FAA - Advisory Circular AC 23-8C - Flight Test Guide

Section 23.149 Minimum Control Speed testing

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Relevant paragraphs are highlighted.

In comment text boxes, V_{MCA} (A for Airborne) is used rather than V_{MC}, just like Flight Test Guide AC 25-7C does: "V_{MCA} is commonly used for V_{MC}."

These comments were added by a Test Pilot School graduate of AvioConsult(.com).

4. § 23.149 Minimum Control Speed.

a. Background. Section 23.149 requires the minimum control speed to be determined. Section 23.1545(b)(6) requires the airspeed indicator to be marked with a red radial line showing the maximum value of one-engine-inoperative minimum control speed. Section 23.1583(a)(2) requires that V_{MC} be furnished as an airspeed limitation in the AFM. These apply only to multiengine airplanes. A different V_{MC} airspeed will normally result from each approved takeoff flap setting. There are variable factors affecting the minimum control speed. Because of this, V_{MC} should represent the highest minimum airspeed normally expected in service. The variable factors affecting V_{MC} testing include:

(1) *Engine Power*. V_{MC} will increase as power is increased on the operating engine(s). Engine power characteristics should be known and engine power tolerances should be accounted for.

(2) *Propeller of the Inoperative Engine*. Windmilling propellers result in a higher V_{MC} than if the propeller is feathered. V_{MC} is normally measured with propeller windmilling unless the propeller is automatically feathered or otherwise driven to a minimum drag position (for example, NTS-System) without requiring pilot action.

(3) *Control Position*. The value of V_{MC} is directly related to the control surface travel available. Normally, V_{MC} is based on available rudder travel but may, for some airplanes, be based on lateral control travel. A stall speed faster than V_{MC} defines the limit in lieu of a traditional control deflection. For these reasons, V_{MC} tests should be conducted with rudder and lateral (if applicable) controls set at minimum travel. In addition, rudder and lateral control deflections should be adjusted to the minimum production tolerances. If, during V_{MC} tests, control force limits would be exceeded at full deflection, then a lesser deflection should be used so as not to exceed § 23.143 force limits.

(4) *Weight and C.G.* For rudder limited airplanes with constant aft c.g. limits, the critical loading for V_{MC} testing is most aft c.g. and minimum weight. Aft c.g. provides the shortest moment arm relative to the rudder thus the least restoring moments with regard to maintaining directional control. V_{MC} should be determined at the most adverse weight. Minimum practical test weight is usually the most critical because the beneficial effect of banking into the operating engine is minimized. Light weight is also desirable for V_{MC} testing because the stall speed is reduced.

(5) *Lateral Loading*. The maximum allowable adverse lateral imbalance (fuel, baggage, and so forth) should be maintained.

b. Explanation.

(1) *Controllability*. The determination of V_{MC} is closely related to the controllability requirements. It is one of the maneuvers that generally requires either maximum rudder or near maximum aileron deflection (unless limited by temporary control forces), or both, to maintain airplane control. When minimum control speed is determined using maximum rudder deflection, limited airplane maneuvering is still available using the ailerons and elevator. When minimum control speed is determined using near maximum aileron deflection, the airplane may be incapable of further maneuvering in the normal sense.

(2) *Critical Engine*. The regulation requires that V_{MC} determination be made "when the critical engine is suddenly made inoperative." The intent is to require an investigation to determine which engine is critical from the standpoint of producing a higher V_{MC} speed. This is normally accomplished during static V_{MC} tests.

(3) *Straight Flight*. Straight flight is maintaining a constant heading. Section 23.149(a) requires the pilot to maintain straight flight (constant heading). This can be accomplished either with wings level or, at the option of the applicant, with up to five degrees of bank toward the operating engine. Normally, 2-3 degrees of bank allows the airplane to attain zero sideslip so that at five degrees of bank, the beneficial effects of directional stability to counter the yaw produced by asymmetric thrust can be utilized.

(4) *Control Forces*. The rudder and aileron control force limits may not exceed those specified in § 23.143.

at V_{YSE} (is the case for a PA-44-180).

At V_{MCA}, which is a lower speed than V_{YSE}, 5° might be required for zero sideslip (hence max. climb performance).

(5) *Deicer Boots, Antennas, and other External Equipment*. The installation of deicer boots, antennas, and other external gear could change the V_{MC} speed significantly. Re-evaluation of the V_{MC} speed should be considered when these installations are made. Refer to AC 23.1419-2 if a "flight into icing" approval is being sought.

