanes and with the conditions for which the published V$_{MC}$ is valid, which is of vital importance for preventing engine failure related accidents and for getting home safely after an engine failure. Accident Investigations will also improve.

2.5.5.   *Limitations Due To the Size of the Vertical Tail*. In Figure 4 below, the most important forces and moments are shown that act on a multi-engine airplane during steady straight flight when engine #1 is inoperative and the wings are kept level. As for any physical body, an airplane is in equilibrium if both the sum of the forces and the sum of the moments that act on the airplane are zero. To counteract the asymmetrical thrust yawing moment, the deflected rudder

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[15] Avio*Consult*, *Background information for the definition, theory, flight test and use of V$_{MC}$*, https://www.aviocon-sult.com/downloads/Background VMC(A) Regulations and Flight Test.pdf

generates a side force that causes a rudder yawing moment opposite of the thrust yawing moment. The rudder side force however, also causes an acceleration to the dead engine side which results in a sideslip angle and in an opposite side force due to sideslip. The sideward acceleration continues and the resulting side force due to sideslip increases, until the sum of the side forces is zero. The aerodynamic rudder side force is proportional to the (square of the) airspeed ($\equiv V^2$). The lowest airspeed at which straight flight can just be maintained while either the rudder or the ailerons are maximum deflected and the asymmetrical thrust is maximum is called V_{MC}, in this case V_{MC} with the wings level. The sideslip angle, which can be up to 14°, also causes drag which reduces the remaining climb performance significantly and should therefore be kept to a minimum, especially during initial climb when an engine is inoperative, but also during cruise for maximum range. To achieve minimum sideslip hence drag, a small bank angle of *"not more than 5° "* can be used during *"maintaining straight flight"*, as explained next.
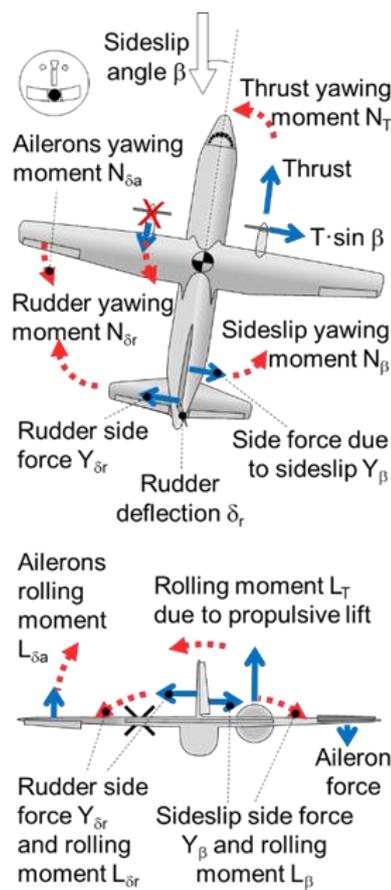
Figure 4. Lateral-Directional forces and moments in body axis coordinate system, wings level. OEI, straight flight. Forces are not to scale.
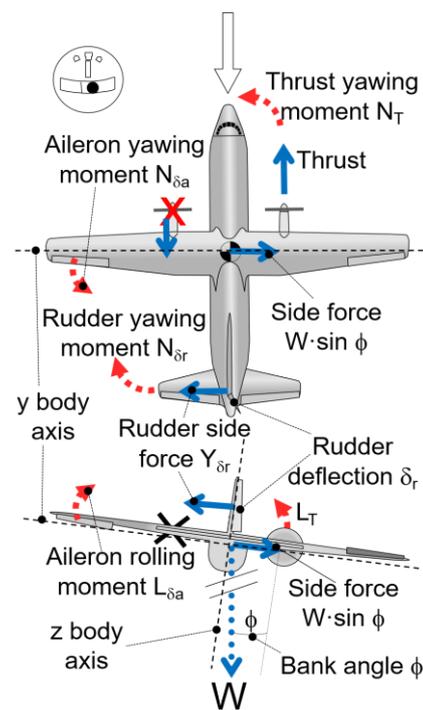
Figure 5. Lateral-Directional forces and moments in body axis coordinate system, bank angle 5° into good engine. OEI, steady straight flight. Forces are not to scale.

2.5.6.   For explaining turns, pilots use the centripetal force, being a horizontal component of the lift of the wings in the earth axis coordinate system. However, following an engine failure, the required counteracting rudder side force affects the magnitude of the centripetal force. In addition, the increased drag due to sideslip might affect the remaining wing lift. Hence, the centripetal force can only be used for coordinated flight, i.e. when all engines are operating and the controls are near center. This cannot be the case following an engine failure, therefore airplane design engineers and test pilots use the *body axis coordinate system* in which a component of the weight, rather than the wing lift, provides the side force, because gravity (Weight) always acts on an airplane, whatever the bank angle or attitude. The lift of the wings acts in the direction of the z-body axis and hence, has no side component in the body-axis system, but the Weight does (W·sin φ). In the body axis system, a knife-edge maneuver (straight nose-up flight

with 90° bank) can be explained.

2.5.7.   When banking, a component of the weight (W) results in a side force due to bank angle (W·sin φ in Figure 5), that can replace the side force due to sideslip that was a consequence of the rudder deflection (Figure 4). Hence, the small bank angle decreases the sideslip angle of the airplane to a minimum, decreasing the total drag and hence, increasing the engine-out (climb) performance. Side force W·sin φ acts in the center of gravity (moment arm is zero) and therefore does not cause a yawing moment. As the rudder side force, generated by the vertical tail with rudder, no longer must act against the side force due to sideslip as well (see Figure 5), but only against the thrust yawing moment, the rudder deflection can be smaller, or the vertical tail can be designed smaller to save manufacturing cost and weight, and still comply with the Regulations. A smaller rudder deflection makes it possible to reduce the speed further until again the rudder is maximum deflected to counteract the same thrust yawing moment and hence, the V_{MC} is lower than V_{MC} with the wings level, and the sideslip angle, hence drag is minimal and the Rate of Climb maximal. This is why FAR 23.149 allows the engineer designing the vertical tail to use a bank angle of *"not more than 5° "* (away from the inoperative engine), while *"maintaining straight flight"*, for sizing the vertical tail with rudder; it is for engine-out control and performance. The AFM-published V_{MC} is the V_{MC} with the small bank angle.

2.5.8.   A smaller vertical tail requires a higher airspeed to counteract the same maximum thrust yawing moment; V_{MC} will be higher. FAR 23.149(b) however, does not allow the vertical tail to be made so small that V_{MC} for takeoff, i.e. during straight flight with max. 5° of bank, exceeds 1.2 times the stall speed (V_S). Hence, the vertical tail is made just large enough to be able to maintain straight flight at airspeed V_{MC} while the thrust of the opposite engine is at the maximum takeoff setting, the rudder is maximal deflected and a small bank angle is being maintained as opted during sizing the vertical tail, which is usually between 3° and 5° away from the inoperative engine. Refer to *Airplane Design Part VII,* Dr. Jan Roskam of Kansas University (footnote 12 on page 6).

> **The vertical tail with rudder is only sized large enough for maintaining straight flight at V_{MC} at maximum asymmetrical thrust and with 5° bank into the good engine**

In-flight, the pilot controls the bank angle (if control is not lost) and hence, determines the magnitude of side force W·sin φ, hence the pilot controls the actual V_{MCA} with bank angle and thrust (yawing moment – required rudder deflection). Therefore, the effect of bank angle (φ) and weight on V_{MCA} is worth reviewing in greater detail for other bank angles than 5° into the good engine.

2.5.9.   ***Effect of Bank Angle and Weight on V_{MCA}.*** When, during the design phase of the airplane, the size of the vertical tail with rudder is either known or assumed, graphs can be calculated using lateral-directional equations of motion with the stability derivatives of the airplane to show the effect of bank angle and weight on V_{MCA} while the thrust is maximum asymmetrical. Such calculations are usually also done to predict V_{MC} prior to conducting V_{MC} flight-testing with prototype airplanes. The V_{MC} prediction method was used to calculate the airspeed for every bank angle between – 15° and + 15° at which either the rudder or the aileron deflection is maximum, or the sideslip angle is 14°, being the stall angle of attack of the fin with deflected rudder (large camber). The results are presented in Figure 6 and Figure 7. The V_{MC} data on the left edge (lowest weight) of Figure 7 coincide with the V_{MC} data in Figure 6. Figure 7 shows that a higher weight affects the *actual* V_{MC}. With zero bank angle, weight has no effect (side force W·sin 0° = 0). The graphs in Figure 6 and Figure 7 are calculated using stability derivative data of a sample 4-engine turbojet airplane used at the USAF Test Pilot School, because data of a twin-engine airplane were not available; the shape of the graphs is approximately similar for all multi-engine airplane types, though. The prediction is explained in paper *The Effect of Bank Angle and Weight*
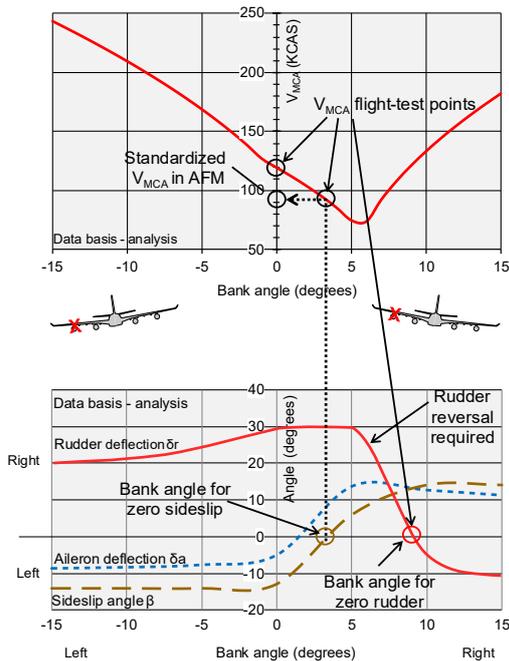
on V$_{MCA}$[16].

Figure 6. Effect of bank angle on V$_{MCA}$, and on rudder, aileron, and sideslip angles.
Equilibrium flight at maximum thrust, for a sample airplane.
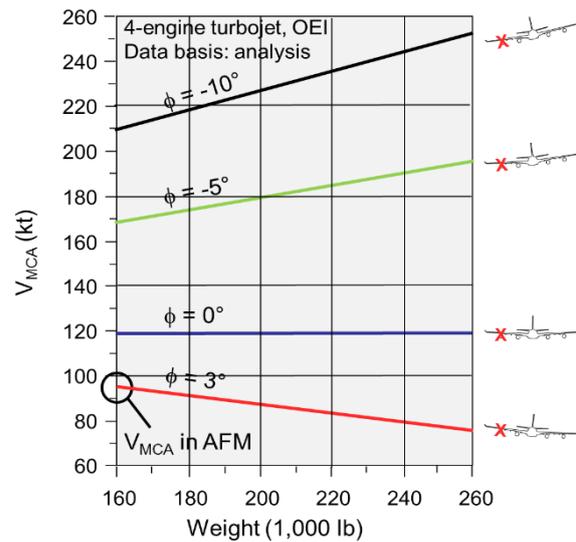
Figure 7. Effect of bank angle and weight on V$_{MC(A)}$.

NOTE. C-130 pilots know this figure, because it is like the Weight and Bank Angle figure in the C-130 Performance Manual SMP-777.

