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18 August 2006

Review of the
Course Notes of Multi-Engine Safety Review
as published on the Internet, website http://faasafety.gov

Reference. Report *Prevention of Airplane Accidents after Engine Failure*, by Avio*Consult*, June 2005, downloadable from the Products page of website www.avioconsult.com.

INTRODUCTION

Every year, all around the world, a number of small and big airplanes crash due to the loss of control following the failure of an engine or while an engine is inoperative. After reviewing many accident investigation reports, Avio*Consult*, having a strong experimental flight-test background, could not understand why these accidents happen, because all multi-engine airplanes are flight-tested and certified, after which operating limitations are calculated and published in airplane manuals for pilots to be able to continue to operate safely, including following the failure of an engine.
The fact that these limitations obviously do not prevent all accidents after engine failure, and during flight with an inoperative engine, was the reason for Avio*Consult* to perform additional research and write a report on the subject that was first published in June 2005 (see reference). The research experience was used to review the *Course Notes of Multi-Engine Safety Review*, as published on the Internet, website http://faasafety.gov.

The real cause of most engine failure related accidents is, to the opinion of Avio*Consult*, the inappropriate understanding of the minimum control speed in the air (V_{MCA}) by most pilots, instructors, airplane accident investigators and also by aviation rule makers and authorities. Manufacturers and authors of all kinds of aviation and airplane books on the controllability and performance of multi-engine airplanes, including the authors of the *Course Notes of Multi-Engine Safety Review*, copy paragraphs/ sections out of FAR Part 23 (and 25) into their documents, and seem not to realize that these regulatory paragraphs are for the certification of an airplane, not for its operational use. Some of the paragraphs/ sections cannot just be copied, but should be changed before use in airplane flight manuals, student pilot text books, course notes, etc.
In this review, a limited number of imperfections and deficiencies that were found in the Course Notes are commented on. This review was written by Harry Horlings – AvioConsult, graduate

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The objective of the FAA Safety Program is: *Promoting aviation safety through education and co-operative efforts*. Please consider this review and the comments as a cooperative effort to increase flight safety. Avio*Consult* presents this review to whom it may concern, to learn from it and eventually save lives.

In the paragraphs below, quotes from the course notes are in *Italic* print, comments are in normal print. The remarks and recommendations are thoroughly explained in the referenced report.

REVIEW

The results of the review of the course notes, including brief explanations, are presented page by page. Please refer to the referenced Report to learn almost all there is about the subject, or ask Avio*Consult* by e-mail.

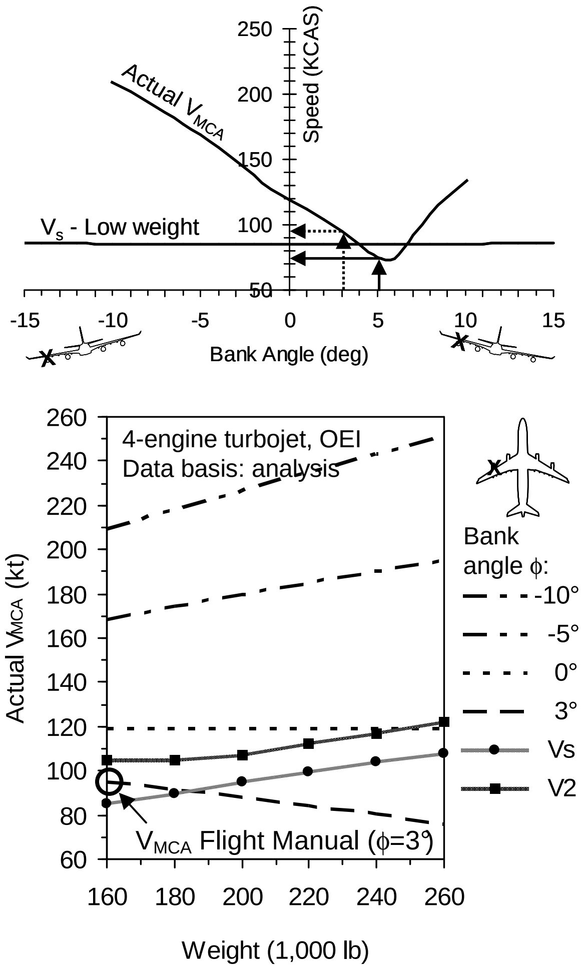
Page 2. *Note: Twins with a counter-rotating right engine do not have a "critical engine".*
This in itself is correct, but both engines are equally critical. It is only of relevance to the certification staff to mention the criticality of an engine. The pilot should, as an engine fails, not have to consider the criticality of an engine. The emergency procedure after failure of either engine, critical or not, is equal. The purpose of using the inoperative "critical" engine is to determine the highest, the worst case V_{MCA} after failure of either of the engines, that will be listed in flight manuals. Weight, for instance, is not considered on page 2, but weight might have an even greater effect on V_{MCA} than the critical engine (refer to the Figure on the next page).

