CHAPTER 1. GENERAL

1. SECTION 23.1 (as amended by amendment 23-34) APPLICABILITY.

a. Explanation.

(1) Airplane Categories. Section 23.1(a) is introductory and prescribes the airplane categories eligible for certification under Part 23. Applicants should refer to Part 21 of the FAR for certification procedures.

(2) Design Data. Section 23.1(b) requires an applicant to demonstrate compliance by some acceptable means even though the FAA has previously certificated an identical alteration for someone else and has the supporting data on file. Design data submitted with an application for certification is not releasable to the public or any other applicant without the consent of the data holder. This decision is based upon exemption 4 of 5 U.S.C. 552(b) (Freedom of Information Act), as implemented by Part 7 of DOT Regulations, § 7.59 (49 CFR), as amended March 28, 1972 (37 F.R. 6315) and July 11, 1972 (37 F.R. 13552). FAA Order 1200.23, paragraph 35, also discusses the subject.

b. Procedures. None.

2.-5. RESERVED.

CHAPTER 2. FLIGHT
Section 1. GENERAL

6. SECTION 23.21 (original issue) PROOF OF COMPLIANCE.

a. Explanation.

(1) Determining Compliance. This section provides a degree of latitude for the FAA test team in selecting the combination of tests or inspections required to demonstrate compliance with the regulations. Engineering tests are designed to investigate the overall capabilities and characteristics of the airplane throughout its operating envelope and should include sufficient combinations of weight, center of gravity, altitude, temperature, airspeed, etc., necessary to define the envelope and show compliance within. Testing should be sufficiently rigorous to define the limits of the entire operating envelope and establish compliance with the regulations at these points. If compliance cannot be established between these points, additional testing should be conducted to determine compliance. Testing should confirm normal and emergency procedures, performance information, and operating limitations that are to be included in the Airplane Flight Manual (AFM).

(2) Flight Tests. Section 21.35 requires, in part, that the applicant make flight tests and report the results of the flight tests prior to official FAA Type Inspection Authorization (TIA) testing. After the applicant has submitted sufficient data to the FAA showing that compliance can be met, the FAA will conduct any inspections, flight, or ground tests required to verify the applicant's test results. Compliance may be based on the applicant's engineering data, and a spot check or validation through FAA flight tests. The FAA testing should obtain validation at critical combinations of proposed flight variables if compliance cannot be established using engineering judgment from the combinations investigated.

(3) Use of Ballast. Ballast may be carried during the flight tests whenever it is necessary to achieve a specific weight and center of gravity (c.g.) location. Consideration should be given to the vertical as well as horizontal location of the ballast in cases where it may have an appreciable effect on the flying qualities of the airplane. The strength of the supporting structures should be considered to preclude their failure as a result of the anticipated loads that may be imposed during the particular tests.

(4) Flight Test Tolerances. The purpose of the tolerances specified in § 23.21(b) is to allow for variations in flight test values from which data are acceptable for reduction to the value desired. They are not intended for routine test scheduling at the lower weights, or to allow for compliance to be shown at less than the critical condition; nor are they to be considered as allowable inaccuracy of measurement (such as in an airspeed calibration). Where variation in the parameter on which a tolerance is allowed will have an effect on the results of the test, the result should be corrected to the most critical value of that parameter within the operating envelope being approved. If such a correction is impossible or impractical, the average test conditions should assure that the measured characteristics represent the actual critical value.

(5) Following are additional tolerances that are acceptable:

Item	Tolerance
Airspeed	3 knots or ±3%, whichever is greater
Power	±5%
Wind (takeoff and landing tests)	As low as possible but not to exceed approximately 12% V_{S1} or 10 knots, whichever is lower, along the runway measured at a height of 6 feet above the runway surface. At higher wind velocities, the data may be unreliable due to wind variations and non-smooth flight conditions.

(6) The following list indicates cases in which corrections to a standard value of the parameter are normally allowed:

Test	Weight	Density	Power	Airspeed	Other
Takeoff Performance	X	X	X	X	Wind, runway gradient
Landing Performance	X	X	--	X	Wind, runway gradient
Stall Speed	X	--	--	--	
Climb Performance	X	X	X	X	Acceleration
V_{MC}	--	X	X	--	

b. Procedures.

(1) Test Plan. Efforts should begin early in the certification program to provide assistance to the applicant to ensure coverage of all certification requirements. The applicant should develop a test plan which includes the required instrumentation.

(2) Instrument Calibration. Test instrumentation (transducers, indicators, etc.) should be calibrated (removed from the airplane and bench checked by an approved method in an approved facility) within 6 months of the tests. When electronic recording devices are used, such as oscillographs, data loggers, and other electronic data acquisition devices, preflight and postflight parameter recalibrations should be run for each test flight to ensure that none of the parameters have shifted from their initial zero settings. Critical transducers and indicators for critical tests (for example, airspeed indicators and pressure transducers for flight tests to V_D) should be calibrated within 60 days of the test in addition to the other requirements mentioned above. The instrument hysteresis should be known; therefore, readings at suitable increments

should be taken in both increasing and decreasing directions. Calibration records, like the one shown below, should be signed by the agent of the repair or overhaul facility doing the work and be available to the test pilot prior to beginning test flying. It should be emphasized that these calibrations must be accomplished in a manner and at a facility approved by the ACO. For example, using a leak checker to "calibrate" an airspeed indicator, whether in or out of the airplane, is not acceptable.

SAMPLE PORTION OF AIRSPEED INDICATOR CALIBRATION

XYZ INSTRUMENT SERVICE, INC.
ABC CITY AIRPORT
FAA-APPROVED REPAIR STATION - NO. 1234

8/12/80
P/N 1701DX8-04
S/N AF55-17044

A/S Ind. KNOTS

Master Test	Ascent Indicator Reads	Descent Indicator Reads
40	38.0	39.0
50	49.0	50.5
60	59.5	61.0
70	70.0	71.0
80	80.0	81.0

(3) Use of Ballast.

(i) Loading. Ballast loading of the airplane can be accomplished in a number of ways to achieve a specific weight and c.g. location as long as the loading remains within the physical confines of the airplane. In flight test work, loading problems will occasionally be encountered making it difficult to obtain the desired c.g. location. Those cases may require loading in engine compartments or other places not designed for load carrying. When this condition is encountered, care should be taken to ensure that local structural stresses are not exceeded or that airplane flight characteristics are not changed due to changes in moments of inertia caused by adding a very long arm (tail post, etc.).

(ii) Solid and Liquid Ballast. There are basically two types of ballast that may be used in airplane loading: solid or liquid. The solids are usually high-density materials such as lead or sandbags, while the liquid is usually water. In critical tests, the ballast should be loaded in a manner so that disposal in flight can be accomplished and be located at a point which will produce a significant c.g. shift forward when jettison takes place. In any case, the load should be securely attached in its loaded position. In airplanes with multiple fuel tank arrangements, the fuel load and distribution should be considered for weight and c.g. control.

7. SECTION 23.23 (as amended by amendment 23-17) LOAD DISTRIBUTION LIMITS.

a. Explanation.