2.5.10. Figure 6 shows that the sideslip angle β is near zero, i.e. the drag is minimal, when the bank angle is 3° away from the inoperative engine for this swept wing airplane. The corresponding *standardized* V$_{MC}$ (with maximum rudder deflection) that is published in the POH/AFM is 95 kt. The small bank angle should be, and sometimes is included as an associated condition in the legend of one engine operating performance diagrams for the presented data to be valid.

2.5.11. As already mentioned above, bank angle not only has great effect on sideslip, hence on drag and performance, but bank angle (ϕ) and Weight (W) both have also great influence on the *actual* V$_{MCA}$ of the airplane, being the V$_{MCA}$ which the pilot will experience in-flight, through side force W·sin ϕ, which is illustrated in Figure 5. Figure 6 and Figure 7 show that the *actual* V$_{MCA}$ of this sample airplane increases from the published 95 kt to 119 kt if the wings are only kept level. For small twins this increase will be ≈ 6 kt. In addition, keeping the wings level or banking to either side results in a large sideslip. Sideslip is a result, not a cause, and increases the drag and hence, reduces the climb performance or leaves no positive climb performance at all (in small twin engine airplanes).

2.5.12. Figure 7 shows the effect of bank angle and weight on V$_{MC}$. V$_{MC}$ when maintaining a 3° bank into the good engine decreases with increasing weight. When the wings are kept level, weight has no influence on V$_{MC}$; the side force due to weight (W·sin ϕ = 0). This graphs also shows that V$_{MC}$ with a small bank angle away from the failed engine is highest at low weight, which is the worst-case weight for V$_{MC}$ while maintaining a small bank angle, and which is the reason that low weight is used to determine V$_{MC}$ (for straight flight – FAR 23.149). When the bank angle into the dead engine increases, V$_{MC}$ not only increases with bank angle, but also with weight. At high weight (takeoff), V$_{MC}$ increases considerable above the low weight values in Figure 6 when banking into the failed engine(s), and so does the drag.

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[16] Harry Horlings, *Avio*Consult, *The Effect of Bank Angle and Weight on V$_{MCA}$*, https://www.avioconsult.com/downloads/Effect of Bank Angle and Weight on Vmca.pdf

2.5.13. It will be clear that the requirement for maintaining straight flight while also maintaining a small bank angle away from the inoperative engine must be made well known to the pilots of multi-engine airplanes to avoid the loss of control when maximum thrust is needed on the operating engine. The saved weight and manufacturing cost of a smaller vertical tail (hardware) needs to be replaced by a quite 'heavy' associated condition / warning in the POH/AFM (software) for only maintaining straight flight and a small bank angle while an engine is inoperative and the asymmetrical power setting is, or is increased to maximum. This prerequisite for being able to maintain control after engine failure is regrettably not presented anymore in most AFMs, in multi-engine rating coursebooks for pilots, and in investigator training manuals; this knowledge is 'forgotten' during the past 50 years, except at test pilot schools.

2.5.14. ***Flight-Testing To Determine V_{MCA}***. During the flight-tests to determine $V_{MC(A)}$ in accordance with the FAA Flight Test Guide[4], the airplane is in the same configuration as was used to design the vertical tail, of which the most important factors are the *lowest* weight possible (smallest side force $W \cdot \sin \phi$), an *aft* center of gravity (smallest rudder moment arm), maximum power setting that the pilot can set from the cockpit on the operating (critical) engine (maximum thrust yawing moment) and a feathered propeller, if applicable and automatic (lowest propeller drag). This configuration results in the 'worst-case' V_{MC} (for straight flight). Two types of V_{MC} are determined, first the static V_{MC} and then the dynamic V_{MC}.

2.5.15. The *static V_{MC}* is the V_{MC} for maintaining straight flight while an engine is inoperative. The airspeed is slowly reduced (keeping the wings level) until the heading can no longer be maintained using maximum rudder or aileron deflection, or up to the FAR defined maximum control force limits (150 lbf for rudder pedal, 25 lbf for roll control). This first data point is the wings-level V_{MC} (Figure 6 - top). Then, while increasing the bank angle to the same value that was used to design the vertical tail (3° to 5° away from the inoperative engine), the speed is (and can be) further reduced until again the heading can no longer be maintained. This speed is the *static* V_{MC} of the airplane and is usually between 6 (small twin) and 25 knots (B707) lower than the wings-level V_{MC}. This V_{MC} is obviously only valid during straight flight when the small favorable bank angle is being maintained. When the bank angle for zero rudder (Figure 6) is attained, V_{MC} is a bit lower, but the sideslip (drag) increases considerable. V_{MC} for other bank angles than wings-level and 3° – 5° (at the option of the manufacturer) is never determined because of the many variables that affect the balance of forces and moments and therewith V_{MC}; it would be too costly and the use of the huge amount of data by pilots would be prone to errors.

2.5.16. The *dynamic V_{MC}* is important for regaining control immediately following the sudden failure of an engine during the resulting dynamics, and is determined by cutting the fuel flow to the critical engine at several speeds down to the speed at which either the heading change is maximum 20°, the bank angle does not exceed 45° and no dangerous attitudes occur.

2.5.17. The static V_{MC} is usually higher than the dynamic V_{MC}. The highest of static and dynamic V_{MC} will be published as the V_{MC} of the airplane in the POH/AFM, but a V_{MC} applies during the remainder of the flight, including the final turn for landing. Flight testing (and demo) of V_{MC} is not without danger; therefore, the test data are acquired at a safe altitude and extrapolated to sea level.

2.5.18. FAR 23.149(b) defines V_{MC} for the takeoff configuration, for straight flight (climb out) at maximum thrust, while maintaining a small 5° bank angle. This V_{MC} is marked with a red (radial) line on the ASI or is placarded as IAS after adding both the position and the instrument errors to the V_{MC} as CAS (§ 2.3.13 above). But a V_{MC} applies during the whole flight when an engine is inoperative, which might be the reason that V_{MCA} (V_{MC} in the Air) is used in many publications, including in POH/AFMs. As was shown above, V_{MCA} during turns is much higher than the published standardized V_{MC} for straight flight.

2.5.19. ***Definition Of V_{MC} in a POH/AFM***. FAR 23 prescribes the airworthiness standards to be used by airplane design engineers (§ 2.3.1 above), including requirements for the case one of the engines is inoperative, including the furnishing the minimum control speed V_{MC}. The V_{MC}

definition in a POH/AFM is often copied out of Federal Aviation Regulation (FAR 23.149) or equivalent, as quoted in § 2.5.3 above. Once the airplane is in operational use, for which the POH/AFM applies, pilots should not keep the wings level to within 5° of bank, left or right, as the definition suggests. On the contrary, in order to ensure that control of their airplane after engine failure can be maintained when maximum thrust is set on the other engine, and that the remaining climb performance is maximum achievable, pilots need to maintain straight flight and the same small bank angle that was used to design the vertical tail and that was also used to determine the AFM-published V_{MC} during flight testing, which is usually between 3° and 5° away from the inoperative engine, as was illustrated in Figure 6 and Figure 7 above. A larger bank angle, or a bank angle into the inoperative engine, will disturb the balance of side forces and yawing moments and will result in lateral accelerations and yawing moments (and sideslip) that cannot guaranteed be balanced using the aerodynamic controls, simply because the vertical tail with rudder (and the ailerons) were not sized large enough to do so when the thrust is maximum and the airspeed is V_{MC}. The words *suddenly made inoperative* and *critical engine* in the V_{MC} definition in a POH/AFM do not make sense at all for, and are misleading to, pilots; a V_{MCA} applies during the entire flight, in anticipation of and following the failure of *any* engine, not only the critical engine, and during climb, cruise and approach or go-around when any of the engines already failed during takeoff. The above quoted FAR definition of V_{MC} is deficient for use in a POH/AFM.

2.5.20. ***The actual V_{MCA}*** that a pilot will experience in-flight will be affected by any change of lateral or directional forces and moments, for instance by an accidently deployed thrust reverser, or an engine or nacelle cowling, an opened cargo hatch, a non-feathering propeller, a camera mounted on a wingtip, unbalanced wing fuel, or a bad functioning throttle friction and, last but not least, yet often occurring, intentional or uncontrolled banking at too low a speed and too high an asymmetrical thrust level (to quickly return to the runway for landing).

2.5.21. The *actual* V_{MCA} is in fact and in general the lowest airspeed which can be obtained with full directional or lateral control deflection and should be a factor of concern when the asymmetrical thrust is or is increased to maximum (during a turn). The need to use near maximum rudder or aileron is a strong signal that the airspeed is close to the *actual* V_{MC}, or the *actual* V_{MC} is close to the current airspeed, and that the loss of control is imminent. The pilot has no choice but to increase the speed ASAP, or reduce the asymmetrical thrust a little, temporarily, until straight flight is again established.).
The one engine inoperative climb performance is only maximal if a small bank angle is being maintained away from the inoperative engine; the bank angle for minimum sideslip can be less than 5° when the airspeed increases; usually at V_{YSE}, 3° is required. The manufacturer should include this bank angle in the legend of the engine-out performance graphs in the POH/AFM.

2.5.22. ***In the new FAR § 23.2135 (c)*** the V_{MC} definition is: "*V_{MC} is the calibrated airspeed at which, following the sudden critical loss of thrust, it is possible to maintain control of the airplane. For multiengine airplanes, the applicant must determine V_{MC}, if applicable, for the most critical configurations used in takeoff and landing operations*". After reading the explanation of V_{MC} above, readers will agree that this definition is even worse than the old one (§ 2.5.3 above). V_{MC} does not only apply during takeoff and landing operations, as accident statistics prove. V_{MC} is determined for recovery and thereafter maintaining straight flight only, while also maintaining a specific bank angle (FAA Flight Test Guide AC 23-8C[4]). The rule makers were obviously still not aware of the forces and moments acting on an engine-out airplane, including the role of the 5° bank for small twins, as described above. It is now entirely up to the manufacturer to provide a definition that explains V_{MC} and/or V_{MCA} so excellent and unambiguous, that accidents after engine failure will never ever occur anymore. The reviews of POH/AFMs and of GAMA Specification No. 1 prove that manufacturers are not ready to do so. Supervision of rule makers and manufacturers with higher level knowledge is still required.

2.5.23. ***Takeoff Speeds***. The POH/AFM-published V_{MC} is one of the factors used for calculating the takeoff speeds, including the rotation speed V_R and the takeoff safety speed V_2. Since the

published V_{MC} is valid only while maintaining a small bank angle (3° to 5° away from the inoperative engine at the option of the manufacturer), both calculated takeoff speeds are also valid only while maintaining this bank angle, unless the 6 – 25 kt higher V_{MC} for wings level (depending on the type of airplane), which is also determined during flight-testing, is being used. Manufacturers regrettably never include this higher wings-level V_{MC} in their POH/AFM, which could be the cause of many occurrences of Loss of Control just after liftoff. They don't mention the increased sideslip hence drag, i.e. the reduced or negative Rate of Climb, either.