Page 3. *The minimum control speed – Vmc – is the minimum speed at which directional control can be maintained with a bank angle of no more than 5 degrees when:*

- *The critical engine is inoperative with prop windmilling, and*
- *The remaining engine is operating at takeoff power.*

This paragraph is copied from Part 23.149 (a) and can also be found in many Airplane Flight Manuals and learning books. Nevertheless, it contains a life-threatening deficiency: the limitation '*bank angle of no more than 5 degrees'* applies to the certification of an airplane and is definitely not for operational use. The manufacturer may, in accordance with Part 23, use a bank angle away from the inoperative engine of not more than 5 degrees. The effect of this small bank angle is that sideslip can be reduced to zero (as correctly stated on page 4), which minimizes the drag and hence, maximizes the remaining climb performance. Many performance diagrams contain data that apply only if a small bank angle is being maintained. But this is not the only effect of bank angle.

Bank angle has also great influence on the value of V_{MCA} as shown in the Figures on the next page in which data of a 4-engine turbojet is used. Data for a 2-engine airplane will not be very different, except for the weight and V_{MCA} numbers. The Figures are copied from my Report *'Prevention of Airplane Accidents after Engine Failure'* and are also used in the Paper '*Staying Alive with a Dead Engine*', that was presented to the European Aviation Safety Seminar of the Flight Safety Foundation in March 2006. The Figures illustrate that if the manufacturer determined V_{MCA} by using a 3 degrees bank angle away from the inoperative engine, then the actual V_{MCA}, when keeping the wings level, will be up to 25 knots higher (120 kt) than the published V_{MCA} (95 kt), provided the other conditions and factors that have influence on V_{MCA} are at their worst case value, as they were during the flight-testing to determine V_{MCA}.
The V_{MCA} increase, if the wings are kept level, for small twin-engine airplanes will be around 8 – 10 knots, and therefore a factor to consider. The effect of bank angle (and weight) on V_{MCA} is often forgotten, or not known at all, except to experimental test pilots and flight-test engineers who are trained by Test Pilot Schools. They notice this effect each time a V_{MCA} is determined.



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

The consequence of keeping the wings level during liftoff or go-around at an airspeed that is only 5 knots above the published V_{MCA} (as recommended on page 5 of the course notes) is that control will be lost as soon as the airplane gets airborne or immediately after the power lever is advanced to maximum takeoff setting (during approach or go-around), if the variables that have influence on V_{MCA} happen to be at their worst-case value. For safety reasons the worst-case values have to be used for a takeoff speed recommendation, of course, so V_{MCA} + 5 is not safe and should be V_{MCA}+8+5, in this example. Loss of control means that the heading cannot be maintained by either maximum rudder input, maximum aileron input or a pedal force of 150 lb, whichever occurs first. The airplane will continue to yaw and/ or roll into the dead engine side. The resulting sideslip into the dead engine side decreases the performance; the weathercock stability and loss of speed will start pointing the nose of the airplane down. A catastrophe cannot be avoided if the altitude is low, unless the actual V_{MCA} is quickly reduced to below the indicated airspeed by reducing the thrust of the operating engine just a little, until the controls are effective again. There is not much time to do this though, so it should be standard procedure to attain and maintain 5 degrees (or the number of degrees that the manufacturer used) away from the inoperative engine as long as the power setting is high and the altitude and airspeed are both low. Thrust and bank angle are the only two variables that are under direct control of the pilot; both have great effect on the value of the actual V_{MCA}.