(1) C.G. Envelope. The test tolerance of +7% of the total c.g. range (given in § 23.21) is intended to allow some practical relief for inflight c.g. movement. This relief is only acceptable when the test data general scatter is about the limiting c.g. or when c.g. correction from test c.g. to limit c.g. is acceptable. Sufficient points inside the desired weight and balance envelope should be explored to ensure that the operational pilot will not be placed in an unsafe condition. Should unsatisfactory handling qualities be present, the limits of the envelope should be drawn in to ensure safe margins.

(2) Narrow Utility C.G. Envelope. Some utility category airplanes, for which spin approval is sought, may have a very narrow c.g. range. If a limited fuel load is required to achieve the narrow c.g. envelope, the test pilot should ensure that loading instructions or aids (such as fuel tank tabs) will enable the operational pilot to stay in the approved c.g. envelope.

(3) Gross Weight Effects. The test pilot is expected to determine the effect that gross weight, including low-fuel state, may have on the airplane's flight characteristics. If it is found the flight characteristics would be adversely affected, tests should be performed for trim, stability, and controllability including V_{MC}, stalls, and spins under the most adverse weight condition. Separate loading restrictions may apply to certain flight operations, such as spins.

(4) Lateral Loads. If a weight and center of gravity combination is permissible only within certain lateral load distribution limits which could be exceeded inadvertently, such limits shall be established together with the corresponding weight and center of gravity combinations, and should not exceed any of the following:

(i) The limits selected by the applicant;

(ii) the limits for which the structure has been proven; or

(iii) the limits for which compliance with all the applicable flight requirements has been demonstrated. The demonstrated weight and c.g. combinations should consider asymmetric fuel loadings.

b. Procedures. None.

8. SECTION 23.25 (as amended by amendment 23-34) WEIGHT LIMITS.

a. Explanation.

(1) Maximum Weight Limits. The maximum weight may be limited in three ways: at the election of the applicant, by structural design requirements, or by flight requirements.

(2) Maximum Weight Exceptions. The regulations concerning design maximum weight allows an exception in that some of the structural requirements may be met at a lesser weight known as a design landing weight which is defined in § 23.473. Also, see Advisory Circular (AC) 23-7 if the airplane is being modified for an increase in maximum weight. The flight requirements also allow an exception to the design maximum weight to the degree described in appendix E to Part 23 of the FAR, which deals with airplanes equipped with standby power rocket engines.

(3) Weight, Altitude, Temperature (WAT). For turbine-powered multiengine normal, utility, and acrobatic category airplanes, a WAT offload chart may be used as a maximum weight limitation, if the high altitude and high temperature requirement of §§ 23.65(c), 23.67(c)(2), or 23.77(b) limits the maximum weight. The performance weight limitations for commuter category airplanes are specified in § 23.1583(c)(3).

(4) Ramp Weight. The applicant may elect to use a "ramp weight" provided compliance is shown with each applicable section of Part 23 of the FAR. Ramp weight is the takeoff weight at brake release plus an increment of fuel weight consumed during engine start, taxiing, and runup. Generally, this increment of fuel should not exceed 1% of the maximum permissible flight weight. The pilot should be provided a means to reasonably determine the airplane gross weight at brake release for takeoff. A fuel totalizer is one way of providing the pilot with fuel on board. Alternately, a mental calculation by the pilot may be used, if the pilot is provided the information to make the calculation and the calculation is not too complex. Normally, fuel for engine start and runup will be sufficiently close to a fixed amount that taxi can be considered as the only variable. If the pilot is provided with taxi fuel burn rate in lbs./minute, then the resulting mental calculation is acceptable. The pilot will be responsible to ensure that the takeoff gross weight limitation is complied with for each takeoff, whether it be limited by altitude, temperature, or other criteria. The maximum ramp weight should be shown as a limitation on the Type Certificate (TC) Data Sheet and in the AFM.

(5) Lowest Maximum Weight. Based on an FAA General Counsel decision of August 1977, §§ 23.25(a)(2)(i) and 23.25(a)(2)(ii) require that each of the two conditions, (i) and (ii), must be considered and that the maximum weight, as established, not be less than the weight under either condition.

b. Procedures. None.

9. SECTION 23.29 (as amended by amendment 23-21) EMPTY WEIGHT AND CORRESPONDING CENTER OF GRAVITY.

a. Explanation.

(1) Fixed Ballast. Fixed ballast refers to ballast that is made a permanent part of the airplane as a means of controlling the c.g.

(2) Equipment List. Compliance with § 23.29(b) may be accomplished by the use of an equipment list which defines the installed equipment at the time of weighing and the weight, arm, and moment of the equipment.

b. Procedures. For prototype and modified test airplanes, it is necessary to establish a known basic weight and c.g. position (by weighing) from which the extremes of weight and c.g. travel required by the test program may be calculated. See AC 91-23A, Pilot's Weight and Balance Handbook, for sample weight and balance procedure. Normally, the test crew will verify the calculations.

10. SECTION 23.31 (as amended by amendment 23-13) REMOVABLE BALLAST.

a. Explanation. This regulation is associated only with ballast which is installed in certificated airplanes under specified conditions. The ballasting of prototype airplanes so that flight tests can be conducted at certain weight and c.g. conditions is covered under § 23.21, paragraph 6, of this AC.

b. Fluid Cargo. For those airplanes configured to carry fluid cargo (such as agricultural chemical tanks, minnow tanks, slurry tanks, etc.), airplane handling qualities should be investigated with full and the most critical partial fluid loads. Also, when so equipped, the effects of in-flight jettison or dumping of the fluid load should be evaluated.

11. SECTION 23.33 (original issue) PROPELLER SPEED AND PITCH LIMITS.

a. General. Section 23.33(a) requires that propeller speed and pitch be limited to values that will ensure safe operation under normal operating conditions.

b. Procedures. Assuming that both the tachometer and the airspeed indicator system of the test airplane have been calibrated within the past 30 days and that the best rate of climb speed is known, the following appropriate tests should be conducted:

(1) Fixed Pitch Propellers.

(i) Maximum Revolutions per Minute (R.P.M.). The regulation is self-explanatory.

(ii) Static R.P.M. Determine the average static r.p.m. with the airplane stationary and the engine operating at full throttle under a no-wind condition. The mixture setting should be the same as used for maximum r.p.m. determination. If the wind is light (5 knots or less), this static r.p.m. can be the average obtained with a direct crosswind from the left and a direct crosswind from the right.

(iii) Data Sheet R.P.M. Determination. For fixed pitch propellers, the static r.p.m. range is listed in the TC Data Sheet; for example, not more than 2200 r.p.m. and not less than 2100 r.p.m. The allowable static r.p.m. range is normally established by adding and subtracting 50 r.p.m. to an average no-wind static r.p.m. An applicant may desire to obtain approval for one or more additional propellers and retain only one r.p.m. range statement. An applicant may also choose to extend the propeller's static r.p.m. range.

(A) Lower R.P.M. The static r.p.m. range may be extended on the low side by obtaining approval for a propeller with a lower static r.p.m. In this case, the approval must be accomplished with due consideration of performance requirements. The airplane with the new propeller installed must be able to meet the minimum climb performance requirements.

(B) Higher R.P.M. If the static r.p.m. range is to be extended upward, the new propeller would have to be tested to ensure that it did not cause an engine speed above 110% of maximum continuous speed in a closed throttle dive at the never-exceed speed. It must not exceed the rated takeoff r.p.m. of the engine up to and including the best rate of climb speed of the airplane. An engine cooling climb test may also be required due to the additional power produced by the faster turning propeller.