2.5.24. The V_{MCA} data presented in Figure 6 and Figure 7 above apply for maximum asymmetrical thrust. The actual V_{MCA} decreases when reducing the asymmetrical thrust a little. This decrease can be temporarily used by pilots to conduct a turn, following a straight climb to a safe altitude. This asymmetrical thrust reduction reduces the thrust yawing moment and therewith the required counteracting rudder deflection; the actual V_{MCA} is lower. During turns, the sideslip increases though, and therewith the Rate of Climb decreases. Some altitude might have to be sacrificed during turns, but control will be maintained. Engine-out flight is never a coordinated flight. Pilots need to be made aware and reminded of the significance of V_{MCA} for engine-out flight in the POH/AFM, as FAR 23.1583(a)(1) requires, not only of V_{MC} for takeoff (§ 2.4.2 and § 2.3.13 above).

2.5.25. Examples of ***controlling $V_{MC(A)}$*** and of the **significance of $V_{MC(A)}$** are included in the following abbreviated accident reports:

> The distribution of engine thrust for keeping the actual V_{MCA} under control, and for allowing safe turns, when one or more engines are inoperative, was applied by a competent Boeing 707 flight crew after both engines #3 and #4 separated off the right wing above the French Alps (31 March 1992). During the turns for the approach, the copilot reduced the thrust of outboard engine #1 a bit and increased the thrust of inboard engine #2, thus reducing the sum of the asymmetrical thrust yawing moments while maintaining the same total thrust level. He in fact decreased the actual V_{MCA}. He also recommended a minimum speed of 200 kt to the captain, who was the pilot-flying, and selected flaps one to unlock the outboard ailerons, therewith increasing the lateral control power. They landed safely on Airbase Istres – Le Tubé in France. Knowledge of forces and moments saved lives. Well done! Not all pilots think of managing forces and moments.

> Six months later, on 21 Dec. 1992 a Boeing 747 freighter also lost the two right engines #3 and #4 shortly after takeoff from Amsterdam Airport. Despite the damaged leading edge of the right wing, the airplane remained controllable and completed nearly two full descending turns at less than maximum thrust on engines #1 and #2. When, during a right-hand turn to position for the approach, the thrust on both left-hand engines was increased to maximum, control was lost and the airplane went down in a suburb of the city. The asymmetrical thrust yawing moment had increased above the level that could be counteracted by the aerodynamic controls. The pilots were regrettably never made aware of the effect of bank angle and thrust on the actual V_{MCA} of their airplane. The investigators of the accident interviewed the Boeing 707 pilots, but did regrettably not conclude the increase of V_{MCA} due to the inappropriate increase of thrust during the turn as cause of the accident.

2.5.26. ***Conclusion*** of the above is that $V_{MC(A)}$ varies with bank angle and thrust level. Manufacturers are regrettably not required to publish the bank angle that was used to determine V_{MC}, neither in the V_{MC} definition, nor with V_{MC} data in the POH/AFM, while some manufacturers do publish the bank angle for minimum drag/maximum performance in the legend of OEI performance charts (Piper in the PA-44 POH, and Lockheed in C-130 manuals). The POH/AFM should remind pilots with: '**Published $V_{MC(A)}$ is valid for straight flight only while maintaining a 5° bank angle into the good engine when the asymmetrical thrust is maximum. $V_{MC(A)}$ increases during turns**', and: '**The pilot controls the actual $V_{MC(A)}$ with bank angle and (asymmetrical) level of thrust'**.

2.5.27. To prevent accidents after engine failure, the manufacturer should describe how the published $V_{MC(A)}$ is determined, when this $V_{MC(A)}$ is valid, and elaborate on the variation of $V_{MC(A)}$ with bank angle, thrust, and other effects. An improved $V_{MC(A)}$ definition for pilots could be:

> **'Minimum Control speed V$_{MC(A)}$ is the lowest airspeed which can be obtained during steady straight flight while maintaining 5° bank towards the good engine, with full rudder and/or aileron control inputs when one engine fails or is inoperative, and the opposite engine is set at maximum thrust.**
> **The actual V$_{MC(A)}$ increases while banking to either side and with the thrust level of the good engine and hence, is controlled by the pilot'.**

2.5.28. Pilots receive their multi-engine rating in Part 23 airplanes, and take this experience with them during their whole career in Part 23 and Part 25 airplanes. Wrong learned is wrong applied. Even Boeings 747 crashed after engine(s) separation because the pilots were not made aware of the increase of V$_{MC(A)}$ to a much higher actual V$_{MC(A)}$ while banking at maximum asymmetrical thrust. ICAO would call this a Systemic Error. GAMA Specification No. 1 must therefore provide adequate guidance on engine-out flight to prevent future Systemic Errors as well.

2.5.29. The actual V$_{MCA}$ depends on many factors, the worst cases of which are used during flight-testing. Actual V$_{MCA}$ can also be lower than the POH/AFM-published V$_{MCA}$, for instance due to a forward center of gravity. The paper *Airplane Control and Analysis of Accidents after Engine Failure*[17], explains almost all about V$_{MCA}$, and analyses a few accidents after engine failure.
So far, the airspeed theory. In the next chapters, the Beech 200 POH will be reviewed.

2.6.   Copies of the applicable regulations, flight test guide and course books are compiled in one Background Info pdf file[18] for the reader to quickly and easily verify the above.

3.   POH Section I – Symbols, Abbreviations, and Terminology

3.1.   On page 1-11, the following general airspeed terminology is defined and explained. Some remarks will be presented below.

GENERAL AIRSPEED TERMINOLOGY

CAS   *Calibrated Airspeed* is the indicated airspeed of an airplane corrected for position and instrument error. ~~Calibrated airspeed is equal to true airspeed in standard atmosphere at sea level.~~

GS   *Ground Speed* is the speed of an airplane relative to the ground.

IAS   *Indicated Airspeed* is the speed of an airplane as shown on the airspeed indicator ~~when corrected for instrument error~~. IAS values published in this handbook assume zero instrument error.

KCAS   *Calibrated Airspeed* expressed in knots.

KIAS   *Indicated Airspeed* expressed in knots.

TAS   *True Airspeed* is the airspeed of an airplane relative to undisturbed air, which is the CAS corrected for altitude, temperature, ~~and compressibility~~.

V$_{MCA}$ *Air Minimum Control Speed* is the minimum flight speed at which the airplane is ~~directionally controllable~~ as determined in accordance with Federal Aviation Regulations. The airplane certification conditions include one engine ~~becoming~~ inoperative ~~and windmilling~~, a 5-degree bank towards the operative engine, take-off power on operative engine, landing gear up, flaps in the take-off position, and most rearward C.G. For some conditions of weight and altitude, stall can be encountered at speeds above V$_{MCA}$ as established by the certification procedure described above, in which event stall speed must be regarded as the limit of effective directional control.

V$_{MCG}$ *Ground Minimum Control Speed*

3.1.1.   This table is obviously copied out of GAMA Specification No. 1, § 1.31 (a) and changed a bit. The definitions in the Specification and in the POH are both reviewed and approved by the

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[17] Harry Horlings, Avio*Consult*, *Airplane Control and Analysis of Accidents after Engine Failure,* https://www.aviocon-sult.com/downloads/Airplane Control and Analysis of Accidents after Engine Failure.pdf.
[18] Avio*Consult*, *Background information for the definition, theory, flight test and use of V$_{MCA}$,* https://www.aviocon-sult.com/downloads/Background VMC(A) Regulations and Flight Test.pdf

FAA, but are not quite correct. Given these definitions, it was found to be necessary to provide some remarks on airspeed theory in § 2 above. Additional remarks on the terminology are presented below.

3.1.2.   **CAS**. The definition above only describes how to calculate CAS from IAS, but not what CAS really is. A proper definition of CAS is given and explained in § 2.2.4 above: CAS is the airspeed in undisturbed air with respect to the standard atmospheric pressure and temperature at sea level. A pilot can calculate CAS from the IAS indicated in the cockpit by first adding the instrument error, which yields the instrument corrected airspeed Vic, and then enter the position error chart with Vic to find the position error. CAS = IAS + instrument error + position error. As mentioned before, the errors can be positive or negative.

3.1.3.   At sea level in standard temperature CAS is indeed equal to TAS, but at higher altitude CAS is lower than TAS. This sentence belongs not here, but reversed in the TAS description, because CAS is the origin of all speeds. TAS is equal to CAS in a standard atmosphere at sea level.

3.1.4.   **GS**. Only the definition of GS is given. Added could be: GS is the TAS of the airplane corrected for a head- or tailwind component.

3.1.5.   **IAS**. The correct definition is: Indicated Airspeed is the airspeed of an airplane as indicated on the airspeed indicator, period. IAS is CAS including the inherent pitot-static position and instrument errors; the pilot does not have to correct CAS to obtain IAS. In the path from CAS to IAS, there are two errors (Figure 2) which are the consequence of pitot-tube placement and ASI manufacturing which cannot be called *"correction"*. In the terminology of IAS in the POH, the instrument error correction is mentioned, which is not correct; the POH writer might have realized that the IAS values in the POH only include the position error, but not yet the instrument error. But in the indication of IAS, the instrument error is included; the instrument error is in the ASI. This part of the definition is wrong.
In addition, it is just intolerable to consider that the instrument error is assumed zero. An ASI is never perfect, and a replacing ASI will have a different instrument error than the replaced ASI. This statement suggests that this Beech 200 POH is for a certain tail number and for one particular ASI, in which case it should include the serial number(s) of the ASI(s) that is/are installed, for which the furnished IAS data applies. Impossible, isn't it?
IAS is equal to the CAS plus or minus the position and the instrument errors. The use of zero instrument errors in this handbook may lead to a 4 kt error in the IAS, and is not in compliance with the airworthiness requirements in FAR 23. IAS values cannot be published in a POH, if the POH is for a series of airplanes of the same type (§ 2.3.16 above).

3.1.6.   **TAS**. True Airspeed is indeed the airspeed of an airplane relative to undisturbed air, but is used by pilots mainly for navigation purposes. It is calculated from CAS using ambient pressure and ambient temperature. Compressibility does not appear in the TAS equation (Figure 1); refer to the E-6B flight computer and to the course book in footnote 13 on page 6. "*Undisturbed*" does not have to be mentioned in this definition, it does not add anything; the source CAS is already the airspeed in undisturbed air.

3.1.7.   A proper definition of TAS is given and explained in § 2.2.2 above: TAS is the true airspeed of the airplane in undisturbed air with respect to the ambient pressure and temperature. Add here from the CAS definition: 'TAS is equal to CAS at sea level in a standard atmosphere'. This is the case because CAS was measured with reference to the standard atmospheric pressure and temperature at sea level (§ 2.2.2).

3.1.8.   **V$_{MCA}$**. Aviation Regulations (FAR 23/25.149) (§ 2.5.3), which are for the certification of aircraft, hence for aircraft design engineers and test pilots, do not require the airplane to be *"directionally controllable"* at airspeed V$_{MC}$ or V$_{MCA}$, but only to be able to regain control after a sudden failure, and thereafter *maintain straight flight* when the thrust is maximum asymmetrical, and the rudder and/or ailerons are maximum deflected, or to the specified maximum control forces. Is an airplane directionally controllable if the pilot needs full rudder to counteract the yawing

moments caused by the asymmetrical thrust, windmilling propeller, and other asymmetries? Maintaining straight flight is not the same as "*directionally controllable*". **The rudder and ailerons of a multi-engine airplane do not have to be sized large enough to be able to maintain control during turns (during banking away from the favorable 5°) at V_{MCA} when the asymmetrical thrust is maximum** (§ 2.5.5).