An interesting line in the second Figure for pilots of Part 25 airplanes is V_2. Takeoff safety speed V_2 is calculated from both V_{MCA} and V_S and is not providing the safety margin that the authorities had in mind if the bank angle is not the same as the bank angle that was used to determine V_{MCA}, and if the other factors that have influence on V_{MCA} happen to be at their worst case value. Then the actual V_{MCA} at airplane weights below 250,000 lb, when the wings are kept level (as many manufacturers recommend after engine failure), is higher than V_2, which leads to an uncontrollable airplane. Takeoff safety speed V_2 is not safe by itself. As for V_{MCA}, there is an important bank angle restriction/ condition required for ensuring that V_2 is really a safe takeoff safety speed.

FAR 23 and 25 should be amended to require that the bank angle used to determine V_{MCA} be listed with V_{MCA} data in the manuals as well as on the required V_{MCA} placard in Part 23 airplanes. Many more suggestions for improving FAR 23 and 25 are presented in the referenced report.

The quoted line *"with a bank angle of no more than 5 degrees"* must be replaced by either "with a bank angle of 5 degrees away from the inoperative engine ", or – even better – by "with a bank angle of X degrees away from the inoperative engine", where X is the bank angle used to determine V_{MCA}.

Page 3 also presents a link to the *14 CFR 23 Criteria for establishing V_{MC}.* The list of specific set of circumstances required to determine V_{MCA} is correct, except for the takeoff weight. Currently, 23.149 (b) calls for the most unfavorable weight, not for "*maximum takeoff weight (or any lesser weight necessary to show Vmc)".* The regulatory paragraph requires that V_{MC} for takeoff must not exceed 1.2 V_{S1}, where **V_{S1} and not V_{MC}** is determined at the maximum takeoff weight. I will briefly explain why the weight should be low for determining V_{MCA}.
The Figure presented above illustrates the effect of weight on V_{MCA}. V_{MCA} at low weight is higher than V_{MCA} at high weight while maintaining a small bank angle away from the inoperative engine. If V_{MCA} would be determined at high weight as the course notes mention, the actual V_{MCA} at low weight would be higher. V_{MCA} is determined while all of the variables that have influence on V_{MCA} are at their worst-case value. This provides the highest V_{MCA}. The actual V_{MCA} will always be lower, which is safer. As can be seen from the Figure, *maximum takeoff weight* does not provide the worst case (the highest) V_{MCA}, but low weight does. Therefore, flight testing to determine V_{MCA} is always performed while the airplane is at the lowest possible, the most unfavorable weight, because then the resulting V_{MCA} that is published in Flight Manuals is safe for any weight, provided the bank angle is away from the inoperative engine. If, after engine failure, an equilibrium is established while the wings are level, or even with the wings banking into the dead engine, V_{MCA} increases considerably, as the Figure shows. So turns into the dead-engine side should be avoided. Not mentioned in the course notes is the lateral cg, which should be at the worst case too, i.e. into the dead engine. Please refer to my Report for the other variables/ conditions that are used to determine V_{MCA}.

Note: I keep saying V_{MCA}, because there is also a V_{MC} on the ground (V_{MCG}) and a V_{MC} for landing (V_{MCL}).

Page 3 – Criteria (Cont'd). *Under these conditions, the flight test pilot must be able to:*
1. Stop the turn that results when the critical engine is suddenly made inoperative within 20 degrees of the original heading, using maximum rudder deflection and a maximum of five degrees angle of bank into the operative engine; and
2. Thereafter, maintain straight flight with not more than a five degree angle of bank.