(2) Controllable Pitch Propellers Without Constant Speed Controls.

(i) Climb R.P.M. With the propeller in full low pitch, determine that the maximum r.p.m. during a climb using maximum power at the best rate of climb speed does not exceed the rated takeoff r.p.m. of the engine.

(ii) Dive R.P.M. With the propeller in full high pitch, determine that the closed throttle r.p.m. in a dive at the never-exceed speed is not greater than 110% of the rated maximum continuous r.p.m. of the engine.

(3) Controllable Pitch Propellers With Constant Speed Controls.

(i) Climb R.P.M. With the propeller governor operative and prop control in full high r.p.m. position, determine that the maximum power r.p.m. does not exceed the rated takeoff r.p.m. of the engine during takeoff and climb at the best rate of climb speed.

(ii) Static R.P.M. With the propeller governor made inoperative by mechanical means, obtain a no-wind static r.p.m. Determine that the maximum power static r.p.m., with the propeller blade operating against the low pitch stop, does not exceed 103% of the rated takeoff r.p.m. of the engine. Although this rule references manifold pressure, it has been considered to be applicable to turbopropeller installations. Propellers that go to feather when the governor is made inoperative need not be tested.

(iii) Safe Operation Under Normal Operating Conditions.

(A) Reciprocating Engines. Descent at V_{NE} or V_{MO} with full power, although within the normal operating range, is not a normal operating procedure. Engine r.p.m., with propeller on the high pitch blade stops, that can be controlled by retarding the throttle may be considered as acceptable in showing compliance with § 23.33(a).

(B) Turbopropeller Engines. Perform a maximum r.p.m. at maximum torque (or power) descent at V_{MO} to ensure that overspeed does not exceed the engine/propeller manufacturer's limits.

(4) Data Acquisition and Reduction. The observed r.p.m. data in each case must be corrected for tachometer error. The airspeed system error must also be taken into consideration to determine the proper calibrated airspeed. True airspeed may also need to be considered because propeller angle of attack is a function of true airspeed.

12.-15. RESERVED.

Section 2. PERFORMANCE

16. SECTION 23.45 (as amended by amendment 23-34) GENERAL.

a. Explanation.

(1) Atmospheric Standards. The purpose of § 23.45(a) is to set the atmospheric standards in which the performance requirements should be met. The air should be smooth with no temperature inversions, mountain waves, etc. This is essential to obtaining good data and repeatable results. Nonstandard conditions of temperature, pressure, etc., can be corrected to standard, but there are no corrections to compensate for poor quality data due to turbulence or poor pilot technique. A thorough knowledge of the limitations of the testing procedures and data reduction methods is essential so that good engineering judgment may be used to determine the acceptability of any tests.

(i) Normal, Utility, and Acrobatic Category Airplane. Performance tests will normally be conducted in nonstandard atmospheric conditions, but ideally for accuracy in data reduction and expansion, tests should be conducted in still air and atmospheric conditions as near those of a standard atmosphere as possible. Accounting for winds and nonstandard conditions requires testing procedures and data reduction methods that reduce the data to still air and standard atmospheric conditions.

(ii) Commuter Category Airplanes. Performance tests should be conducted in the range of atmospheric conditions that will show compliance with the selected weight, altitude, and temperature limits. See paragraph 19 of this AC for guidance on extrapolation of takeoff data and paragraph 27 for extrapolation of landing data.

(2) Standard Atmosphere. The standard atmosphere is defined in Part 1 of the FAR as the U.S. Standard Atmosphere, 1962 (geopotential altitude tables). The U.S. Standard Atmosphere is identical to the International Civil Aviation Organization (ICAO) Standard Atmosphere for altitudes below 65,000 feet. Appendix 7, figure 1, gives properties of the U.S. Standard Atmosphere in an abbreviated format.

(3) Installed Power. The installed propulsive horsepower/thrust of the test engine(s) may be determined using the applicable method described in appendix 1. The methods in appendix 1 account for installation losses and the power absorbed by accessories and services. Consideration should also be given to the accuracy of the power setting instruments/systems, and the pilot's ability to accurately set the power/thrust.

(4) Flight Test Data. For calibrated engines, test day power would be the calibrated test day power. For uncalibrated engines, an acceptable method is to assume that the test day power is the upper tolerance chart brake horsepower. See appendix 1 for further discussion. The performance data required by § 23.1587 is dependent on the horsepower assumed for the various temperature and altitude conditions. Refer to appendix 1, which deals both with test data reduction and expansion.

(5) Humidity Correction. See appendix 1.

b. Procedures. See appendix 1.

c. Time Delays. The reasonable time delays, required by § 23.45f(5)(iii), for different procedures are covered in respective sections, such as accelerate-stop and landing.

17. SECTION 23.49 (as amended by amendment 23-21) STALLING SPEED.

a. Explanation.

(1) 61 Knot Stall Speed. The 61 knot (70 m.p.h.) stalling speed applies to the maximum takeoff weight for which the airplane is to be certificated.

(2) Background. Since many of the regulations pertaining to performance, handling qualities, airspeed indicator markings, and other variables which are functions of stall speeds, it is desirable to accomplish the stall speed testing early in the program, so the data are available for subsequent testing. Because of this interrelationship between the stall speeds and other critical performance parameters, it is essential that accurate measurement methods and careful piloting techniques be used. Most standard airplane pitot-static systems have not been found to be acceptable for stall speed determination. These tests require the use of properly calibrated instruments and usually require a separate test airspeed system, such as a trailing bomb, a trailing cone, or an acceptable nose or wing boom. The stall speed determinations necessary for marking the airspeed indicator are in terms of indicated airspeed (IAS) corrected for instrument error. The other stall speeds are in terms of calibrated airspeed (CAS). Thus, a production airspeed system should be available during stall speed measurements to determine stall speeds in terms of IAS.

(3) Stall Definition. Section 23.49(d) requires the V_{SO} and V_{S1} speeds to be determined using the procedures specified in § 23.201. See Part 1 of the FAR and § 23.49 for definitions of V_{SO} and V_{S1}. Section 23.201(c) defines when the airplane can be considered stalled, for airplane certification purposes. When either of two conditions occurs, whichever occurs first, the airplane is stalled. The conditions are:

(i) Uncontrollable downward pitching motion; or

(ii) the control reaches the stop.

For those airplanes where the control reaches the stop, V_S is considered to be the minimum speed obtained while the control is held against the stop. Elevator limited airplanes may or may not develop a minimum steady flight speed. See figure 17-1 for a graphic representation of stall speed time histories for various configurations. The time the control is held against the stop for stall speed determination should be consistent with the time against the stop for stall characteristics testing (§ 23.201). Additionally, for airplanes with a stall barrier system, stick pusher operation has been considered as the stall speed. The term "uncontrollable downward pitching motion" is the point at which the pitching motion can no longer be arrested by application of nose-up elevator and not necessarily the first indication of nose-down pitch.

