

(i) Two-engine and three-engine turbopropeller and reciprocating engine powered airplanes; and

(ii) Turbojet powered airplanes without provisions for obtaining a significant reduction in the one-engine-inoperative power-on stall speed;

(2) 1.08 V_{SR} for—

(i) Turbopropeller and reciprocating engine powered airplanes with more than three engines; and

(ii) Turbojet powered airplanes with provisions for obtaining a significant reduction in the one-engine-inoperative power-on stall speed; and

(3) 1.10 times V_{MC} established under § 25.149.

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

(1) V_{2MIN} ;

(2) V_R plus the speed increment attained (in accordance with § 25.111(c)(2)) before reaching a height of 35 feet above the takeoff surface; and

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

(d) V_{MU} is the calibrated airspeed at and above which the airplane can safely lift off the ground, and continue the takeoff. V_{MU} speeds must be selected by the applicant throughout the range of thrust-to-weight ratios to be certificated. These speeds may be established from free air data if these data are verified by ground takeoff tests.

(e) V_R , in terms of calibrated airspeed, must be selected in accordance with the conditions of paragraphs (e)(1) through (4) of this section:

(1) V_R may not be less than—

(i) V_1 ;

(ii) 105 percent of V_{MC} ;

(iii) The speed (determined in accordance with § 25.111(c)(2)) that allows reaching V_2 before reaching a height of 35 feet above the takeoff surface; or

(iv) A speed that, if the airplane is rotated at its maximum practicable rate, will result in a V_{LOF} of not less than 110 percent of V_{MU} in the all-engines-operating condition and not less than 105 percent of V_{MU} determined at the thrust-to-weight ratio corresponding to the one-engine-inoperative condition.

(2) For any given set of conditions (such as weight, configuration, and temperature), a single value of V_R , obtained in accordance with this paragraph, must be used to show compliance with both the one-engine-inoperative and the all-engines-operating takeoff provisions.

(3) It must be shown that the one-engine-inoperative takeoff distance, using a rotation speed of 5 knots less than V_R established in accordance with paragraphs (e)(1) and (2) of this section, does not exceed the corresponding one-engine-inoperative takeoff distance using the established V_R . The takeoff distances must be determined in accordance with § 25.113(a)(1).

(4) Reasonably expected variations in service from the established takeoff procedures for the operation of the airplane (such as over-rotation of the airplane and out-of-trim conditions) may not result in unsafe flight characteristics or in marked increases in the scheduled takeoff distances established in accordance with § 25.113(a).

(f) V_{LOF} is the calibrated airspeed at which the airplane first becomes airborne.

(g) V_{FTO} , in terms of calibrated airspeed, must be selected by the applicant to provide at least the gradient of climb required by § 25.121(c), but may not be less than—

(1) 1.18 V_{SR} ; and

(2) A speed that provides the maneuvering capability specified in § 25.143(h).

(h) In determining the takeoff speeds V_1 , V_R , and V_2 for flight in icing conditions, the values of V_{MCG} , V_{MC} , and V_{MU} determined for non-icing conditions may be used.

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§ 25.109 Accelerate-stop distance.

(a) The accelerate-stop distance on a dry runway is the greater of the following distances:

(1) The sum of the distances necessary to—

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(i) Accelerate the airplane from a standing start with all engines operating to V_{EF} for takeoff from a dry runway;

(ii) Allow the airplane to accelerate from V_{EF} to the highest speed reached during the rejected takeoff, assuming the critical engine fails at V_{EF} and the pilot takes the first action to reject the takeoff at the V_1 for takeoff from a dry runway; and

(iii) Come to a full stop on a dry runway from the speed reached as prescribed in paragraph (a)(1)(ii) of this section; plus

(iv) A distance equivalent to 2 seconds at the V_1 for takeoff from a dry runway.

(2) The sum of the distances necessary to—

(i) Accelerate the airplane from a standing start with all engines operating to the highest speed reached during the rejected takeoff, assuming the pilot takes the first action to reject the takeoff at the V_1 for takeoff from a dry runway; and

(ii) With all engines still operating, come to a full stop on dry runway from the speed reached as prescribed in paragraph (a)(2)(i) of this section; plus

(iii) A distance equivalent to 2 seconds at the V_1 for takeoff from a dry runway.