3.1.9. *"Becoming inoperative …"*. V_{MCA} not only applies when an engine becomes inoperative, but also when an engine is inoperative during the remainder of the flight. Therefore, the FAA requires both a dynamic (when becoming inoperative) and also a static V_{MCA} (to maintain straight flight thereafter) to be determined[19], the highest of which (usually the static) will be published as the V_{MCA} of the airplane in the POH/AFM.

3.1.10. *"windmilling"* of a propeller applies when the airplane is not equipped with auto feathering propellers. FAR 23.149 requires the propeller in a position it automatically assumes after engine failure during flight-testing to determine V_{MCA}. A windmilling propeller causes higher propeller drag, and hence increases the thrust yawing moment, and consequently increases V_{MCA}; a larger rudder deflection is required, or a higher airspeed to act against the increased thrust yawing moments. If autofeather is not armed or not operating, V_{MCA} will be higher than the POH-published value, if this value is for a feathered propeller. The V_{MCA} definition does specify a windmilling propeller; is this correct? Is V_{MCA} lower than the published value when the autofeather operates? Such a decrease is not furnished in the POH. The V_{MCA} definition should make this clear.

3.1.11. Good is that 5° of bank is included in this definition. When $V_S > V_{MCA}$, the airplane is said to be controllable down to the stall, but only during straight flight while maintaining 5° away from the failed engine. When banking to either side, V_{MCA} increases (from § **Fout! Verwijzingsbron niet gevonden.**). The increase of V_{MCA} with bank angle is much larger than the increase of V_S. The definition tells the pilot that the V_{MCA} certification conditions include a 5° bank towards the operative engine and takeoff power on the operative engine, but not that V_{MCA} varies with bank angle, and that an associated condition is that the pilot needs to maintain this bank angle when an engine indeed fails and the asymmetrical power is, or is increased to maximum. Accident reports show that pilots after an engine failure during takeoff do not hesitate to turn back to downwind to land as soon as possible, but they don't live to tell what happened. §§ **Fout! Verwijzingsbron niet gevonden.** and 2.5.12 describe what happened: the sideslip and therewith the drag increases, the decreasing ROC might become a ROD, and V_{MCA} increases as well to a much higher actual value than the takeoff speed V_2 after which control is lost; the airplane starts yawing, rolling, and descending uncontrollable until it collides with the ground. Physics has no mercy.

3.1.12. This is not the worst definition of V_{MCA} as seen in many publications. But given the many accidents after engine failure with Beechcraft (and other) airplanes, pilots and manual writers obviously do not understand the controllability after engine failure, and don't realize why V_{MCA} was determined during straight flight with a 5-degree bank towards the operative engine (for lowest V_{MCA} and minimum sideslip/drag). No word is found in the POH on the effect of bank angle on V_{MCA}, i.e. when the small bank angle is not being maintained, which is quite important for pilots to be aware of, and will prevent accidents after engine failure. For this reason, explaining paragraphs were included in § 2.5 above to emphasize the operational significance of V_{MCA} and its associated conditions. FAR 23 requires that such information be provided in the POH/AFM for the safe operation and best performance after engine failure, as shown next.

FAR 23.1585 on Operating Procedures requires: *"(a) For all airplanes, information concerning normal, abnormal (if applicable), and emergency procedures and other pertinent information necessary for safe operation and the achievement of the scheduled performance must be furnished, including— (1) An explanation of significant or unusual flight or ground handling characteristics"*. Not explaining the significant consequences on the flight handling characteristics of a

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[19] FAA Flight Test Guide, Advisory Circular AC 23-8C, § 4c(6) Static V_{MCA}, and § 4c(8) Dynamic V_{MCA}. http://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_23-8C.pdf.

bank angle other than the 5° of bank towards the operative engine when maximum asymmetrical thrust is set or selected, in other words of the consequences of initiating a turn, or allowing a bank to develop, when the thrust is asymmetrical, is not complying with FAR 23.1585.

"Information that is necessary for safe operation because of design, operating, or handling characteristics", as required by FAR 23.1581(2) on AFM Material (§ 2.3.12), and the *"significance of V_{MC} as an operational limitation"*, as required by FAR 23.1583(2) on Operating Limitations (§ 2.3.13), are not adequately provided on the subject of engine-out flight.

For pilots, the definition of minimum control speed in general is the lowest speed at which the control surfaces at maximum deflection generate just large enough control forces and moments to act against the forces and moments caused by asymmetrical thrust, sideslip, drag, and gravity to recover from a sudden failure, and thereafter maintain straight flight when the asymmetrical thrust is maximum. This does not only apply during takeoff, but also during the remainder of the engine-out flight. When turns must be made, the airspeed must be increased first or the asymmetrical thrust reduced (a little – temporarily). The V_{MCA} definition and its associated conditions must be improved to comply with FAR 23 (§ 2.5.27), and information on the safe operation, including maneuvering, while an engine is inoperative must be furnished.

3.1.13. **V_{MCG}** is mentioned as abbreviation, but is explained and presented only in the Performance Section on page 5-7 (84 kt). A definition for pilots could be: 'V_{MCG} is the minimum speed at which the deviation from the takeoff path on the runway after a sudden engine failure is 30 ft or less' (FAR 23.149(f)). The POH on page 5-7 mentions 25 ft. When an engine fails during the takeoff run at speeds lower than V_{MCG}, the deviation will be larger, reason why the takeoff should be aborted immediately to avoid vacating the runway. V_{MCG} is one of the factors used to calculate V_1.
If the runway is less than 60 ft wide, or during a crosswind takeoff, V_{MCG} should be considered higher than the published V_{MCG} and hence, V_1 will be as well. The V_{MCG} definition should be improved.

3.1.14. **V_S (V_{SO})**. *"Stalling Speed or the minimum steady flight speed at which the airplane is controllable (in the landing configuration)"*. Like for V_{MCA}, an airplane is not controllable at V_S and V_{SO}, but only straight flight can be maintained. No pilot will initiate a turn when the stall horn sounds, or control will be lost.

3.1.15. **V_{XSE} and V_{YSE}** are properly defined, but the associated conditions for maximum angle or rate of climb (ROC) are not included, which is maintaining a small ≈ 3° of bank away from the inoperative engine for the sideslip to be minimum, and hence, the angle or ROC to be maximum. The bank angle is not included in the OEI Performance Data in Section V either, but on POH Page 10-15 one of the criteria listed for the greatest gain in altitude at V_{YSE} is *"Airplane flown at the recommended bank angle"*. This is correct, but why is this not included with the Performance data where this associated condition belongs? Banking away from the small bank angle increases the drag and hence, decreases the angle or ROC considerable. Pilots should be made aware.

4.   POH Section II - Limitations

4.1.   POH Page 2-3 Airspeed limitations

AIRSPEED LIMITATIONS			
SPEED	KCAS	KIAS	REMARKS
Air Minimum Control Speed V_{MCA}	91	86	This is the lowest airspeed at which the airplane is directionally controllable when one engine suddenly becomes inoperative and the other engine is at take-off power. (See definition in Section I.)

4.1.1. V_{MCA} in this POH-table is 91 KCAS or 86 KIAS. The difference of 5 kt is the position error

furnished in POH Section V Airspeed Calibration on page 5-14, for flaps up. The instrument error of the ASI is not included, as announced in POH Section I where is stated "*IAS values published in this handbook assume zero instrument error*". Hence the listed 86 KIAS is not the indicated airspeed, but Vic + 0 (Figure 2). The Instrument error is allowed to be ± 4 kt, and could be almost as large as the maximum allowed position error of 5 kt. An instrument error of 4 kt does not seem large, but keep in mind that the generated rudder and aileron control forces are proportional to the square of the airspeed ($(86 + 4)^2$ versus 86^2), not of only the 4 kt error (refer to § 2.4.4). If the instrument error is indeed + 4 kt, the indicated V_{MCA} would be equal to 90 KIAS. The red line marking should also be at 90 KIAS, not at 86. If the pilot maintains the 86 KIAS of this table, his airspeed is 4 kt below the real V_{MCA}; control might be lost. And if he keeps the wings level, the difference will be even larger (Figure 6). See also remarks on the Airspeed Calibration chart on page 5-14 in § 8.2 below.

4.1.2.   In the definition of V_{MCA} (§ 3.1 above) is mentioned that the conditions to determine V_{MCA} include "*a 5-degree bank towards the operative engine*". Not mentioned is that both the V_{MCA} as well as the sideslip (drag) increase when this bank angle is not being maintained. The V_{MCA}-increase when keeping the wings level depends on the type of airplane, but can easily be 6 kt or more. Larger bank angles to either side will increase the actual V_{MCA} even more (Figure 6, page 19 above). This increase is not included in the Remarks of V_{MCA} in the Airspeed Limitations table, while FAR 23.1581 (2) requires "*Other information that is necessary for safe operation because of design, operating, or handling characteristics*" (§ 2.3.12 above).

4.1.3.   Refer to § 3.1.11 above for comments on the Remarks in this table. The definition differs from POH Section I. V_{MCA} also applies during the remainder of the flight when an engine fails or is inoperative. If during the final approach for landing the thrust is increased, V_{MCA} increases as well.

4.1.4.   **V_{MCG}** is not included in the Airspeed Limitations table. A Remark could be: At V_{MCG}, 'the deviation from the takeoff path on the runway after a sudden engine failure can be up to 30 ft', of which the pilots should be made aware (§ 3.1.13). In addition, a large crosswind reduces V_{MCG} because less rudder is available to keep the airplane on the runway when the upwind engine fails or is inoperative. After engine failure below V_{MCG} (when uncontrolled yawing occurs), abort the takeoff immediately (§ 3.1.13).

4.2.   POH Page 2-4 Airspeed Indicator Markings

AIRSPEED INDICATOR MARKINGS

MARKING*	KCAS VALUE OR RANGE	KIAS VALUE OR RANGE	SIGNIFICANCE
Red Line	91	86	Air Minimum Control Speed (V$_{MCA}$)

* The airspeed indicator is marked in IAS values.

4.2.1.   This is only a part of the table. The red line and other markings in the table determine the location of the marking of V_{MCA} and other limiting airspeeds in 'KIAS' on the ASI. The CAS values in the table are the origin, are determined during flight-testing and/or analysis. The markings on the face of the ASI must be located at the corresponding indicated airspeeds (FAR § 23.1545). The corresponding IAS are the CAS plus or minus the position error (resulting in Vic – Figure 2) and plus or minus the airspeed indicator instrument error of the installed ASI. Since the manual writer does not know the instrument error of a particular ASI installed in any of the airplanes, the KIAS values or range in the table are not at all IAS values, but in fact only the Vic (zero instrument error). The position error is presented in Section V of the POH, and the instrument errors are reported in the calibration report of each individual ASI (i.a.w. FAR § 23.1323). The instrument errors of the left and right (copilot or backup) ASIs in the cockpit might be different, hence, the IAS values differ as well, and the markings should be at a different location. A second KIAS column should be needed in the POH table.

