FAA - Advisory Circular AC 25-7C - Flight Test Guide

Section 25.149 Minimum Control Speed

Relevant paragraphs highlighted.

23. Minimum Control Speed - § 25.149.

a. Explanation.

(1) General. Section 25.149 defines requirements for minimum control speeds during takeoff climb (V_{MC}), during takeoff ground roll (V_{MCG}), and during approach and landing (V_{MCL} and V_{MCL-2}). The V_{MC} (commonly referred to as V_{MCA}) requirements are specified in § 25.149(a), (b), (c) and (d); the V_{MCG} requirements are described in § 25.149(e); and the V_{MCL} and V_{MCL-2} requirements are covered in § 25.149(f), (g) and (h). Section 25.149(a) states, "...the method used to simulate critical engine failure must represent the most critical mode of powerplant failure with respect to controllability expected in service." That is, the power or thrust loss from the inoperative engine must be at the rate that would occur if an engine suddenly became inoperative in service. Prior to Amendment 25-42 to § 25.149, the regulation required that rudder control forces must not exceed 180 lbs. With the adoption of Amendment 25-42, rudder control forces became limited to 150 lbs. The relationships between V_{EF}, V_1, and V_{MCG} are discussed in paragraph 10, Takeoff and Takeoff Speeds, and paragraph 11, Accelerate-Stop Distance.

(2) Safety concerns addressed by V_{MCA}. When flying with an inoperative engine, the asymmetric yawing moment must be compensated by aerodynamic forces created by rudder

deflection and sideslip. When the speed decreases, sideslip increases rapidly in a non-linear manner. The purpose of the V_{MCA} requirement is to ensure the airplane remains safely controllable with the maximum power or thrust asymmetry at any speed down to V_{MCA}.

(3) Weight effect on V_{MCA}. To maintain straight flight with an inoperative engine, as required by § 25.149(b), the lateral aerodynamic forces resulting from sideslip and rudder deflection must be balanced by the lateral component of weight (i.e., W * sin(bank angle)). The bank angle necessary to maintain straight flight is therefore approximately inversely proportional to the weight. Since § 25.149(b) allows V_{MCA} to be determined with up to 5 degrees of bank angle, this introduces a weight effect on V_{MCA}. The heavier the weight, the lower the V_{MCA}, but the greater will be the demonstrated sideslip. As an example, flying a heavy airplane at a V_{MCA} speed determined at a lighter weight will result in the same sideslip, but a smaller bank angle (e.g., 4 degrees instead of 5 degrees if the airplane is 25 percent heavier).

b. Procedures.

(1) General.

(a) Prior to beginning the minimum control speed tests, the applicant should verify which engine's failure will result in the largest asymmetric yawing moment (i.e., the "critical" engine). This is typically done by setting one outboard engine to maximum power or thrust, setting the corresponding opposite engine at idle, and decelerating with wings level until full rudder is required. By alternating power or thrust on/power or thrust off from left to right, the critical engine can be defined as the idle engine that requires the highest minimum speed to maintain a constant heading with full rudder deflection.

(b) For propeller-driven airplanes, V_{MCA}, V_{MCG}, and V_{MCL} (and V_{MCL-2}, as applicable) should be determined by rendering the critical engine(s) inoperative and allowing the propeller to attain the position it automatically assumes. However, for some engine/propeller installations, a more critical drag condition could be produced as the result of a failure mode that results in a partial power condition that does not activate the automatic propeller drag reduction system (e.g., autofeather system). One example is a turbopropeller installation that can have a fuel control failure, which causes the engine to go to flight idle, resulting in a higher asymmetric yawing moment than would result from an inoperative engine. In such cases, in accordance with § 25.149(a), the minimum control speed tests must be conducted using the most critical failure mode. For propeller-driven airplanes where V_{MCA} is based on operation of a propeller drag reduction system, V_{MCA} should also be defined with the critical engine at idle to address the training situation where engine failure is simulated by retarding the critical engine to idle. If V_{MCA} at idle is more than one knot greater than for the engine failure with an operating drag reduction system, the idle engine V_{MCA} should be included in the normal procedures section of the AFM as advisory information to maintain the level of safety in the aforementioned training situation.