(b) The accelerate-stop distance on a wet runway is the greater of the following distances:

(1) The accelerate-stop distance on a dry runway determined in accordance with paragraph (a) of this section; or

(2) The accelerate-stop distance determined in accordance with paragraph (a) of this section, except that the runway is wet and the corresponding wet runway values of V_{EF} and V_1 are used. In determining the wet runway accelerate-stop distance, the stopping force from the wheel brakes may never exceed:

(i) The wheel brakes stopping force determined in meeting the requirements of §25.101(i) and paragraph (a) of this section; and

(ii) The force resulting from the wet runway braking coefficient of friction determined in accordance with paragraphs (c) or (d) of this section, as applicable, taking into account the distribution of the normal load between braked and unbraked wheels at the most adverse center-of-gravity position approved for takeoff.

(c) The wet runway braking coefficient of friction for a smooth wet runway is defined as a curve of friction coefficient versus ground speed and must be computed as follows:

(1) The maximum tire-to-ground wet runway braking coefficient of friction is defined as:

| <u>Tire Pressure (psi)</u> | <u>Maximum Braking Coefficient (tire-to-ground)</u> |
|----------------------------|--|
| 50 | $\mu_{t/g_{MAX}} = -0.0350 \left(\frac{V}{100}\right)^3 + 0.306 \left(\frac{V}{100}\right)^2 - 0.851 \left(\frac{V}{100}\right) + 0.883$ |
| 100 | $\mu_{t/g_{MAX}} = -0.0437 \left(\frac{V}{100}\right)^3 + 0.320 \left(\frac{V}{100}\right)^2 - 0.805 \left(\frac{V}{100}\right) + 0.804$ |
| 200 | $\mu_{t/g_{MAX}} = -0.0331 \left(\frac{V}{100}\right)^3 + 0.252 \left(\frac{V}{100}\right)^2 - 0.658 \left(\frac{V}{100}\right) + 0.692$ |
| 300 | $\mu_{t/g_{MAX}} = -0.0401 \left(\frac{V}{100}\right)^3 + 0.263 \left(\frac{V}{100}\right)^2 - 0.611 \left(\frac{V}{100}\right) + 0.614$ |

Where—

Tire Pressure=maximum airplane operating tire pressure (psi);

$\mu_{t/g_{MAX}}$ =maximum tire-to-ground braking coefficient;

V=airplane true ground speed (knots); and

Linear interpolation may be used for tire pressures other than those listed.

(2) The maximum tire-to-ground wet runway braking coefficient of friction must be adjusted to take into account the efficiency of the anti-skid system on a wet runway. Anti-skid system operation must be demonstrated by flight testing on a smooth wet runway, and its efficiency must be determined. Unless a specific anti-skid system efficiency is determined from a quantitative analysis of the flight testing on a smooth wet runway, the maximum tire-to-ground wet runway braking coefficient of friction determined in paragraph (c)(1) of this section must be multiplied by the efficiency value associated with the type of anti-skid system installed on the airplane:

| Type of anti-skid system | Efficiency value |
|--------------------------|------------------|
| On-Off | 0.30 |
| Quasi-Modulating | 0.50 |

| Type of anti-skid system | Efficiency value |
|--------------------------|------------------|
| Fully Modulating | 0.80 |

(d) At the option of the applicant, a higher wet runway braking coefficient of friction may be used for runway surfaces that have been grooved or treated with a porous friction course material. For grooved and porous friction course runways, the wet runway braking coefficient of friction is defined as either:

(1) 70 percent of the dry runway braking coefficient of friction used to determine the dry runway accelerate-stop distance; or

(2) The wet runway braking coefficient defined in paragraph (c) of this section, except that a specific anti-skid system efficiency, if determined, is appropriate for a grooved or porous friction course wet runway, and the maximum tire-to-ground wet runway braking coefficient of friction is defined as:

Tire Pressure (psi)

Maximum Braking Coefficient (tire-to-ground)

$$\begin{aligned}
 50 \quad \mu_{t/GMAX} &= 0.1470 \left(\frac{V}{100}\right)^5 - 1.050 \left(\frac{V}{100}\right)^4 + 2.673 \left(\frac{V}{100}\right)^3 - 2.683 \left(\frac{V}{100}\right)^2 + 0.403 \left(\frac{V}{100}\right) + 0.859 \\
 100 \quad \mu_{t/GMAX} &= 0.1106 \left(\frac{V}{100}\right)^5 - 0.813 \left(\frac{V}{100}\right)^4 + 2.130 \left(\frac{V}{100}\right)^3 - 2.200 \left(\frac{V}{100}\right)^2 + 0.317 \left(\frac{V}{100}\right) + 0.807 \\
 200 \quad \mu_{t/GMAX} &= 0.0498 \left(\frac{V}{100}\right)^5 - 0.398 \left(\frac{V}{100}\right)^4 + 1.140 \left(\frac{V}{100}\right)^3 - 1.285 \left(\frac{V}{100}\right)^2 + 0.140 \left(\frac{V}{100}\right) + 0.701 \\
 300 \quad \mu_{t/GMAX} &= 0.0314 \left(\frac{V}{100}\right)^5 - 0.247 \left(\frac{V}{100}\right)^4 + 0.703 \left(\frac{V}{100}\right)^3 - 0.779 \left(\frac{V}{100}\right)^2 - 0.00954 \left(\frac{V}{100}\right) + 0.614
 \end{aligned}$$