(6) *Variable V_{MC}*. For commuter category airplanes, a V_{MC} that varies with altitude and temperature is a permissible condition for use in determining § 23.53 takeoff speeds, provided that the AFM does not show a V_R below the red radial line speed required by § 23.1545(b)(6).

(7) *Autofeather Annunciations.* If autofeather is installed, there should be annunciations to advise of the status. This will include at least green advisory any time the system is armed. For some airplanes, the autofeather system will be identified as a critical system. This could be because V_{MC} has been determined with an operative autofeather system or because commuter category takeoff conditions were predicated on an operative autofeather system. For such installations, additional annunciations may be necessary to ensure that the system is armed and that malfunctions are immediately recognized. This could include caution/warning/advisory annunciations as follows:

(i) Caution or warning, if autofeather switch is not armed.

(ii) Caution or advisory if the autofeather is armed then is subsequently disarmed because of a system malfunction.

(a) All annunciations should be evaluated to verify that they can be easily and quickly recognized. For critical systems, the AFM limitations should require both a satisfactory preflight check and an armed autofeather for takeoff and landing.

c. Procedures.

(1) *Configuration*. Prior to conducting V_{MC} tests, rudder and aileron control travels should be set to the minimum allowable production travels. Rudder and aileron control cable tensions should be adjusted to the minimum value for use in service. The critical loading for V_{MC} testing is generally minimum weight and maximum aft c.g.; however, each airplane design should be evaluated independently to be assured that tests are conducted under the critical loading conditions. Variable aft c.g. limits as a function of weight, tip tanks, and so forth, can cause the critical loading condition to vary from one airplane to another.

(2) *Power*. An airplane with a sea-level engine will normally not be able to produce rated takeoff power at the higher test altitudes. Under these circumstances, V_{MC} should be determined at several power settings and a plot of V_{MC} versus power will allow extrapolation to determine V_{MC} at maximum takeoff power. Refer to paragraph c(6) for a further explanation of extrapolation methods. If tests are conducted at less than approximately 3,000 feet density altitude, no corrections to V_{MC} are normally necessary. If tests are conducted above 3,000 feet density altitude, then additional tests should be conducted to allow extrapolation to sea level thrust. Because propeller thrust decreases with increasing true airspeed, V_{MC} will increase with decreasing altitude and temperature, even at constant power. The results of testing are used to predict the V_{MC} for a maximum takeoff power condition at sea level unless, because of turbocharging or other reasons, some higher altitude prevails as the overall highest V_{MC} value.

(3) *Engine Controls*. All engine controls have to stay in the recommended takeoff or approach position, as appropriate, throughout the whole procedure.

(4) *Flap Settings*. An applicant may want to specify more than one takeoff or landing flap setting, as appropriate, that would require V_{MC} investigation at each flap setting.

(5) *Stalls.* Extreme caution should be exercised during V_{MC} determination due to the necessity of operating with asymmetric power, full rudder and aileron at speeds near the aerodynamic stall. In the event of inadvertent entry into a stall, the pilot should immediately reduce the pitch attitude, reduce power on the operating engine(s), and return rudder and aileron controls to neutral to preclude possible entry into a spin.

(6) *Static Minimum Control Speed.* The test pilot should select test altitude based on the capability to develop takeoff power and consistent with safe practices. It will be necessary to determine which engine is critical to the V_{MC} maneuver by conducting static tests with first one then the other engine inoperative to discover which one produces the higher V_{MC}. Power should be set to the maximum available for the ambient condition. If possible, test weights should be light enough to identify the limits of directional control without stalling or being in prestall buffet. For each test altitude condition, the following should be accomplished:

(i) *Flaps and Gear*. For the takeoff conditions, the gear should be retracted and the flaps in the takeoff position(s). For the landing conditions, the gear should be extended and the flaps in the landing position(s).

(ii) *Trim*. The airplane should be trimmed to the settings associated with normal symmetrical power for takeoff or approach (as appropriate) with all engines operating, as indicated.

(iii) *Power*. Set takeoff power on one engine and render the other engine inoperative. The propeller on the inoperative engine should be windmilling, or in the condition resulting from the availability of automatic feathering or other devices.

(iv) *Controls*. Gradually reduce airspeed until it is no longer possible to prevent heading changes with maximum use of the directional and near maximum use of the lateral controls, or the limit control forces have been reached. No changes in lateral or directional trim should be accomplished during the speed reduction. Usually the five-degree bank option will be used (refer to paragraph b(3)) to maintain straight flight. A yaw string may be used to assist the test pilot in attaining zero sideslip (or minimum sideslip).