(c) AFM values of V_{MCA}, V_{MCG}, and V_{MCL} (and V_{MCL-2}, as applicable) should be based on the maximum net power or thrust reasonably expected for a production engine. These speeds should not be based on specification power or thrust, since this value represents the minimum power or thrust guaranteed by the engine manufacturer, and the resulting minimum control speeds will not be representative of what could be achieved in operation. The maximum power or thrust used for scheduled AFM minimum control speeds should represent the high side of the tolerance band, but may be determined by analysis instead of tests.

(d) When determining V_{MCA}, V_{MCL} and V_{MCL-2}, consideration should be given to the adverse effect of maximum approved lateral fuel imbalance on lateral control availability. This is especially of concern if tests or analysis show that the lateral control available is the determining factor of a particular V_{MC}.

(e) For changes to approved designs, the effect of any aerodynamic or propulsive changes on compliance with 25.149 must be assessed per § 21.20. For example, for design changes involving an increase in engine thrust, the effect of the higher thrust on minimum control speeds must be specifically evaluated, and, if found to be not negligible, must be accounted for.

(2) Minimum Control Speeds - Air (V_{MCA}).

(a) In showing compliance with the V_{MCA} requirements, the following two conditions should be satisfied: (Separate tests are usually conducted to show compliance with these two conditions.)

1 The stabilized (static) condition where constant heading is maintained without exceeding a 5-degree bank angle, and

2 The dynamic condition in which control is maintained without exceeding a heading change of 20 degrees.

(b) Static Test Procedure and Required Data.

1 To determine V_{MCA}, use the configuration specified in § 25.149, except that V_{MCA} is normally determined at minimum weight in order to minimize the stall speed and because static V_{MCA} decreases with increased weight if a 5 degree bank angle is used. The requirement of § 25.149(c) that V_{MCA} not exceed 1.13 V_{SR} is based on V_{SR} at maximum sea level takeoff weight. With the critical engine inoperative, the corresponding opposite engine should be adjusted to maximum takeoff power/thrust, and the airspeed decreased until heading can just be maintained with full rudder and no more than a 5 degree bank into the operating engine. For airplanes with more than two engines, the inboard engine(s) may be set to any power or thrust necessary to assist in developing the desired level of asymmetric power or thrust, or to achieve the desired flight path angle (normally level flight).

2 If the maximum asymmetric power or thrust that is permitted by the AFM operating limitations was maintained at the test day V_{MCA}, and the rudder pedal force did not exceed the limit specified in § 25.149(d), the resulting speed may be used as the single value of V_{MCA} for the airplane. If, at the option of the applicant, the AFM value of V_{MCA} is to vary with pressure altitude and temperature, the test day minimum control speed and the corresponding

power or thrust should be used to calculate an equivalent yawing moment coefficient (C_N). This C_N value may then be used to calculate V_{MCA} as a function of takeoff power or thrust, thus permitting V_{MCA} to be scheduled as a function of pressure altitude and temperature for takeoff data expansion and presentation in the AFM. (See Appendix 6 for further discussion of V_{MCA} correction.)

3 If maximum allowable takeoff power or thrust could not be developed at the flight test conditions, but maximum rudder deflection was achieved, then the V_{MCA} value corresponding to sea level standard day maximum asymmetric power or thrust may be calculated from the C_N attained at the test value of V_{MCA}. Extrapolation using this constant C_N method should be limited to 5 percent of the test day asymmetric power or thrust, and should only be permitted if the rudder pedal force at the test day V_{MCA} was not more than 95 percent of the limit value specified in § 25.149(d). For extrapolation beyond 5 percent power or thrust, a more rigorous analysis, using all the applicable stability and control terms, should be made. (See Appendix 6 for further discussion of V_{MCA} correction.)

4 If V_{MCA} could not be achieved due to stall buffet, or excessive rudder pedal force, a parametric investigation should be undertaken to determine whether V_{MCA} is limited by stall speed, maximum rudder deflection, or maximum allowable rudder pedal force. (See Appendix 7.)

(c) Dynamic Test Procedures and Required Data.