(4) Reciprocating Engine Throttle Position. For reciprocating engine airplanes, the stalling speed is that obtainable with the propellers in the takeoff position and the engines idling with throttles closed. As an alternative to "throttles closed," the regulations allow the use of sufficient power to produce zero propeller thrust at a speed not more than 10% above the stalling speed. The regulations do not allow any alternative to the use of "propellers in the takeoff position," nor is any alternative intended except that the use of a feathered propeller in certification stalling speed tests is acceptable only when it has been determined that the resulting stalling speed is conservative (higher). If the stalling speed tests are to be conducted with the propellers delivering zero thrust, some dependable method, such as a propeller slipstream rake, should be available in flight. The practice of establishing zero thrust r.p.m. by calculation is also acceptable. One calculation method is given in subparagraph (5) below. Analytical corrections may be acceptable if satisfactory accounting is made for the effects of propeller efficiency, slipstream, altitude, and other pertinent variables.

(5) Zero-Thrust R.P.M. Calculation.

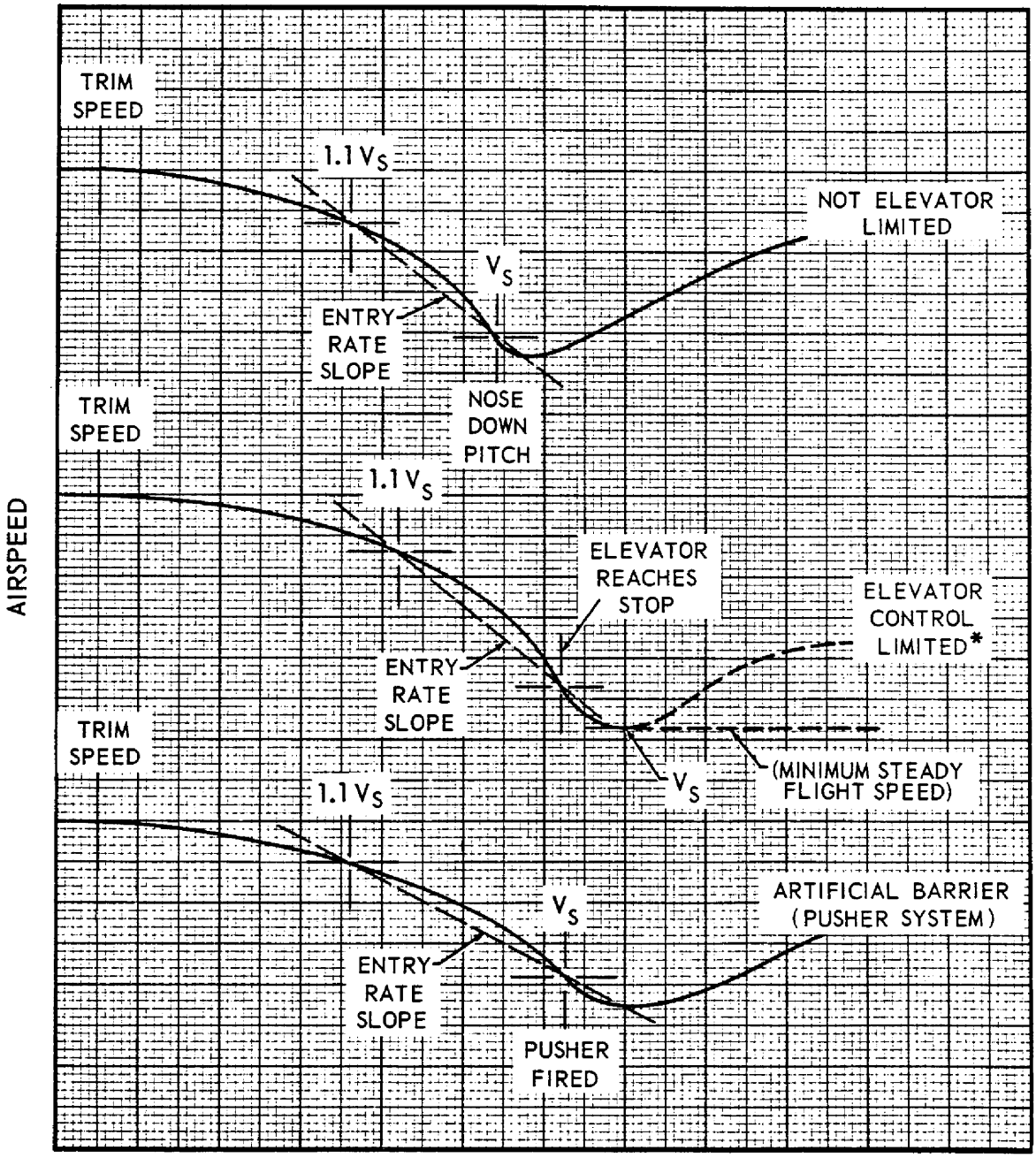
(i) Zero-thrust r.p.m. can be calculated by using the propeller manufacturer's propeller coefficient curves. The thrust will be zero when the propeller thrust coefficient is zero for the particular propeller blade angle. Using the propeller coefficient curves, obtain or construct a chart like figure 17-2.

Where C_T = thrust coefficient

C_p = power coefficient

β = blade angle setting

J = advance ratio



*Airplanes may or may not develop a minimum steady flight speed.

Figure 17-1 - STALL SPEED

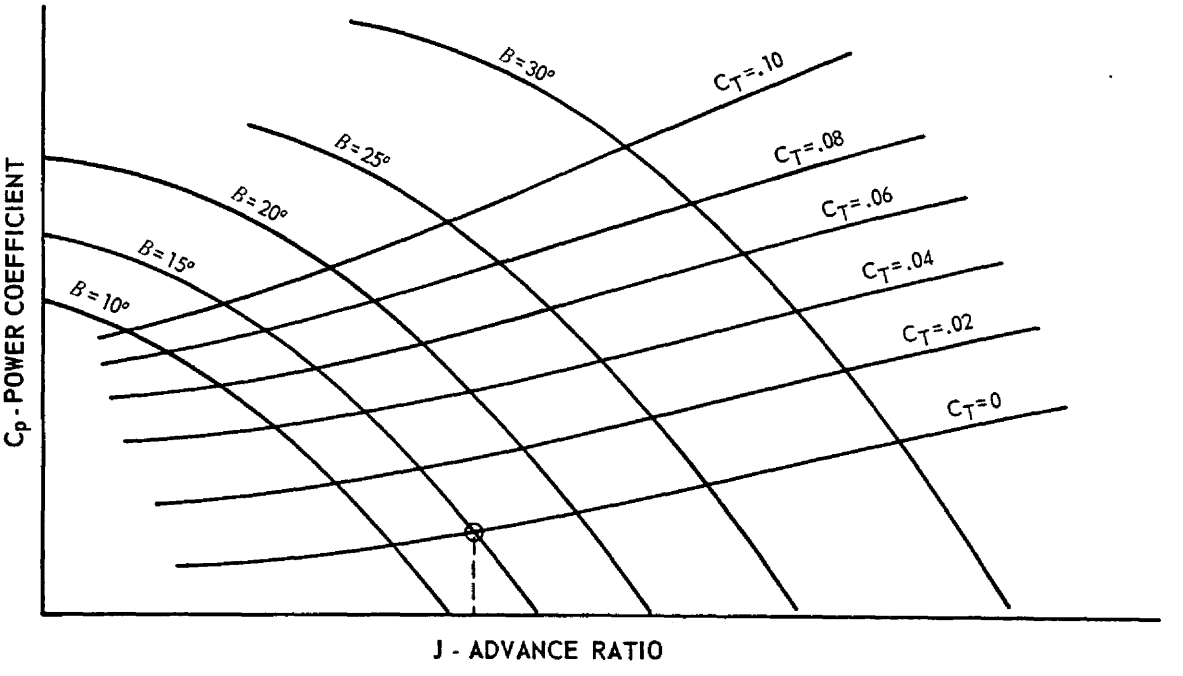


Figure 17-2 - PROPELLER COEFFICIENTS

(ii) The propeller blade is usually against the low pitch stop position, in the speed range of interest. Knowing the blade angle setting, the advance ratio J, can be determined to give zero-thrust for the particular propeller under consideration. Knowing the value of J for zero-thrust, the propeller r.p.m. for various velocities can be calculated as follows:

$$\text{propeller r.p.m.} = \frac{101.27\ V}{JD}$$

Where: V = airplane true airspeed in knots
J = advance ratio
D = propeller diameter in feet

(iii) The calculated velocities and propeller r.p.m. for zero-thrust can be plotted as shown in figure 17-3.