Where—

Tire Pressure=maximum airplane operating tire pressure (psi);

$\mu_{t/GMAX}$ =maximum tire-to-ground braking coefficient;

V=airplane true ground speed (knots); and Linear interpolation may be used for tire pressures other than those listed.

(e) Except as provided in paragraph (f)(1) of this section, means other than wheel brakes may be used to determine the accelerate-stop distance if that means—

(1) Is safe and reliable;

(2) Is used so that consistent results can be expected under normal operating conditions; and

(3) Is such that exceptional skill is not required to control the airplane.

(f) The effects of available reverse thrust—

(1) Shall not be included as an additional means of deceleration when determining the accelerate-stop distance on a dry runway; and

(2) May be included as an additional means of deceleration using recommended reverse thrust procedures when determining the accelerate-stop

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distance on a wet runway, provided the requirements of paragraph (e) of this section are met.

(g) The landing gear must remain extended throughout the accelerate-stop distance.

(h) If the accelerate-stop distance includes a stopway with surface characteristics substantially different from those of the runway, the takeoff data must include operational correction factors for the accelerate-stop distance. The correction factors must account for the particular surface characteristics of the stopway and the variations in these characteristics with seasonal weather conditions (such as temperature, rain, snow, and ice) within the established operational limits.

(i) A flight test demonstration of the maximum brake kinetic energy accelerate-stop distance must be conducted with not more than 10 percent of the allowable brake wear range remaining on each of the airplane wheel brakes.

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§ 25.111 Takeoff path.

(a) The takeoff path extends from a standing start to a point in the takeoff at which the airplane is 1,500 feet above the takeoff surface, or at which the transition from the takeoff to the en route configuration is completed and V_{FTO} is reached, whichever point is higher. In addition—

(1) The takeoff path must be based on the procedures prescribed in § 25.101(f);

(2) The airplane must be accelerated on the ground to V_{EF} , at which point the critical engine must be made inoperative and remain inoperative for the rest of the takeoff; and

(3) After reaching V_{EF} , the airplane must be accelerated to V_2 .

(b) During the acceleration to speed V_2 , the nose gear may be raised off the ground at a speed not less than V_R . However, landing gear retraction may not be begun until the airplane is airborne.

(c) During the takeoff path determination in accordance with paragraphs (a) and (b) of this section—

(1) The slope of the airborne part of the takeoff path must be positive at each point;

(2) The airplane must reach V_2 before it is 35 feet above the takeoff surface and must continue at a speed as close as practical to, but not less than V_2 , until it is 400 feet above the takeoff surface;

(3) At each point along the takeoff path, starting at the point at which the airplane reaches 400 feet above the takeoff surface, the available gradient of climb may not be less than—

(i) 1.2 percent for two-engine airplanes;

(ii) 1.5 percent for three-engine airplanes; and

(iii) 1.7 percent for four-engine airplanes.

(4) The airplane configuration may not be changed, except for gear retraction and automatic propeller feathering, and no change in power or thrust that requires action by the pilot may be made until the airplane is 400 feet above the takeoff surface; and

(5) If § 25.105(a)(2) requires the takeoff path to be determined for flight in icing conditions, the airborne part of the takeoff must be based on the airplane drag:

(i) With the takeoff ice accretion defined in appendix C, from a height of 35 feet above the takeoff surface up to the point where the airplane is 400 feet above the takeoff surface; and

(ii) With the final takeoff ice accretion defined in appendix C, from the point where the airplane is 400 feet above the takeoff surface to the end of the takeoff path.

(d) The takeoff path must be determined by a continuous demonstrated takeoff or by synthesis from segments. If the takeoff path is determined by the segmental method—

(1) The segments must be clearly defined and must be related to the distinct changes in the configuration, power or thrust, and speed;

(2) The weight of the airplane, the configuration, and the power or thrust must be constant throughout each segment and must correspond to the most critical condition prevailing in the segment;

(3) The flight path must be based on the airplane's performance without ground effect; and

(4) The takeoff path data must be checked by continuous demonstrated