1 After the static V_{MCA} tests have been completed, dynamic engine cuts should be evaluated at a series of decreasing airspeeds to show that sudden engine failure at any speed down to the static V_{MCA} value meets the requirements of § 25.149. The dynamic V_{MCA} test is conducted by applying the maximum approved power/thrust to all outboard engines, stabilizing at the test airspeed, and then cutting fuel to the critical engine. The pilot must be able to recover to a straight flight condition (constant heading) with an angle of bank of not more than 5 degrees --

(aa) Without deviating more than 20 degrees from the original heading,

(bb) While maintaining the test airspeed, without reducing power/thrust on the operating engine(s), and

(cc) Without exceeding the rudder pedal force limit of § 25.149(d).

2 In accordance with § 25.149(d), the airplane may not assume any dangerous attitude, nor require exceptional piloting skill, alertness, or strength. The maximum bank angle achieved during the tests may exceed 5 degrees provided the airplane characteristics comply with this qualitative requirement. If the dynamic tests result in a V_{MCA} greater than the static value, the increment between the static and dynamic V_{MCA} at the same altitude should be added to the sea level extrapolated value. If the dynamic value is less than the static value, the static V_{MCA} should be used for the AFM data expansion.

3 If static V_{MCA} is near stall speed at the minimum practicable test weight, or if the thrust-to-weight ratio (T/W) results in a trimmed pitch attitude of more than 20 degrees, it is not feasible to attempt to accurately define a quantitative value of V_{MCA} using a sudden engine cut because of the dynamics of the rapid pitch down maneuver required, and the hazard associated with a potential spin entry. Additionally, an extreme nose up attitude followed by an engine cut is not representative of an operational takeoff engine failure. Since § 25.107(e)(1)(ii) requires V_R to be not less than 1.05 V_{MCA}, and there is some additional speed increase prior to lift off, a transport airplane is typically never airborne below approximately 1.08 V_{MCA}. Therefore, instead of using the dynamic method to define V_{MCA} for these aircraft with high T/W or stall speed coincident with V_{MCA}, it is more appropriate for a dynamic engine cut to be evaluated only for acceptable controllability, and at a more representative speed. For these airplanes, a dynamic engine cut should be evaluated at an airspeed of either 1.08 V_{SR} or 1.1 V_{MCA} (static), whichever is greater. During the entry to, and recovery from this maneuver, all the requirements of § 25.149(d) must be met.

4 For airplanes with rudder travel-limited V_{MCA}'s that have increased power or thrust engines installed, with no changes to the airframe's geometric layout or dimensions, it may not be necessary to conduct dynamic V_{MCA} flight testing if the power or thrust has not increased more than 10 percent above the level at which dynamic V_{MCA} had previously been demonstrated. (See Appendix 6).

(3) Minimum Control Speed - Ground (V_{MCG}) - § 25.149(e).

(a) It must be demonstrated that, when the critical engine is suddenly made inoperative at V_{MCG} during the takeoff ground roll, the airplane is safely controllable if the takeoff is continued. During the demonstration, the airplane must not deviate more than 30 ft. (25 ft. prior to Amendment 25-42) from the pre-engine-cut projected ground track. The critical engine) for ground minimum control speed testing should be determined during the takeoff ground run using techniques similar to these described in paragraph 23b(1). If there is a significant difference in left and right rudder deflection, the loss of asymmetric propeller disc loading, due to near zero angle-of-attack during the takeoff roll, could result in the critical engine being on the opposite side of the airplane relative to the airborne minimum control speed tests.

(b) Work up tests may be conducted by abruptly retarding the critical engine to idle to determine the airplane asymmetric control characteristics and provide data from which an estimate of V_{MCG} can be made. Due to the engine spindown characteristics with the critical engine retarded to idle, the speed will not, in general, be representative of the V_{MCG} speed that would be obtained with a fuel cut. Therefore, the certification tests for V_{MCG} should be conducted using fuel cuts. Starting from a speed comfortably above the estimated V_{MCG} and with the maximum takeoff power or thrust level to be certified, several fuel cuts should be made at decreasing calibrated airspeeds to establish the minimum airspeed at which the lateral deviation is less than or equal to 30 ft. V_{MCG} is determined for zero crosswind conditions. However, in light crosswind test conditions the V_{MCG} value determined should be that which is appropriate to the adverse crosswind or, at the applicant's option, may be corrected to a zero crosswind value using runs made on reciprocal headings.