(6) Turbopropeller Thrust. For turbopropeller airplanes, § 23.49(e)(2) requires the propulsive thrust not be greater than zero during stall speed determination, or as an alternative to zero thrust, if idle thrust has no appreciable effect on stall speed, stall speed can be determined with the engines idling. If the airplane has a flight idle position, this would be the appropriate throttle position. Flight test experience has shown that some turbopropeller-powered airplanes may demonstrate a relatively high positive propeller thrust at the stall speed with the engines at flight idle. This thrust condition may yield an unconservative (lower) stall speed. Therefore, just as for piston-powered airplanes, some dependable method to determine zero thrust should be available for comparison of zero thrust stall speed and flight idle stall speed or for

determination of zero thrust stall speed. Residual jet thrust should be considered. Comparisons of zero thrust stall speed and flight idle stall speed should be investigated at high and low altitudes. Use of feathered propellers is acceptable if the feathered stall speeds are found to be conservative (higher).

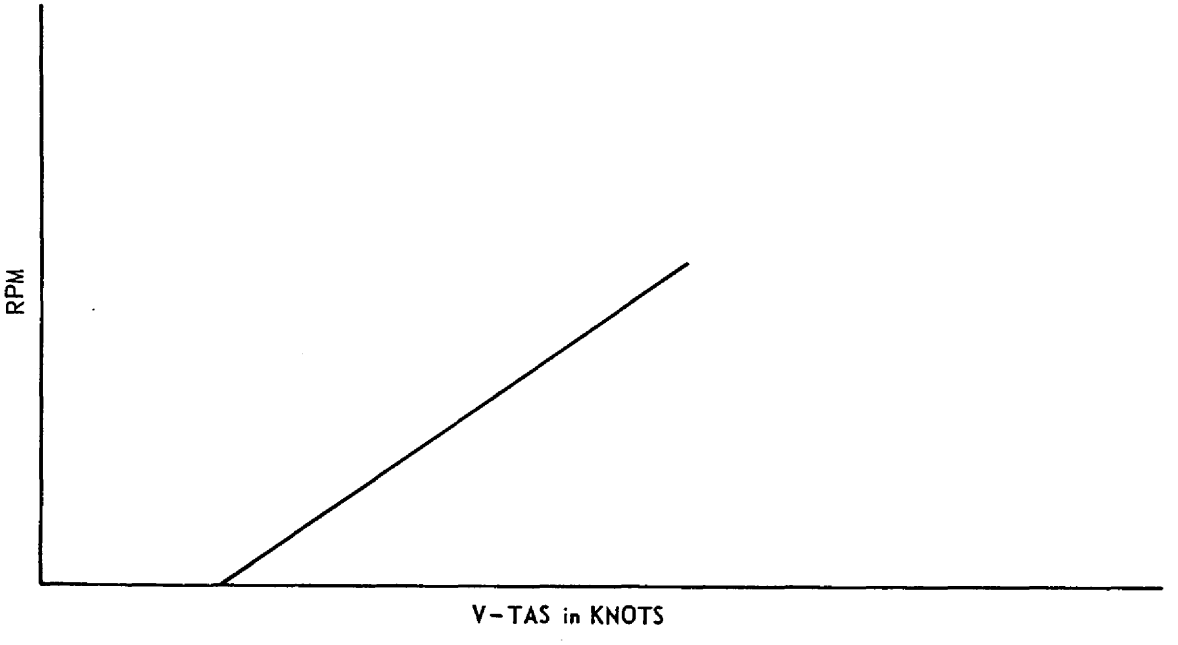


Figure 17-3 - ZERO THRUST

(7) Fixed Shaft Turboprops. Experience on some fixed-shaft turboprop installations indicates that stall speeds can be evaluated at mid-altitudes and appear to be totally conservative. However, if stalls are conducted at altitudes of 5000 feet or below, the stall speed can increase dramatically. This occurs because the propeller drag characteristics are a function of true airspeed, and as true airspeed decreases, the drag goes up substantially and the flow behind the propeller on wing-mounted engines causes premature inboard wing airflow separation. In addition, if the horizontal tail and the elevator are exposed to the same flow, the elevator power is decreased and tends to compound the problem. It is recommended that stall speeds be reevaluated at low altitudes on all fixed shaft turboprops to assure that the stall speeds have not changed significantly.

b. Procedures.

(1) Instrumentation.

(i) Test Systems. As previously mentioned, the production airspeed system is normally not sufficiently predictable or repeatable at high angles-of-attack to accurately measure the performance stall speeds of an airplane. However, a production airspeed system should be installed during stall speed tests to define the airspeed indicator markings required by § 23.1545.

The performance stall speed test system utilized in a type certification program should be calibrated to a minimum speed at least as low as the predicted minimum stall speed anticipated on the test airplane. Test systems that have been utilized to accurately define the performance stall speeds include:

(A) Boom Systems. Swivel-head, boom-mounted, pitot-static systems with sufficient free-swivel angle to cover the stall angle-of-attack range of the airplane have been found to be acceptable. Some angle-of-attack compensated fixed pitot heads have also been found to be acceptable over a wind-tunnel defined angle-of-attack range. In all wing-mounted boom systems, the boom-mounted static source should be at least one chord length ahead of the wing leading edge. On nose-boom mounted systems, it has been generally accepted that the static source should be at least one and one-half fuselage diameters ahead of the nose. All boom systems should be installed in a manner which assures that the boom and boom pitot-static head are structurally sound (both static and dynamic) within the proposed operating range.

(B) Pitot-Static Bombs. Pitot-static bombs that are stable through the stall maneuvers have been found to provide acceptable data.

(C) Trailing Cones. A trailing cone static source dynamically balanced with a swivel head pitot source, or dynamically balanced with a fixed pitot source of proven accuracy in the stall angle-of-attack range has been acceptable. The stability of the cone should be verified during stall tests and throughout its intended operating range. The length of the cone may need to be adjusted on individual airplane installations to assure cone stability.

(ii) Lag Equalization. All of the systems described in paragraph (i) could involve the use of long lengths of pressure tubing and the associated pressure lags then occur whenever speed and/or altitude are changed. Probably the most important consideration in these installations (on most small general aviation airplanes) is that the test pitot-static systems should be dynamically balanced. This is easily accomplished experimentally by putting both the total head and static orifices in a common chamber and varying the pressure in the chamber at a rate corresponding to a 2000 to 3000 feet-per-minute rate of descent. Various volumes are inserted in the total head line until the airspeed indicator has no tendency to move in either direction from zero during the simulated rate of descent. This method results in approximately the same volume in both systems, and for the same size tubing, the Reynolds Number of the flow through both lines will be the same. A dynamically balanced airspeed system has equal lag in both the total and static sides. Use of a balanced system simplifies the interpretation of recorded stall time histories.