Comments:
1. This paragraph is about the dynamic V_{MCA} which is determined by suddenly shutting down the critical engine. The resulting motion following the sudden failure of an engine is not a *turn*, but a yawing and rolling motion due to asymmetrical thrust from the operating engine and propulsive lift from the wing section behind the operating propeller. The pilot should be able to regain control after the sudden failure of an engine while the heading change does not exceed 20 degrees and no abnormal flight attitudes develop. The sentence: *maximum of five degrees angle of bank into the operative engine,* does not belong here, but in the next paragraph.
2. The manufacturer may opt for a bank angle of not more than 5 degrees to determine the static V_{MCA}. The experimental test pilot will use this opted bank angle, which is then not a "*not more than a five degree angle of bank"* anymore, but a fixed bank angle used to determine V_{MCA}. It would be better to write: "Thereafter maintain straight flight while maintaining a bank angle as determined by the applicant". A pilot might interpret the line as it is right now as "maintain the wings level to within 5 degrees either side". But this might turn out to be a very dangerous interpretation and the very last that a pilot ever makes, as is illustrated in the Figures by the increase of actual V_{MCA}.
The highest of static and dynamic V_{MCA} will be published in a Flight Manual as the V_{MCA} of the airplane.

Page 5. *Never try to fly before reaching Vmc. If an engine fails below that speed, the rudder will not be effective enough to counteract the yaw resulting from asymmetric thrust, and you will not be able to control the airplane.*

It is recommended to say "never try to fly before reaching V_{MCA} plus (10+5)", because wings level might increase actual V_{MCA} up to 10 knots on small airplanes, if the other factors that have influence on V_{MCA} happen to be at their worst case value too. And worst-case is what has to be taken into account – always.

Page 5 (Cont'd). The linked takeoff briefing checklist says: *If an engine fails after liftoff and the landing gear is down, I will close both throttles and land straight ahead.* That is OK if the runway is long enough, but V_{MCA} is determined and published to be able to continue to fly if an engine fails. Climb should be possible if the small bank angle is attained and maintained and the airplane weight is not limiting climb performance. It is recommended to add: "If an engine is inoperative, I will maintain straight flight and maintain 5 degrees of bank away from the inoperative engine until reaching a (t.b.d.) safe altitude."
In the third bullet, it is recommended to add "5 degrees of bank away from the inoperative engine" to *pitch & power for Vyse*.

Page 7. *Twin Climb Performance. "… and maintain Vy until you reach a safe single engine maneuvering altitude (typically at least 400 feet AGL)".* Actual V_{MCA} can easily increase above Vy if the same bank angle is not being maintained that was used to determine V_{MCA}, as shown in the Figures. 400 Feet is not a safe altitude for maneuvering while an engine is inoperative. Remember, V_{MCA} is a safe minimum control speed for maintaining straight flight only while a small bank angle is being maintained; V_{MCA} is not a minimum speed for maneuvering safely! This is not understood by most multi-engine rated pilots, but it simply is the way V_{MCA} is determined and, hence, is to be used when the thrust is asymmetrical, not only during takeoff and go-around, but also during approach and landing, because an increase of power to the setting used to determine V_{MCA} might be required to maintain the glide slope. Actual V_{MCA} increases with the power increase.

The loss of performance can be minimized by banking 3 to 5 degrees away from the inoperative engine because then, as was already stated, the sideslip and hence, the drag are minimum. The bank angle at Vyse could be a little less, but performance does not suffer as long as the bank angle is 5 degrees, provided it is away from the inoperative engine for control reasons.

"… Vxse ("blue line") is used to clear obstructions during initial OEI climbout … It may be just a very few knots above Vmc." Very few knots, alright, but only if the bank angle is the same as used to determine V_{MCA}. If not, actual V_{MCA} will increase above Vxse instead and cause control problems; the obstruction might not be cleared at all.