Since the instrument errors are not included in the POH and not included in the calculation of the KIAS values, the published KIAS values are definitely not IAS values. The markings on the face of the ASIs in each airplane of the whole B200 fleet using the KIAS data in this POH table are only at the right location if indeed the instrument error is zero. This will never be the case, hence most, if not all markings in all B200 airplanes for which this table is used, are at the wrong location with an error between − 4 and + 4 kt, being the maximum approved, not-included instrument error, which is large for limiting and operational speeds. The use of IAS in a POH as pushed by the GAMA, such as the column KIAS VALUE OR RANGE, should never have been required and approved by the authorities (§ 2.3.3). Refer also to § 2.4.3 and § 2.4.4 for the effect of such an error on the control power of rudder and ailerons.

These and all other IAS data in this POH are not correct, and might have caused, and still causes too many fatal accidents.

5. POH Section III – Emergency Procedures

5.1. POH Page 3-3 All airspeeds are Indicated Airspeeds

5.1.1. On the top of the page, the following line is printed:

Beechcraft
Super King Air B200/B200C

Section III
Emergency Procedures

All airspeeds quoted in this section are indicated airspeeds (IAS) and assume zero instrument error.

The airspeeds in this section are not IAS, but an airspeed which is equal to CAS minus position error, also called Vic (Figure 2). The instrument error can be up to ± 4 kt depending on the calibration results of the ASI, as already mentioned several times above. The IAS indicated on the ASI can be 4 kt higher or lower than the IAS in the tables. Refer to § 3.1.5 above on the use of IAS and assuming zero instrument error. Assuming zero instrument error is not in compliance with FAR 23. The airspeeds in this section are not to be called Indicated Airspeeds, because they are not. In a POH/AFM only CAS should be used; all limiting and operational speeds are determined and/or analyzed in CAS.

5.1.2. On this page 3-3, a table with emergency airspeeds is presented.

EMERGENCY AIRSPEEDS (12,500 LBS)

One-Engine-Inoperative Best
Angle-of-Climb (V_{XSE}) ....115 kts
One-Engine-Inoperative Best
Rate-of-Climb (V_{YSE}) ....121 kts
Air Minimum Control Speed (V_{MCA}) ....86 kts
One-Engine-Inoperative Enroute Climb ....121 kts
Emergency Descent ....181 kts
Maximum Range Glide ....135 kts

5.1.3. These emergency airspeeds are originally determined during flight-testing and/or analysis as Calibrated Airspeed (CAS). The kts values in the table are CAS minus the position error, the result of which is not IAS, as defined in the Airspeed Calibration graph on POH page 5-14, but Vic (the instrument corrected airspeed in Figure 2 above). This might be the reason that kts is used as unit in the table above; the writer obviously struggled with the presentation of the unit of the speeds which are not IAS. These are only IAS in case the instrument error of a particular ASI, of a series of airplanes for which the POH applies, is zero. A legend with the table should have mentioned to correct the speed in kts (which formally should be the symbol kt) with the instrument error (up to ± 4 kt) to obtain the real IAS.

A minimum control speed of 91 KCAS (POH page 2-3, § 4.1 above), a position error of − 5 kt (POH page 5-14), results in a Vic of 86 kt in the table above. When the instrument error happens to be + 4 kt, the airspeed indicated on the ASI is 90 kt. When the pilot maintains the V_{MCA} of 86 kt

of the table, then his airspeed is lower than the real flight-test determined V$_{MCA}$ of 90 KIAS, and he will lose control when an engine fails or is inoperative and the throttle of the remaining engine is, or is advanced to maximum. If the pilot decides to initiate a turn at this speed, V$_{MCA}$ will increase even more and Loss of Control cannot be avoided (§ 2.5.11). There are no warnings to prevent this from happening, because neither the writers of the GAMA Specification, nor the writers of this POH have shown to possess adequate knowledge of pitot-static systems and its errors, and the consequences of zeroizing the instrument error for flight safety.

5.1.4.   V$_{MCG}$ is missing in this table (is 84 kts on page 5-7) and the associated conditions for V$_{XSE}$, V$_{YSE}$, and V$_{MCA}$ are not included (in the legend).

5.1.5.   The data in this emergency airspeeds table, by neglecting the instrument error, are misleading, and must have led to fatalities.

5.1.6.   The note under the title Engine Failure on this page is of interest:

ENGINE FAILURE

NOTE

To obtain best performance with one engine inoperative, the airplane must be banked 3° to 5° into the operating engine while maintaining a constant heading.

5.1.7.   The writer of this note obviously knows about the favorable effect of a small bank angle on engine-out performance. A small bank angle into the operating engine, to the same side as foot pressure, reduces the rudder deflection (§ 0) and hence the sideslip, decreasing the drag (which maximizes climb performance). The required bank angles for the listed speeds to be valid, which are ≈ 3° for V$_{YSE}$, V$_{XSE}$, and OEI enroute climb, and 5° for V$_{MCA}$, should have been printed in the airspeed lines in the table above to get more attention from the pilots. Why did this cognizant writer not review the whole POH?
The other effect of bank angle, being the increase of V$_{MCA}$ when not maintaining the small 3° to 5° bank angle into the operating engine, is regrettably not mentioned in the note and not as warning in the engine failure procedures either. V$_{MCA}$ is determined with a small bank angle, but if the wings are kept level, then the actual V$_{MCA}$ might be ≈ 6 kt higher than the published V$_{MCA}$ (Figure 6). At other bank angles, i.e. during a turn to either side, the actual V$_{MCA}$ increases even much more due to the effect of gravity, the Weight of the airplane, on the side force (Figure 5 – Figure 7). The airspeed required for the control surfaces to be able to generate large enough forces and moments for maintaining the equilibrium of forces and moments is higher (Figure 6 above). Below this speed, controls are not effective anymore; the loss of control cannot be avoided unless the asymmetrical thrust is decreased a bit, temporarily during the turn. Pilots have the right to be informed about this effect, they need to know; it's about physics, and physics has no mercy.

5.1.8.   Many accidents after engine failure occurred because the pilot did not maintain straight flight with up to maximum rudder, and with 5° of bank towards the operating engine (same side as rudder pedal), while the asymmetrical thrust was, or was increased to maximum, resulting in an increase of the actual V$_{MCA}$ above the current airspeed, with Loss of Control and a fatal accident as consequences. Pilots obviously must be made better aware than only with a performance note at the beginning of the Engine Failure Section. Suggestions are presented below.

5.2.   POH page 3-4 Engine Failure procedures

ENGINE FAILURE AFTER LIFT-OFF (If Conditions Preclude an Immediate Landing)

1. **Power - MAXIMUM ALLOWABLE**
2. **Airspeed - MAINTAIN (take-off speed or above)**
3. **Landing Gear - UP**

NOTE

If the autofeather system (if installed) is being used, do not retard the failed engine power lever until the autofeather system has completely stopped propeller rotation. To do so will deactivate the autofeather circuit and prevent automatic feathering.

4. **Propeller Lever (inoperative engine) - FEATHER (or verify FEATHER if autofeather is installed)**
5. **Airspeed - V_{YSE} (after obstacle clearance altitude is reached)**

5.2.1.   When maximum allowable power is set (Step 1), the actual V_{MCA} increases above the published value, unless 5° bank is attained (immediately) and maintained into the operating engine. When the wings are kept level, the drag increases as well and hence, the ROC decreases. When the autofeather fails or is not armed, V_{MCA} increases even more. This increase was not found in the POH. It is not clear whether the furnished V_{MCA} is for a feathered or windmilling propeller, given a remark in a bullet on POH page 10-15. See § 9.4.1 below.

5.2.2.   It is recommended to include a Warning prior to step 1: 'While setting maximum power, attain a 5° bank into the operating engine and maintain straight flight with rudder and ailerons until reaching a safe altitude. Do not turn at maximum power while airspeed is the (takeoff) speed and/or V_{YSE}, but increase airspeed first (sacrificing some altitude) and/or reduce asymmetrical thrust a bit, temporarily during the turn'.
These are training manual words and could, of course, also be used, or abbreviated for use, in the POH. Pilots should think of forces and moments acting on a crippled airplane, and analyze how to manage the equilibrium of forces and moments, and not only follow the airspeed numbers in the manual. The separation of engine(s), cowlings or baggage doors, the inadvertent selection of beta range on one of the engines, an inadvertent thrust reverser deployment, or a non-feathering propeller cause asymmetry of directional and lateral forces and moments, and affect V_{MCA}. Some require a higher airspeed, others a lower airspeed to maintain control of the airplane.

5.3.   POH page 3-4 Engine failure in-flight below V_{MCA}

ENGINE FAILURE IN FLIGHT BELOW AIR MINIMUM CONTROL SPEED (V_{MCA})

1. **Power - Reduce as required to maintain directional control.**
2. **Nose - Lower to accelerate above V_{MCA}.**
3. **Power (operative engine) - AS REQUIRED**
4. **Failed Engine - SECURE (See EMERGENCY ENGINE SHUTDOWN)**

5.3.1. V_{MCA} is not only the minimum speed after the failure of one of the engines, but also the minimum speed to be observed in anticipation of an engine failure. The airspeed should never be below published V_{MCA}, keeping also in mind the increased V_{MC-A} during turns which is not published. Pilots have the right to be made aware of this increase, in tables, notes or warnings, as already mentioned above.
Step 1 tells the pilot to reduce power as required to maintain control, which in itself is the only option in this case to maintain control – by definition; this decreases the thrust yawing moment and hence, reduces the rudder deflection to counteract the thrust yawing moment, and therewith reduces actual V_{MCA}. Attaining a bank angle as small as 5° into the good engine also reduces the actual V_{MCA} with ≈ 6 kt and is therefore also worth mentioning, besides maintaining straight flight. Actual V_{MCA} might also be lower than the red-lined or published V_{MCA} if not all of the

factors that have influence on V_{MCA} are at their worst-case value, such as a forward center of gravity.

The actual V_{MCA} that the pilot experiences in-flight will be higher though when banking away from the small favorable bank angle of 5° to either side, because the sideslip increases due to the sideward component of the Weight of the airplane (gravity). This increased side force needs to be counteracted with increased rudder or, if rudder is already maximum, by a higher airspeed (aerodynamic rudder force is proportional to V^2).

When the airspeed is just below or decreases below the *actual* V_{MCA}, then the uncommanded change of heading due to asymmetrical thrust cannot be counteracted with maximum rudder, and/ or the uncommanded banking cannot be counteracted with maximum ailerons; the motion is initially quite slow. The question is whether pilots recognize a slow heading change as an imminent loss of control that requires immediate action: apply rudder (and/ or aileron) as to maintain heading (and bank angle) and if this is not adequate, reduce asymmetrical thrust (a bit, temporarily) until straight flight with a small 5° bank angle and an airspeed of at least V_{MCA} is established, because nothing else can be done to avoid a collision with the ground when at low altitude. The only other option is to close the throttles and land straight ahead (in the dirt), which might be more survivable.

5.3.2.　Safety-critical procedure development requires high level multi-disciplinary knowledge, not only piloting skills. This is also the title of the paper I presented during the Safety and Procedures Forum of Eurocontrol in Brussels, 4 - 5 June 2019, which can be accessed via the Downloads Page of my website (#12).

5.3.3.　In POH Section III, under head Engine Failure of another B200 manual (1996 – accident 2020-08), a NOTE: "*To obtain best performance with one engine inoperative, the airplane must be banked 3° to 5° into the operating engine while maintaining a constant heading*".
This is good, but included should be a WARNING: When banking away from this small favorable bank angle to either side while asymmetrical thrust is maximum, the actual V_{MCA} will increase considerable.