(iii) Lag Correction. When a balanced test airspeed system is used, it is often unnecessary to determine the actual amount of lag present. When such a determination is necessary, a method for accounting for lag errors is described in NASA Reference Publication 1046, "Measurement of Aircraft Speed and Altitude," by W. Gracey, May 1980.

(2) Test.

(i) Stall Speed. The actual test should be commenced with the airplane in the configuration desired and trimmed at approximately 1.5 V_{S1} or the minimum speed trim, whichever is greater. The airplane should be slowed to about 10 knots above the stall, at which time the speed should be reduced at a rate of one knot per second or less until the stall occurs or the control reaches the stop. Where exact determination of stalling speed is required, entry rate should be varied to bracket one knot per second, and data should be recorded to allow the preparation of time histories similar to those shown in figure 17-1. The indicated airspeed at the stall should be noted, using the production airspeed system. Both the indicated airspeeds and the calibrated stall speeds may then be plotted versus entry rate to determine the one knot per second values.

(ii) Bomb. When using a bomb, caution should be used in recovering from the stall so that the bomb is not whipped off the end of the hose.

(iii) Weight and C.G. The stalling speed should be determined at all weight and c.g. positions defining the corners of the loading envelope. Data should be recorded so that the weight and c.g. at the time of the test can be accurately determined. This can often be done by recording the time of takeoff, time of test, time of landing, and total fuel used during the flight.

(iv) Power and Configuration. The stall should be repeated enough times for each configuration to ensure a consistent speed. If a correction is to be made for zero thrust, then the stall speed and power at several power settings may be recorded for later extrapolation to zero thrust.

(v) Control Stops. The elevator up stop should be set to the minimum allowable deflection. Flap travels should be set to minimum allowable settings.

(3) Data Reduction. The correction involves:

(i) Correction for airspeed error - IAS to CAS (correct for instrument as well as position error) when CAS is required.

(ii) Correction for weight - multiply the test calibrated stall speed times the square root of the standard weight divided by the test weight.

$$V_S = V_{st}\sqrt{\frac{W_s}{W_t}}$$

Where V_S = Stall speed (CAS)

V_{st} = Test stall speed (CAS)

W_s = Standard weight (lbs.)

W_t = Test weight (lbs.)

(CAUTION -- Do not use for minimum steady flight speed)

(iii) The correction for weight shown above applies only where the c.g. is not also changing with weight. Where c.g. is changing with weight, such as between forward regardless and forward gross, stall speed should account for this. A straight line variation between the measured stall speeds for the two weight and c.g. conditions has been found to be an acceptable method.

18. SECTION 23.51 (as amended by amendment 23-21) TAKEOFF - NORMAL, UTILITY, AND ACROBATIC CATEGORY AIRPLANES.

a. Explanation.

(1) Objective of Takeoff Requirement. The primary objective of the takeoff requirement is to establish, for information of the operator, a takeoff distance within which the airplane may be expected to achieve a speed and height sufficient to ensure capability of performing all maneuvers that may become necessary for safe completion of the takeoff, and for safe landing if necessitated by power failure. An airspeed margin above stall in conjunction with a height of 50 feet is presumed to assure the desired maneuvering capability.

(2) Multiengine 50-foot Speed. For multiengine airplanes, § 23.51(c)(1) requires the speed at the 50-foot point to be the higher of:

(i) 1.1 V_{MC}, or

(ii) 1.3 V_{S1}, or any lesser speed, down to V_X + 4 knots.

(3) Single Engine 50-foot Speed. For single-engine airplanes, § 23.51(c)(2) requires the speed at the 50-foot point to be:

(i) 1.3 V_{S1}, or

(ii) any lesser speed, down to V_X + 4 knots.

(4) Takeoff Speed Investigations - General.

(i) For those airplanes in which the takeoff distance is based on the 1.3 V_{S1} speed corresponding to maximum takeoff weight, no further consideration of the acceptability of such speed is generally necessary, except for investigating the handling characteristics with maximum approved fuel unbalance.

(ii) Specific investigations for acceptability of the takeoff speed should be made for all airplanes for which the takeoff distance is based on a speed less than the 1.3 V_{S1} speed. Investigation of the acceptability of the takeoff speed, and of the associated takeoff procedure, should include a demonstration that controllability and maneuverability in the takeoff configuration are adequate to safely proceed with the takeoff in turbulent crosswind conditions and maximum approved lateral fuel unbalance.

(5) Single-engine Airplane Takeoff Speeds. The takeoff speed investigation should include demonstration that controllability and maneuverability following engine failure at any time between lift-off and the 50-foot point are adequate for safe landing. Applicants are encouraged to schedule both a rotation speed and a speed for 50-foot height. If a single speed has been chosen for lift-off and climb-out to 50-foot height, the resulting airplane deck angle may be too high to successfully accomplish a safe landing.

(6) Multiengine Airplane Takeoff Speeds. For multiengine airplanes, the investigation should include a demonstration that the controllability and maneuverability following critical engine failure at any time between lift-off and the 50-foot point are adequate for either safe landing or for safe continuation of the takeoff. There will be some combinations of weight, altitude, and temperature where positive climb at the 50-foot height with one engine inoperative is not possible. Because of this, a satisfactory re-land maneuver should be demonstrated. Applicants are encouraged to schedule both a rotation speed and a speed for 50-foot height. Rotation speed should be scheduled so that V_{LOF} is not less than V_{MC}, in accordance with § 23.51(b). If a single speed has been chosen for lift-off and climb-out to 50-foot height, the resulting airplane deck angle may be too high to successfully accomplish a safe landing.

(7) Multiple Takeoff Weights. For those multiengine airplanes for which takeoff distance data are to be approved for a range of weights, and for which the takeoff distance is based upon takeoff speeds which decrease as the weight decreases, the investigations of paragraph 4 of this section also should include consideration of the minimum control speed, V_{MC}. The 1.2 V_S design limit imposed on V_{MC} by § 23.149 is intended to provide a controllability margin below the takeoff speed that is sufficient for adequate control of the airplane in the event of engine failure during takeoff. Hence, to maintain the intended level of safety for the lower takeoff speeds associated with the lighter takeoff weights, investigation of the acceptability of such speeds for compliance with § 23.51(c)(1) should include demonstration of acceptable characteristics following engine failure at any time between lift-off and the 50-foot point during takeoff in accordance with the established takeoff procedures.

(8) Complete Engine Failure. The term, "complete engine failure," as used in § 23.51(c)(1), was defined in the preamble to amendment 23-21. The pertinent portion of the preamble is as follows:

> ". . . current section 23.51(a)(2)(ii) has been consistently interpreted to require that for multi-engine airplanes which meet the powerplant isolation requirements of section 23.903(c) in the takeoff configuration, only one engine need be made inoperative in the specified investigations."