Page 9. Actual V_{MCA} during a single engine approach will become dangerously high if the power setting needs to be increased to maximum during the final turn or in order to maneuver on the glide path. Then, actual V_{MCA} increases considerably and might cause control problems if a 5 degrees bank angle is not maintained away from the inoperative engine. This leads to the recommendation for requesting a long straight-in approach if an engine is inoperative, rather than an *approach and landing as near to normally as possible*, as is recommended on this page. Also recommended is to request a circuit pattern in which (shallow) turns into the good engine are required only, which is the safest direction to turn. Never ever turn into the dead engine' side if the power setting is high and the airspeed low.
If a go-around might become necessary, whether already OEI or in anticipation of an engine to fail, accelerate down the glide path while adding power and simultaneous bank 5 degrees away from the inoperative engine, until Vyse is reached and only then initiate the climb. If a go-around has to be made at the destination, the airplane weight might be low, which increases actual V_{MCA}. So control problems are close, even while maintaining the 5 degree favorable bank angle.

Page 10. *Paragraph 4. Know the basic OEI emergency procedures common to all conventional light twins.*

- ***"Control**. Maintain directional control with rudder and aileron. Assume the pitch attitude for Vyse."* The requirement for banking is not mentioned here for control of the airplane, but only under the next bullet for Climb. However, for the safety it is definitely required to establish a 5 degree bank angle as soon as the (asymmetrical) power is increased. In some emergency procedures, attaining the bank angle is a step in the engine emergency procedures, but is most often considered only for maximizing climb performance, not for maintaining control. The bank angle step therefore is always executed too late.

Third bullet under *Regular training …*

- *"Accomplish all simulated engine failures below 3,000 AGL by smoothly retarding the throttle – never with mixture!"* All OEI training should be performed at an altitude of 5,000 ft AGL or above; V_{MCA} demos are dangerous, especially following a sudden failure as might be meant here. Smoothly retarding a throttle will not show the dynamics that might be the objective. It is far safer to demo the static V_{MCA} by reducing the speed at a rate of 1 knot per second from the safe intentional one engine inoperative speed Vsse until either one of the control limits is reached and the heading cannot be maintained. It is recommended to set the 'inoperative' engine to the zero thrust setting, rather than shutting it down. The effect for demonstrating V_{MCA} is the same.

Page 12. Course Review; comments are not repeated.

CONCLUSION

The course notes begin with: *"Safe operation of multi-engine aircraft starts with a solid understanding of how an engine failure affects **control** and **performance**. This course reviews these concepts, but be sure to consult the Pilot's Operating Handbook (POH) or Airplane Flying Manual (AFM) for your specific airplane."*
The most important 'concept' for the safe operation of airplanes (***control***) is not included in this course, and – regrettably – neither in most airplane flight manuals, student pilot text books, training programs, etc. Manufacturers and writers only seem concerned with the remaining climb performance after engine failure and not with airplane control, while the lack of control is the real cause of most engine failure related accidents, but apparently is not recognized as such. This might have been caused by copying a paragraph out of FAR 23.149 that is applicable to the certification of an airplane, unchanged into books and manuals that are applicable to the operation of the airplane. That is where the safety- and life-threatening mis-interpretation of V_{MCA} starts.

This applies not only to Part 23 airplanes, but also to Part 25 airplanes! Please refer to the paper 'Staying Alive with a Dead Engine', or to the referenced Report 'Prevention of Airplane Accidents After Engine Failure', both available on www.avioconsult.com. In addition, on the website a review and comments are presented on a number of engine failure related accidents that happened all over the world.

RECOMMENDATIONS

It is strongly recommended to review my Report 'Prevention of Airplane Accidents after Engine Failure', in which almost all there is to know about V_{MCA} is explained, and to use the recommendations included in that Report for improving the Multi-Engine Safety Review Course, if the clarifications presented above are not sufficient. ■