(v) *Critical Engine*. Repeat steps (a) through (d) to identify which inoperative engine results in the highest minimum control speed. [If an autofeather system is installed and static V_{MC} was determined with the propeller feathered, repeat steps (a) through (d) with the critical engine inoperative and with the propeller windmilling.]

(7) *Extrapolation to Sea Level.* The only V_{MC} test data that can be extrapolated reliably are static V_{MC} data, where most of the variables can be carefully controlled to a constant value. Because V_{MC} data are typically collected in ambient conditions less critical than sea level standard day, extrapolation is nearly always necessary. Therefore, the usual way to establish an AFM V_{MC} is to extrapolate static V_{MC} data. When V_{MC} is determined for an airplane with an automatically feathered propeller, special techniques are required. Appendix 3 shows one method for extrapolating static V_{MC} from test conditions to sea level standard day.

(8) *Dynamic Minimum Control Speed.* After determining the critical engine static V_{MC}, and at some speed above static V_{MC}, make a series of engine cuts (using the mixture control or idle cutoff control) dynamically while gradually working speed back toward the static speed. While maintaining this speed after a dynamic engine cut, the pilot should be able to control the airplane and maintain straight flight without reducing power on the operating engine. During recovery, the airplane should not assume any dangerous attitude nor should the heading change more than 20 degrees when a pilot responds to the critical engine failure with normal

The effect of the critical engine is included in the published/ indicated V_{MCA}. V_{MCA} after failure of any other engine is a little lower, safer. Hence, pilots need not know which engine is critical.

skill, strength, and alertness. The climb angle with all engines operating is high, and continued control following an engine failure involves the ability to lower the nose quickly and sufficiently to regain the initial stabilized speed. The dynamic V_{MC} demonstration will normally serve as verification that the numbers obtained statically are valid. If, in fact, the dynamic case is more critical, then the extrapolated static V_{MC} value should be increased by that increment. Frequently, the dynamic V_{MC} demonstration will indicate a lower V_{MC} than is obtained from static runs. This may be because the inoperative engine, during spooldown, may provide net thrust or control force peaks that exceed limit values for a short period and go undetected, or, due to high yaw and pitch angles and rates, the indicated airspeed values are erroneous. Because of the multi-variable nature of the dynamic V_{MC} demonstration, the AFM V_{MC} value should represent the highest of the static or dynamic V_{MC} test data, corrected to critical conditions. Specifically in test conditions with a high thrust/weight ratio, a modified procedure may be applied to avoid extreme pitch attitudes. In this case, decelerate to below V_{MC}, all engines, accelerate with two x maximum takeoff power (MTOP) to a representative climb pitch attitude, and cut the critical engine at static V_{MC} (verify in advance that V_{MC} is acceptably above actual stall speed).

(9) *Repeatability*. Once determined, and if the dynamic V_{MC} seems to be the critical one, the dynamic V_{MC} should be verified by running a series of tests to determine that the speed is repeatable.

(10) *AFM Minimum Control Speed Value*. V_{MC} is usually observed at either several different power settings or altitudes, or both. Sufficient test data should be obtained such that the V_{MC} for the highest power and sea level density conditions may be determined. The V_{MC} resulting from this extrapolation to sea level is the one entered into the AFM and marked on the airspeed indicator. If this V_{MC} is determined with an autofeather system, the AFM required equipment list, as well as the Kind of Equipment List (KOEL), should list autofeather as a required item and the AFM would normally state the V_{MC} with the autofeather system inoperative (propeller windmilling) in the procedures section. The procedures section should also require the autofeather to be armed (if applicable) during takeoff and landing.

(12) *Safe, Intentional, One-Engine Inoperative Speed, V_{SSE}*. Reserved.

The objective of V_{MCA} testing is to publish the highest V_{MCA}, normally expected in service, in the flight manual. This - red lined - V_{MCA} is always safe, but is for straight flight only, while banking the specified number of degrees (usually 5°), with maximum thrust and with maximum rudder to counteract the adverse yaw.

A smaller bank angle, for instance keeping the wings level, will increase both V_{MCA} (8 knots or more) and the sideslip angle, which might lead to the (immediate) loss of control, if max. thrust is maintained, and to less than maximum climb performance.

With one engine out, the other at max. thrust and rudder and/or aileron (near) maximum, the IAS is near V_{MCA}: do not turn. Climb first during straight flight while maintaining a small (5°) bank angle away from the inoperative engine, then decrease thrust a bit and turn. Refer to the papers on the Download pages of AvioConsult.com.