5.3.4.　Found missing is the need to frequently balance wing fuel during prolonged flight with OEI. A lateral cg into the good engine is favorable to the balance of forces and moments.

6.　POH Section IIIA – Abnormal procedures

6.1.　POH Page 3A-3 All airspeeds are Indicated Airspeeds

6.1.1.　This line is similar to the line on top of page 3-3, that all airspeeds are IAS and assume zero instrument error. Refer to § 5.1.1 above for remarks.

6.2.   POH page 3A-5 One-Engine-Inoperative Approach and Landing

ONE-ENGINE-INOPERATIVE APPROACH AND LANDING

1. Approach Speed - CONFIRM
2. Fuel Balance - CHECK
3. Pressurization - CHECK
4. Cabin Sign - NO SMOKE & FSB

When It is Certain that the Field Can Be Reached:

5. Flaps - APPROACH
6. Landing Gear - DN
7. Propeller Lever - FULL FORWARD
8. Airspeed - 10 KNOTS ABOVE NORMAL LANDING APPROACH SPEED
9. Interior and Exterior Lights - AS REQUIRED
10. Radar - AS REQUIRED
11. Surface Deice - CYCLE (as required)

When It is Certain There is No Possibility of a Go-Around:

12. Flaps - DN
13. Airspeed - NORMAL LANDING APPROACH SPEED
14. Perform normal landing.

6.2.1.   Recommended is to add a Warning not to increase the thrust during the final turn for landing, to avoid the actual V_{MCA} to increase above the approach speed, and prevent the loss of control. It is much safer to conduct a long straight-in approach.

6.3.   POH Page 3A-5 One-Engine-Inoperative Go-Around

ONE-ENGINE-INOPERATIVE GO-AROUND

1. Power - MAXIMUM ALLOWABLE
2. Landing Gear - UP
3. Flaps - UP
4. Airspeed - INCREASE TO BLUE LINE, 121 KNOTS

6.3.1.   It is recommended, altitude permitting, to increase the airspeed first to V_{YSE} down the glideslope before increasing the power to maximum allowable. It is also recommended to add a warning like in § 5.2.2 on takeoff above, to maintain straight flight while attaining a small 3° bank angle into the good engine for maximum climb performance to a safe altitude where a turn back to the runway can be made without losing control.

6.4.   POH page 4-14 Before takeoff checklist

6.4.1.   The last step (13) of the Before takeoff checklist is: *"V₁, VR, V₂, and Minimum Takeoff Power - CONFIRM".* Given the speed data in the POH, the takeoff speeds are without correction for the ASI instrument errors. Hence, the takeoff speeds might be up to 4 kt too low, when the instrument error happens to be the maximum approved. Takeoff speeds in CAS should be used, and both position and instrument errors added to calculate the takeoff speeds in IAS.

6.4.2.   The pilots should be prepared for handling an engine failure by somehow reminding them before every takeoff to, in case an engine fails, use up to maximum rudder to maintain the heading, attain a small bank angle as soon as possible (for maximizing ROC and minimizing V_{MCA}), and only maintain straight flight until reaching a safe altitude (to avoid loss of control).

7.   POH Section IV – Normal Procedures

7.1.   POH page 4-26 Practice Demonstration of V$_{MCA}$

7.1.1.   This is a quite good demo procedure, only one remark. Step 5 is Power Lever (simulated inoperative engine) – IDLE. Usually, an RPM or Torque for zero thrust is selected, because idle causes more propeller drag which enhances the thrust yawing moment and increases V$_{MCA}$. The demo should be conducted at a low weight and an aft cg, i.e. at the end of a flight (Figure 7). It is recommended to determine V$_{MCA}$ with the wings level first, and then bank 5° towards the operative engine and decrease the speed further down to V$_{MCA}$. It is recommended to alternate the simulated inoperative engine (and note the difference in V$_{MCA}$). Reducing the thrust of the operating engine just a little will decrease V$_{MCA}$ enough to regain or maintain control; pilots should learn this in case an engine really fails. Never restore thrust when close to V$_{MCA}$; recover to straight flight with idle thrust, neutralize controls (and trims), and increase speed and symmetrical thrust.

8.   POH Section V – Performance

8.1.   POH page 5-5 Introduction To Performance and Flight Planning

8.1.1.   On page 5-7 is printed: *"The Ground Minimum Control Speed (V$_{MCG}$) has been determined to be 84 knots. At this speed, control within 25 feet of the runway center line is possible"*. FAR 23.149(f) requires a V$_{MCG}$ at which the deviation after engine failure during the takeoff run and recovery is not more than 30 ft. V$_{MCG}$ is not listed in any table, but only here, while V$_{MCG}$ is needed for calculating V$_1$ i.a.w. FAR 23.51(c)(1)(i).

8.1.2.   In this Section, on page 5-9, knots are also used as unit of speed without specifying whether KCAS or KIAS (or KCAS with position error correction) are meant.
On page 5-12, § 4 the following comment pertinent to the use of performance graphs is presented: *"Indicated airspeeds (IAS) were obtained using the Airspeed Calibration - Normal System graph"*. This is not how IAS should be obtained. Refer to § 5.1.3 above.

8.2.   POH Pages 5-13, 5-14, 5-16 (Airspeed calibration), and 5-15 and 5-17 (Altimeter Correction)

8.2.1.   The entrance variable for these five charts is *"IAS INDICATED AIRSPEED ~ KNOTS"*, while the entrance variable should be the 'INDICATED AIRSPEED CORRECTED FOR INSTRUMENT ERROR' (Vic). The graphs show the system error, including the position error but excluding the airspeed indicator instrument calibration error determined in accordance with FAR § 23.1323(b). The system error is determined during pitot-static system calibration flight-tests.
Using Indicated airspeed means that the instrument error is not used, but is considered zero as stated before in this POH. The approved tolerance of an airspeed indicator is ± 4 kt. This means that the calibrated airspeed, when calculated from the IAS, can be 3 – 4 kt higher or lower, for use in performance data graphs.
Hence, these graphs are not in compliance with FAR 23, and should not have been approved by the FAA or equivalent organizations.
The titles of the charts should be (AIRSPEED/ALTIMETER) POSITION ERROR, rather than airspeed calibration, because the charts only show the airspeed and altimeter position corrections, and do not refer to the instrument errors determined during their calibration in a laboratory. See also § 4.1.1 above.

8.2.2.   The data in these charts are worrying; the position error is zero or near zero for all IAS, except below 100 kt. Are these data correct? Were the pitot-static systems calibrated by experimental test pilots educated at a test pilot school? Are the position errors of both systems equal? And were the Airspeed Indicators calibrated in a laboratory? Where can a pilot find the data?

8.3.   POH Page 5-18 Indicated Outside Air Temperature Correction

8.3.1.   The entrance variable of this chart is Calibrated Airspeed, which is good, but is unlike the other charts.

8.4. POH page 5-21 Stall speeds

8.4.1.   This chart uses both CAS and IAS as entry variables; the difference being only the position error. The POH writer just drew IAS lines in the original CAS stall speed chart after subtracting the position error. The airspeed instrument error is assumed zero, which is incorrect, and not in compliance with FAR 23, even if the chart in this POH is copied from the source Airplane Flight Manual, if any, which is approved by the FAA. Another complication introduced by using zero instrument error is the question for which airspeed indicator in the cockpit the stall speed data are valid. The left, the right, or the alternate?
The stall speed in CAS is accurate because it is determined during flight-testing. The stall speed indicated on the airspeed indicator can be 4 kt higher or lower than the stall speed in IAS in this chart due to the instrument error, in other words, the airplane may stall while the pilot considers to be safe because the IAS is at or above the stall speed in IAS. Even worse is that the takeoff speeds, which are calculated using the stall speed, may be too low, leading to an immediate stall at takeoff.
These stall speed data found in this chart using IAS, which is not in compliance with FAR 23, are not valid, and should not have been approved by the authorities.

8.5. POH Page 5-33 Take-off Distance – Flaps up

8.5.1.   This page also presents a table with Take-off speeds V_R (in knots) and the required airspeed at 50 ft. For maximum take-off weight, V_R = 95 kt, $V_{50\,ft}$ = 121 kt. In accordance with FAR § 23.51, V_R must be greater than 1.1 V_S and greater than 1.05 V_{MCA}. Power-on stall speeds were not found in the POH, so power-off stall speed was used. 1.1 V_S wings level, flaps up for 12,500 lb is 1.1 × 99 = 109 KIAS (Page 5-21), and 1.05 V_{MCA} for wings-level is 1.05 × 86 = 91 KIAS plus the additive for wings level (§ 2.5.11) is ≈ 97 KIAS. Hence V_R must be larger than 109 KIAS. V_R in the table (95 knots) is 14 knots too low. What is wrong here?

8.6. POH Page 5-43 Climb – One Engine Inoperative

8.6.1.   As explained in § 0 above, a small bank angle is required to reduce the sideslip angle to a minimum, hence to reduce the drag to a minimum and hence, maximize the Rate of Climb. The required bank angle (≈ 3° toward the operating engine) is not presented in the legend on this page as associated condition.

8.7. POH Page 5-46 – 5-115 Cruise Power charts Several RPMs, All Engines Operating and OEI

8.7.1.   The IAS column in all of these charts must be replaced with CAS data. As mentioned in § 8.2.2 above, IAS data cannot be accurate, are only corrected for position error, not for instrument error.

9.   POH Section X – Safety Information

9.1.   Section X presents Safety Information and general information on specific topics.

9.2.   On page 10-4 is stated: "*Beech has revised and reissued many of the early manuals for certain models of airplanes in GAMA Standard Format as Pilot's Operating Handbooks and FAA Approved Airplane Flight Manuals*".

9.2.1.   The GAMA Standard Format is presented in GAMA Specification No. 1[2]. This Specification is regrettably not prepared with a high level of aeronautical expertise and put the POH/AFM-writers of Beechcraft and other member companies on the wrong foot, on several subjects. The GAMA specification does not comply with FAR 23 and FAA Flight Test Guide AC 23-8C, although it is approved by the authorities. GAMA forces its members (including Textron/Beechcraft) to break both the airworthiness law as well as the FAR requirements for the contents of an POH/AFM. A critical review of GAMA Specification No. 1 is available on the Downloads page (as #14) of website https://www.avioconsult.com.

9.2.2.   Nevertheless, Beechcraft is responsible for manuals that are issued with the airplanes,

and should make sure to employ expertise at the highest available level, because pilots have the right to be provided with faultless manuals.

9.3.   POH Page 10-14 Flight with One Engine Inoperative

9.3.1.   In the second paragraph: *"Loss of power from one engine obviously represents a 50% loss of power but, in virtually all twin-engine airplanes, climb performance is reduced by at least 80%"*. And: *"Single-engine climb performance depends on four factors"*, one of which is *"Drag"* due to *"Gear, flaps, and windmilling prop"*.

9.3.2.   Climb performance is indeed reduced by more than 50%. Drag can be reduced, not only by feathering the propeller of the failed engine, but also by reducing the sideslip angle using a small bank angle into the good engine, to the same side as foot pressure, which is explained in the next paragraph.