(9) AFM Takeoff Distance. Section 23.1587(a)(5) requires the takeoff distance determined under § 23.51 to be furnished in the AFM. Section 23.1587(a)(8) further requires the calculated approximate effect of altitude from sea level to 8000 feet and temperature from ISA - 60°F to ISA + 40°F be furnished in the AFM. Propulsive thrust available should be accounted for in accordance with § 23.45 and appendix 1 of this AC. For turbine-powered airplanes, distances should be presented up to the maximum takeoff temperature limit. A data expansion method appropriate to the airplane's features should be used.

(10) AFM Takeoff Technique. For multi-engine airplanes, § 23.1585(c)(4) requires the AFM to furnish the procedures for the § 23.51 takeoff. The recommended technique that is published in the AFM and used to achieve the performance should be one that the operational pilot can duplicate using the minimum amount of type design cockpit instrumentation and the minimum crew.

(11) Tire Speed Limits. If TSO'd tires are used, it should be determined that, within the weight, altitude, and temperature for which takeoff performance is shown in § 23.1587, that the TSO tire speed ratings are not exceeded at V_{LOF}. If the tire speed rating would be exceeded under some combinations of weight, altitude, and temperature, then the tirespeed limit should be established as an operating limitation, and a maximum takeoff weight limited by tire speed chart should be included in the AFM performance section in compliance with § 23.1581(a)(2).

b. Procedures.

(1) Takeoff Distance Tests. The takeoff distance should be established by test, and may be obtained either by takeoffs conducted as a continuous operation from start to the 50-foot height, or synthesized from acceleration segments and climb segment(s) determined separately. Recording theodolite or electronic equipment that is capable of providing horizontal distance and velocity, and height above the takeoff surface, is highly desirable for takeoff distance tests. Additional required special ground equipment includes a sensitive anemometer capable of providing wind velocity and direction, a thermometer capable of providing accurate free-air temperature under all conditions, and an altimeter or barograph to provide pressure altitude.

(2) Segment Technique. For the segment technique, the airplane should be accelerated on the surface from brake release to rotation speed (V_R) and on to the speed selected for the 50-foot height point. Six acceptable runs are recommended to establish the takeoff acceleration segment. V_R should be selected so that the 50-foot speed can be achieved. A climb segment based on the rate of climb, free of ground effect, is added to the acceleration segment. See paragraph 25 of this AC and appendix 2 for climb performance methods. Total distance is the sum of the acceleration segment plus the climb segment. For AFM presentation, the ground run would be the ground acceleration distance to V_{LOF}, and the air distance would be the horizontal distance to climb at the 50-foot speed for 50 feet plus the ground acceleration distance from V_{LOF} to the 50-foot speed. For those airplanes with retractable gear, the landing gear should be extended throughout, or alternatively, retraction may be initiated at a speed corresponding to a safe speed for gear retraction following lift-off in normal operations. If takeoff distance is determined using the "segmented" method, actual takeoffs using the AFM takeoff speed schedule should be conducted to verify that the actual takeoff distance to the 50-foot height does not exceed the calculated takeoff distance to the 50-foot height.

(3) Weight. Takeoff distance tests should be conducted at the maximum weight, and at a lesser weight if takeoff distance data for a range of weights is to be approved. The test results may be considered acceptable without correction for weight if a $\pm$0.5% weight tolerance is observed.

(4) Nosewheel/Tailwheel. In the absence of evidence to the contrary, the "critical" c.g. position for takeoff distance tests may be assumed to be forward.

(5) Wind. Wind velocity and direction should be measured adjacent to the runway during the time interval of each test run. See paragraph 6a(5) of this AC for wind velocity and direction tolerances. For the ground run portion of the segment technique, the following relationship was developed empirically and is an acceptable method for correction of low wind conditions:

$$S_g = S_{gw} \left(1 \pm \frac{V_w}{V_{tow}} \right) 1.85$$

Where: S_g = no-wind takeoff ground distance (feet)

S_{gw} = takeoff ground distance at a known wind velocity (feet)

V_w = wind velocity (feet/second)

V_{tow} = true ground speed at lift-off with a known wind velocity (feet/second)

+ is used for headwind and - for tailwind

Wind, then slope corrections should be applied before further data reduction.

(6) Runway Slope. The effect of runway gradient can be significant for heavy airplanes or for low thrust-to-weight ratio airplanes even if the gradient of the runway is small. Gradient should be controlled by proper runway selection. The correction is:

$$S_G = \frac{S_{G_{sl}}}{1 \pm \left(\frac{2gS_{G_{sl}}}{V_{to}^2} \right) \sin \theta}$$

Where: $S_{G_{sl}}$ = ground distance on a sloping runway

g = acceleration of gravity, 32.17 ft./sec^2

V_{to} = airplane velocity at lift-off in ft./sec. (true)

θ = angle of the slope in degrees (not percent)

+ for upslope and - for downslope

19. SECTION 23.51 (as amended by amendment 23-34) TAKEOFF - COMMUTER CATEGORY AIRPLANES.

a. Objective of Takeoff Requirement. Section 23.51(d) requires that performance be determined that provides accountability for the selected operating weights, altitudes, ambient temperatures, configurations, and corrected for various wind and runway gradient conditions.

b. Takeoff Profile. Tests are required to determine the performance throughout the takeoff path as specifically defined by §§ 23.53 through 23.59 and as discussed in paragraphs 20 through 23 of this AC.

c. Expansion of Takeoff Data for a Range of Airport Elevations.

(1) These guidelines are applicable to expanding takeoff data above the altitude at which the basic or verifying tests were obtained.

(2) In general, takeoff data may be extrapolated above and below the altitude at which the basic test data was obtained without additional conservatism within the following constraints.

(3) When the basic takeoff tests are accomplished between sea level and approximately 3000 feet, the maximum allowable extrapolation limits are 6000 feet above and 3000 feet below the test field elevation. If it is desired to extrapolate beyond these limits, one of two procedures may be employed.

(i) Extrapolation of Performance Data for a Range of Altitudes When Verifying Tests are Not Conducted. The approval of performance data for airport elevations beyond the maximum elevation permitted by basic tests may be allowed without conducting verirying tests if the calculated data include a conservative factor. This conservatism should result in an increase of the calculated takeoff distance at the desired airport elevations by an amount equal to zero percent for the highest airport elevation approved on the results of the basic tests and an additional cumulative 2 percent incremental factor for each 1000 feet of elevation above the highest airport elevation approved for zero percent conservatism. The 2 percent incremental factor should have a straight line variation with altitude. When performance data are calculated for the effects of altitude under this procedure, the following provisions are applicable:

(A) Previously established calculation procedures should be used, taking into account all known variables.

(B) The calibrated installed engine power for the pertinent speed and altitude ranges should be used.

(C) The brake kinetic energy limits established by airplane ground tests should not be exceeded.

(ii) Extrapolation of Performance Data When Verifying Tests are Conducted.

(A) If data approval is desired for a greater range of airport elevations, the performance may be calculated from the basic test data up to the maximum airport elevation, provided verifying tests are conducted at appropriate elevations to substantiate the validity of the calculations. The actual airplane performance data from the verifying tests should correspond closely to the calculated performance values.

(B) For the verifying tests, it has been found that normally three takeoffs at maximum weights for the elevations tested will provide adequate verification.

(C) If verifying tests substantiate the expanded takeoff data, the data may be further expanded up to 6000 feet above the altitude at which the verifying tests were conducted. At altitudes higher than 6000 feet above the verifying test altitude, the 2 percent per 1000 feet cumulative factor discussed in paragraph (i) above should be applied starting at zero percent at the verifying test altitude plus 6000 feet.