9.3.3.   **The third paragraph** is: *"Loss of power on one engine creates yaw due to asymetric thrust. Yaw forces must be balanced with the rudder. Loss of power on one engine also reduces airflow over the wing. In addition, yaw affects the lift distribution over the wing causing a roll toward the "dead" engine. These roll forces may be balanced by banking slightly (up to 5°) into the operating engine"*.

9.3.4.   The last sentence is not correct. Loss of power results in a thrust yawing moment that yaws the airplane and results in a fin/rudder generated side force. The yawing increases until the fin/rudder generated side force /yawing moment equals the thrust yawing moment. The result is a large sideslip, hence large drag, which decreases the Rate of Climb. To reduce the sideslip, and restore some climb performance, the pilot must apply rudder to arrest the yawing and maintain heading, but a sideslip angle, now from the opposite side, cannot be avoided during straight flight with the wings level (Figure 4 above). The pilot can reduce the sideslip/drag to a minimum by attaining a small bank angle into the good engine (Figure 5). This bank angle generates a side force in the center of gravity and hence, generates no adverse yawing moments. FAR 23 allows a bank angle of maximum 5° to achieve this. When maintaining this bank angle during straight flight, the sideslip angle and hence, the drag are minimal and hence the Rate of Climb is maximal which is quite important for a small twin. The small bank angle has another favorable effect. The rudder does not have to overcome the side force due to sideslip anymore, but only the thrust yawing moment. The rudder deflection can be smaller, which leaves room for a speed decrease until the rudder is again maximum deflected (for maintaining straight flight). The airspeed at which this occurs is the minimum control speed V_{MCA} of the airplane, which is published in the POH/AFM (Figure 6). The published V_{MCA} is only valid when maintaining a small 5° bank angle away from the inoperative engine during straight flight with maximum asymmetrical power. When the airspeed is V_{MCA} or near V_{MCA}, the wings are kept level, and the thrust is maximum, the rudder deflection cannot be large enough to counteract the yawing forces and moments to maintain directional control. When during takeoff an engine fails, straight flight with the small bank angle should be maintained until reaching a safe altitude. This may take 20 minutes or more, depending on the weight of the airplane. At the safe altitude, power should be reduced temporarily during, and to maintain control, during a turn.
The loss of propulsive lift on one wing indeed causes a rolling moment, requiring a roll control input. Some multi-engine airplanes with large propellers require up to maximum aileron deflection to maintain lateral control. Sideslip has effect on rolling moments, not the bank angle. Refer to the lateral-directional stability derivatives in the paper in footnote 16.

9.3.5.   The short version of the definition of V_{MCA} is repeated in this Section: *"V_{MCA} is the Airspeed below which directional control cannot be maintained".* V_{MCA} is defined in FAR 23.149 to be the minimum speed at which control can be established after a sudden failure, and thereafter straight flight can be maintained (§ 2.5.3 above). As explained in § 2.5.11 above, V_{MCA} increases when the wings are kept level, or when banking to either side. Pilots must be made aware to be able to maintain control of the airplane and save their souls following an engine failure.
A better general description of V_{MCA} would be: 'Airspeed below which the rudder and/or ailerons

cannot generate adequate forces and moments to maintain control of the airplane'. The definition for pilots is in § 2.5.27 above.

9.4. POH Page 10-15 Air Minimum Control Speed (V_{MCA})

9.4.1. Although most errors in this text are already discussed above, a few remarks will be given here. V_{MCA} is determined as the minimum calibrated airspeed (FAR 23.149(a)) to maintain control when one engine suddenly fails, and there*after* maintain straight flight, while maintaining a 5 degrees bank angle away from the failed engine (same side as foot pressure), but not more or not less (or V_{MCA} will increase – Figure 6 on page 19).

AIR MINIMUM CONTROL SPEED (V_{MCA})

V_{MCA} is designated by the red radial on the airspeed indicator and indicates the minimum control speed, airborne at sea level. V_{MCA} is determined by FAA regulations as the minimum airspeed at which it is possible to recover ~~directional~~ control of the airplane within 20 degrees heading change and therefore maintain straight flight, with ~~not more than 5 degrees of bank~~ if one engine fails suddenly with:

- Takeoff power on the operative engine
- Rearmost allowable center of gravity
- Flaps in takeoff position
- Propeller on failed engine windmilling (feathered if Auto-Feather system is required)

However, sudden engine failures rarely occur with all factors listed above, and therefore, the actual V_{MCA} under any particular situation may be a little slower than the red radial on the airspeed indicator. Most airplanes will not maintain level flight at speeds at or near V_{MCA}. Consequently, it is not advisable to fly at speeds approaching V_{MCA}, except in training situations or during flight tests. Adhering to the practice of never flying at or below the published V_{MCA} speed for your airplane will ~~virtually eliminate loss of directional control as a problem~~ in the event of an engine failure.

The last bullet raises a question. Is the furnished V_{MCA} for a windmilling or a feathered propeller? An autofeather is not required, but installed in the B200, isn't it? The difference might be some 6 kt. FAR 23 requires V_{MCA} with the propeller in the position it automatically achieves after engine failure.
A bullet missing is
 • lowest weight possible.
Refer to Figure 7 on page 19, and § 2.5.14.

A small bank angle is necessary to reduce the sideslip, hence drag, to be able to maintain level flight, and/or to maximize climb performance.
The last sentence only applies during straight flight. When turns are initiated while an engine is inoperative, and the thrust on the other engine is maximum, V_{MCA} increases considerable, above the flying speed, and control will be lost (§ 2.5.11). This text must be improved.

9.5. POH Page 10-15 Basic Single Engine Procedures

9.5.1. In the right column, in step 1: "The Cardinal rule number one is maintain airplane control and airspeed at all times". But accident statistics prove that pilots don't know how to maintain control, and that they need a much higher airspeed for maintaining control during turns, when an engine is inoperative.

9.5.2. The Cardinal rule number one for engine failure during takeoff is: 'Maintain straight flight while banking 5° into the good engine, until reaching a safe altitude, and increase airspeed with at least 20 kt (t.b.d. by the manufacturer) and/or reduce asymmetrical thrust a bit, before initiating a shallow turn', sacrificing some altitude, but enabling maintaining control.

9.5.3. As described above, it is recommended to add to the basic fundamentals of all engine emergency procedures to 'never ever turn the airplane to either side when the asymmetrical power is maximum, neither at takeoff speeds, nor at higher speeds. Actual VMCA increases considerably during banking'. Refer to § 2.5.11 above.

9.6. In the remainder of Section 10 are several inappropriate paragraphs on V_{MCA} and engine-out flight, but these can be corrected using the remarks presented above in this review.

10.   Summarizing Conclusions of This Limited POH Review

10.1. This review was only limited, but it proves that this Pilot's Operating Manual (POH) is not complying with the requirements in FAR 23, and is deficient on several subjects that have to do with

the safety of flight during or following an engine failure. The most relevant conclusions of the review presented above are presented below.

10.2. All airplanes are equipped with one or two pitot-static systems that are required to measure and display the airspeed and altitude to the pilots. FAR 23.1323(b) requires calibration of each pitot-static system of a type of airplane to determine its position error, and FAR 23.1323(a) requires the calibration of each individual Airspeed Indicator (ASI), to determine its instrument error over a range of airspeeds. The position error (up to 5 kt) of the pitot-static system is usually equal in all airplanes of the same type, and is presented in POH/AFM Performance Section 5, while the instrument error (up to 4 kt + 3 kt friction error) must be provided with each individual ASI. This way, the manufacturer only has to issue one POH for the whole fleet of a series of airplanes of the same type, and the FAA and equivalent organizations only have to approve one POH (§ 2).

10.3. The Beech 200 POH is obviously prepared using General Aviation Manufacturers Association (GAMA) Specification No. 1 which provides guidance to the member-manufacturers for preparing the POH of their Part 23 airplanes. GAMA recommends *"Calibrated Airspeed (CAS) is to be used only as necessary to comply with any applicable requirements of the certificating authority as the pilot works exclusively with Indicated Airspeed (IAS)"*. The Calibrated Airspeed of an airplane is the airspeed at which the airplane is plowing the undisturbed air, which produces the lift of the wings, and the control power generated by the aerodynamic control surfaces elevator, ailerons, and rudder. GAMA might inappropriately state that *"the pilot works exclusively with IAS"*, but 'the airplane works exclusively with CAS'; hence the pilot needs CAS for the flying task. CAS however cannot be displayed directly in the cockpit because of unavoidable position errors in the pitot-static system, and of instrument errors in Airspeed Indicators (ASI). The airspeed indicated by the Airspeed Indicator on the instrument panel(s) in the cockpit is the CAS including both the error due to the position of the pitot tube in disturbed air, and the instrument error of the ASI. Hence, the Indicated Airspeed is not an accurate indication of the speed at which the airplane moves through the air. Therefore, a pilot needs both errors to be able to correct the speed indicated by the ASI to obtain the IAS that corresponds with the limiting and operational airspeeds, as well as the performance data which are determined during flight-testing and which are always provided as or with reference to CAS in the POH/AFM. A pilot cannot exclusively work with IAS, because if he (or she) does, limiting and operational speeds such as stall speed, takeoff speeds, etc., which are required and approved by the FAA as CAS, will be violated, and the rate of climb, range, and other performance data do not match the data in the POH (§ 2.4.2).

10.4. The Indicated Airspeeds presented in tables and charts in the Beech 200 POH are not really the IASs of the airplane, but are CAS including the position error only. The FAR 23 required instrument error is intentionally neglected or, as the POH calls it, is *"assumed to be zero"* (which they are not). Each and every ASI has its own instrument error which has a quadratic influence on the control power generated by rudder and ailerons. The influence of this small error on controllability is larger at higher airspeeds (§ 2.4.4). Using IAS obtained with a zero instrument error in a POH introduces errors and is not in compliance with FAR 23 and equivalent airworthiness regulations which require ASI errors to be determined and furnished separately; not using instrument errors renders the airplane not airworthy (§ 2.2.5.7). The use of IAS in a Beech 200 POH that applies to the whole fleet of the same type should never have been approved, neither by Textron/Beechcraft, nor by the FAA (and EASA, and equivalent). The GAMA recommendation is dead wrong, and must have led to many fatal accidents. In flight-test terms: the POH is deficient, and must be improved by deleting all IAS data (before the next flight).

10.5. IAS data in the POH are used because some FAR 23 paragraphs require the use of IAS in a POH/AFM (§ 2.3.3). These paragraphs were evidently amended after GAMA Specification No. 1 was issued, because they did not exist in the 1970 edition of FAR 23. Other FAR 23 paragraphs still require CAS. It is obvious that the POH writer struggles with the presentation of the unit of the speeds and uses KIAS, KCAS and kts. FAR 23 today is not only confusing to the manual writers, but the use of several units of speed in the POH is also confusing to pilots. Not only the

GAMA Specification was written with incompetence, but also several FAR 23 and equivalent amendments (§ 2.3.16).

10.6. The consequence of not applying the correct instrument error is that the real, the actual airspeed that generates the wing lift and the control power of elevator, ailerons, and rudder, being the CAS, might be lower than the corrected airspeed indicated on the airspeed indicator. The pilot assumes to fly at a safe speed, but the airplane does not respond to control inputs anymore because the generated control forces are lower; control will be lost (§ 2.4.3). The speeds during takeoff might be up to 4 kt lower than the calculated required Indicated takeoff speeds, and the actual minimum control speed (V_{MCA}) might be much higher due to keeping the wings level, or during uncontrolled banking, leading to the loss of control right after liftoff (§ 2.5.11).
The POH does not refer to the instrument calibration errors, and uses IAS incorrectly. The FAA reviewed the POH to determine that the required information is complete and accurate. The IAS data in this POH is not accurate as required by FAR 23. The POH/AFM should also be reviewed to ensure that any additional information provided by the applicant is not in conflict with required information or is contrary to the applicable airworthiness requirements (AC 23-8C page 163). Hence, the use of IAS in the POH is not in compliance with FAR 23; the POH should not have been approved by the FAA and/or equivalent.

10.7. The writers of this POH and the approving authorities might not have had a good understanding of pitot-statics and the difference between CAS and IAS, as taught at universities and test pilot schools. The use of IAS without instrument correction is not only non-compliant with FAR 23, but is also misleading to pilots, because the prescribed emergency, limiting and operational airspeeds are intentionally rendered incorrect by neglecting the instrument errors (§ 5.1.3). Both GAMA and the POH writer might have had in mind that the use of IAS would make the piloting task easier, more convenient, but did not realize that they introduced errors that must have caused many fatal accidents. Regrettably, no one within the FAA or equivalent organizations, in the GAMA and in the Beechcraft manufacturer organization realized this either and objected, most probably because of lost or unknown knowledge.

10.8. The stall speeds (V_S) are presented in a graph in which IAS lines are added (POH page 5-21). As for other "*IAS*" speeds in this manual, this stall speed is not including the correction of the instrument error, which may be up to 4 kt, plus the error due to pointer friction, which is allowed to be up to 3 kt. If the stall speed in IAS is used to calculate takeoff speeds, these might be too low, leading to an immediate stall at liftoff. The stall speeds in IAS in this POH/AFM are invalid and should not have been approved by the FAA (§ 8.4.1).

10.9. Several airspeed definitions in POH Section I, page 1-11 are not appropriate or are incorrect. Other definitions are incomplete or missing (§ 3.1).
The definition of the minimum control speed V_{MCA}, for instance, is neither correct, nor complete (to ensure a safe remainder of the flight after engine failure). The definition of V_{MCA} out of FAR 23 is for the design and certification of multi-engine airplanes, not for their operational use. An airplane is not designed to be controllable at V_{MCA}, but is designed and certificated to recover from a sudden engine failure, and thereafter *maintain straight flight*" only, while maintaining a small bank angle but less than or equal to 5°, at the option of the manufacturer, away from the inoperative engine, when the asymmetrical thrust is maximum. This small bank angle is allowed by FAR 23.149 because it generates a side force due to the Weight (gravity) which decreases the sideslip angle and drag, and hence maximizes the climb performance (§ 0). These associated straight flight and bank angle conditions should also be included in the V_{MCA} definition, and in engine emergency procedures to remind pilots of their importance. The actual V_{MCA} that a pilot will experience in-flight is definitely not the constant value that is furnished in the POH/AFM, but varies with bank angle, asymmetrical thrust level, and many more variables. Flight while an engine is inoperative is not a coordinated flight. It appears that the manual writer was not aware of the controllability of an airplane when one of the engines fails or is inoperative and of the real value of the minimum control speed V_{MCA} and of the associated conditions that come with it. Neither were many if not all mishap pilots, because of a short falling POH.

"Information that is necessary for safe operation because of design, operating, or handling characteristics", as required by FAR 23.1581(2) (§ 2.3.12), and the *"significance of V_{MC} as an operational limitation"*, as required by FAR 23.1583(a)(2) (§ 2.3.13) and by GAMA Specification No. 1 § 2.3 (§ 2.4.2 above) are not adequately provided in the POH (§ 3.1.12). Shortfall of knowledge causes accidents; physics has no mercy.

10.10. The POH/AFM-published V_{MCA}, which is measured while maintaining a small bank angle away from the inoperative engine, is also used for calculating operational speeds V_R, V_2, V_{REF} which are used with the wings level. The ≈ 6 kt increase of V_{MCA} when keeping the wings level is not included in the calculation of these V-speeds, hence some of the presented operational speeds in the POH/AFM seem to be too low (§ 2.4.3 and § 2.5.23).

10.11. The POH on page 2-4 presents a table in which the position of the markings of a number of operational and limiting speeds on the Airspeed Indicator are defined. The IAS data in this table does not include the instrument error; hence, the markings might not be located at the correct position. When two ASIs are installed in the instrument panel, the markings might not have to be at the same location, but could differ by as much as 8 kt (§ 4.2.1). The table is wrong; IAS data should be removed, and CAS, position and instrument errors be used to locate the markings at the correct position on the face of the ASIs.

10.12. This POH does not provide the guidance required to prevent the many accidents after engine failure (§ 1.1); it was not written with expertise. The provided limiting and operational airspeeds are inaccurate with errors up to 4 kt, and the guidance for flight after engine failure is insufficient. Review by FAA was inadequate.
Pilots have the right to be well trained and informed about the characteristics of their airplane; passengers have the right their airplane to be operated by such pilots. Developing airplane flight and operating manuals and pilot training programs requires high level multi-disciplinary knowledge, not just a pilot license for operating an airplane.
This is also why this review was written.

11. Recommendations

11.1. The manufacturer is strongly recommended to improve the POH to be in compliance with FAR 23 and Flight Test Guide AC 23-8C, and their intention, and with the suggestions presented in this review. It is strongly recommended to have the full manual reviewed by a competent multi-disciplinary team, consisting in any case of a graduate of one of the (formal) Test Pilot Schools with a strong engineering background, an aeronautical engineer, an airline pilot, and an aviation human factors expert.
Pilots have the right to be provided with immaculate POHs.

11.2. The IAS data in the POH should be removed if the POH is for a series of Beech 200 airplanes, or recalculated with the instrument errors if the POH is for a specific B200. Besides the suggestions presented above, more are given in § 7 of paper *Airplane Control and Analysis of Accidents after Engine Failure*[17]. Pilots should be furnished with CASs and position error in the POH, and with instrument error (calibration) data of the airspeed and altitude instruments that are installed in their airplane, as required in FAR 23.1323 (for a reason).

11.3. Information necessary for the safe operation after engine failure must be improved. Pilots have the right to be made aware of associated conditions for V_{MCA} to be valid, and of controllability limitations to be able to save their souls. They want to get home safely, as do their passengers. Manufacturers have the duty to provide pilots with pertinent information necessary for safe operation, resulting from the design, operating, or handling characteristics, as required in FAR 23.1585 Operating procedures: *"(a) For all airplanes, information concerning normal, abnormal (if applicable), and emergency procedures and other pertinent information necessary for safe operation and the achievement of the scheduled performance must be furnished, including— (1) An explanation of significant or unusual flight or ground handling characteristics"* (§ 3.1.12).

11.4. Preparing an amendment for an POH takes much time. For the time being, and to prevent accidents after engine failure, it is strongly recommended to issue a temporary revision as soon as possible letting pilots know that:

- the POH-published V_{MCA} and the therewith derived takeoff speeds (V_R and V_2) are valid only during straight flight while maintaining a small specified bank angle (5°) away from the inoperative engine. V_{MCA} increases very much above the published value while banking to either side and with increasing asymmetrical thrust level, requiring a much higher airspeed to prevent the loss of control.

- only the CAS in the POH should be used, not the IAS values. Pilots should use the position error (in the POH), and the ASI instrument error in the ASI calibration report or table to calculate IAS from CAS or vice versa.

11.5. It is also recommended that the manufacturer considers the need to use the wings level V_{MCA} for calculating the takeoff and landing reference speeds.

11.6. FAA, EASA, and equivalent organizations should reconsider the requirements to provide IAS data in a POH/AFM, and review FAR 23 and other regulations, and Advisory Circulars using proper expertise at MSc and/or test pilot school level.

11.7. Textron/Beechcraft should inform GAMA to either revoke or improve Specification No. 1.   ■

LIST OF ABBREVIATIONS AND SYMBOLS

	Sideslip angle	OEI	One Engine Inoperative
ρ	Air density	P_a	Ambient pressure
ϕ	Bank angle	POH	Pilot Operating Handbook
δa	Aileron deflection angle	P_S	Static pressure
δr	Rudder deflection angle	P_T	Total pressure
AC	Advisory Circular (FAA)	q_c	Dynamic pressure
AFB	Air Force Base	ROC	Rate of Climb
AFM	Airplane Flight Manual	S	Surface area
ASI	Airspeed Indicator	SE	Single Engine
ATSB	Australian Transport Safety Board	SFAR	Special Federal Aviation Regulation
CAS	Calibrated Airspeed	SL	Sea Level
CFR	Code of Federal Regulations (USA)	$T \cdot \sin \beta$	Thrust bending side force due to sideslip
cg	Center of gravity	TAS	True Airspeed
C_L	Lift coefficient	TOLD	Takeoff and Landing Data
EAS	Equivalent Airspeed	TPS	Test Pilot School
FAA	Federal Aviation Administration (USA)	USAF	United States Air Force
FAR	Federal Aviation Regulation	V	Velocity or speed
ft	foot, or feet	V_1	Decision speed
FTG	Flight Test Guide	V_2	Takeoff Safety Speed
g	Gravitational Acceleration	V_C	Calibrated Airspeed (CAS)
GAMA	General Aviation Manufacturers Association	V_{EF}	Engine Failure Speed
GS	Ground Speed	V_{ic}	Instrument Corrected Airspeed
IAS	Indicated Airspeed	V_{LOF}	Liftoff speed
ICAO	International Civil Aviation Organization	V_{MC}	Minimum Control Speed
KCAS	Knots Calibrated Airspeed	V_{MCA}	Minimum Control Speed in the Air/Airborne
KIAS	Knots Indicated Airspeed	V_{MCG}	Minimum Control Speed on the Ground
kt	knot or knots	V_R	Rotation speed
L	Lift	V_S	Stall speed
$L_{\delta a}$	Rolling moment due to aileron deflection δa	V_{S0}	Stall speed, landing configuration
$L_{\delta r}$	Rolling moment due to rudder deflection δr	V_{S1}	Stall speed, specified configuration
lbf	Pound force	V_{SR}	Reference stall speed
L_T	Rolling moment due to (asymmetric) thrust T	V_{SSE}	Safe intentional OEI speed
L_β	Rolling moment due to sideslip	V_{XSE}	Speed for best SE angle of Climb
MSc	Master of Science	V_{YSE}	Speed for best SE ROC
MTOW	Maximum Takeoff Weight	W	Weight
N	Yawing moment	$W \cdot \sin \phi$	Side force due to Weight and sinus ϕ
N_β	Yawing moment due to sideslip angle β	x	x body axis (out front and aft, thru cg)
$N_{\delta a}$	Yawing moment due to aileron deflection δa	y	y body axis (out L, R wings, thru cg)
$N_{\delta r}$	Yawing moment due to rudder deflection δr	Y_β	Side force due to sideslip angle β
N_T	Yawing moment due to (asymmetric) thrust T	$Y_{\delta r}$	Side force due to rudder deflection δr
NTSB	National Transportation Safety Board (USA)	z	z body axis (out bottom, thru cg)