20. SECTION 23.53 (as added by amendment 23-34) TAKEOFF SPEEDS.

a. Normal, Utility, and Acrobatic Category Airplanes. See applicable subparagraphs of paragraph 18.

b. Commuter Category Airplanes.

(1) Takeoff Speeds. The following speed definitions are given in terms of calibrated airspeed. The AFM presentations, if required, shall be given in terms of calibrated airspeed (reference § 23.1587(d)(6)). Since the aircrew flies indicated airspeed (IAS), critical AFM operating airspeeds should also be presented in IAS.

(i) Section 23.53(a) - Lift-off Speed (V_{LOF}). V_{LOF} is the calibrated airspeed at which the airplane first becomes airborne.

(ii) Section 23.53(c)(3) - Engine Failure Speed V_{EF}. The engine failure speed (V_{EF}) is defined as the calibrated airspeed at which the critical engine is assumed to fail and must be selected by the applicant. V_{EF} cannot be less than the minimum control speed (V_{MC}) as described in § 23.149. Ground controllability should also be determined to be adequate at V_{EF} to ensure meeting the requirments of § 23.53(c)(1), i.e., speed adequate to safely continue the takeoff. During the demonstration, the airplane should not deviate more than 30 feet from the pre-engine-cut projected ground track. At the applicant's option, in crosswind conditions, the runs may be made on reciprocal headings or an analytical correction may be applied to determine the zero crosswind deviation. If nosewheel steering is an integral part of the rudder system and is required to be operative, then nosewheel steering may be active. Otherwise, control of the airplane should be accomplished by use of the rudder only. All other controls, such as ailerons and spoilers, should only be used to correct any alterations in the airplane attitude and to maintain a wings level condition. Use of those controls to supplement the rudder effectiveness should not be used.

(iii) Section 23.53(c)(1) - Takeoff Decision Speed (V_1). The takeoff decision speed (V_1) may not be less than V_{EF} plus the speed gained with the critical engine inoperative during the time interval between V_{EF} and the instant at which the pilot recognizes the engine failure. This is indicated by pilot application of the first decelerating device such as brakes, throttles, spoilers, etc., during accelerate-stop tests. The applicant may choose the sequence of events. Also, V_1 may not be less than 1.1 V_{MC} or 1.1 V_{S1}. Refer to § 23.55 for a more complete description of refused takeoff (RTO) transition procedures and associated time delays. V_1 should include any airspeed system errors determined during accelerate-takeoff ground runs. Refer to the requirements of § 23.1323(c).

(iv) Section 23.53(c)(2) - Takeoff Safety Speed (V_2). V_2 is the calibrated airspeed that is attained at or before 35 feet above the takeoff surface after an engine failure at V_{EF} using an established rotation speed (V_R). During the takeoff speed demonstration, V_2 should be continued to an altitude sufficient to assure stable conditions beyond 35 feet. Section 23.53(c)(2) requires V_2 not be less than V_1 or 1.2 V_{S1}. However, V_2 should be V_1 plus the speed rise between V_R and V_2, particularly at light weights. Attainment of V_2 by 35 feet should be substantiated by use of procedures consistent with those which will be experienced in service with an actual engine failure; i.e., if autofeather is required, then autofeather should be activated as an integral part of testing.

(v) Section 23.53(c)(4) - Rotation Speed (V_R).

(A) The rotation speed, (V_R) in terms of in-ground effect calibrated airspeed, must be selected by the applicant. V_R is constrained by § 23.53(c)(4), as follows:

(1) V_R may not be less than V_1; however, it can be equal to V_1.

(2) V_R is a speed that allows the airplane to reach V_2 at or before reaching 35 feet above the takeoff surface.

(B) Early rotation, one-engine inoperative abuse test.

(1) In showing compliance with § 23.53(c)(6), some guidance relative to the airspeed attained at a height of 35 feet during the associated flight test is necessary. As this requirement dealing with a rotation speed abuse test only specifies an early rotation (V_R-5 knots), it is assumed that pilot technique is to remain the same as normally used for an engine-out condition. With these considerations in mind, it is apparent that the airspeed achieved at a height of 35 feet can be somewhat below the normal scheduled V_2 speed. However, the amount of permissible V_2 speed reduction should be limited to a reasonable amount as described in paragraph 20b(1)(v)(B)(2) and (3).

(2) In conducting the flight tests required by § 23.53(c)(6), the test pilot should use a normal/natural rotation technique as associated with the use of scheduled takeoff speeds for the airplane being tested. Intentional tail or tail skid contact is not considered acceptable. Further, the airspeed attained at a height of 35 feet during this test is required to be not less than the scheduled V_2 value minus 5 knots. These speed limits should not be considered or utilized as target V_2 test speeds, but rather are intended to provide an acceptable range of speed departure below the scheduled V_2 value.

(3) In this abuse test, the engine cut should be accomplished prior to the V_R test speed (i.e., scheduled V_R-5 knots) to allow for engine spin-down. The normal one-engine-inoperative takeoff distance may be analytically adjusted to compensate for the effect of the early engine cut. Further, in those tests where the airspeed achieved at a height of 35 feet is slightly less than the V_2-5 knots limiting value, it is permissible, in lieu of reconducting the tests, to analytically adjust the test distance to account for the excessive speed decrement.

(C) All-engines-operating abuse tests.

(1) Section 23.53(c)(7) requires that there not be a "marked increase" in the scheduled takeoff distance when reasonably expected service variations such as early and excessive rotation and out-of-trim conditions are encountered. This is considered as requiring takeoff tests with all engines operating with:

(i) An abuse on rotation speed, and

(ii) out-of-trim conditions but with rotation at the scheduled V_R speed.

NOTE: The expression "marked increase" in the takeoff distance is defined as any amount in excess of 5% of the takeoff distance as determined in accordance with §23.59. Thus, the abuse tests should not result in a takeoff distance of more than 105% of the scheduled takeoff distance.

(2) For the early rotation abuse condition with all engines operating and at a weight as near as practicable to the maximum sea level takeoff weight, it should be shown by test that when the airplane is over-rotated at a speed below the scheduled V_R, no "marked increase" in the takeoff distance will result. For this demonstration, the airplane should be rotated at a speed of 10 knots or 7%, whichever is less, below the scheduled V_R. Tests should be conducted at a rapid rotation rate or should include an over-rotation of 2 degrees above normal attitude after liftoff. Tail strikes, should they occur during this demonstration, are acceptable only if a fault analysis (structural, electrical, hydraulic, etc.) has been accomplished and indicates no possible degradation in the control of aircraft, engines, or essential systems necessary for continued safe flight after a reasonable, worst case tail strike.

(3) For out-of-trim conditions with all engines operating and at a weight as near as practicable to the maximum sea level takeoff weight, it should be shown that with the airplane mistrimmed, as would reasonably be expected in service, there should not be a "marked increase" in the takeoff distance when rotation is initiated in a normal manner at the scheduled V_R speed. For those airplanes with an allowable takeoff trim band, the amount of mistrim used should be with the longitudinal control trimmed to its most adverse position within the allowable takeoff trim band as shown on the cockpit indicator. For those airplanes without an allowable takeoff trim band, the amount of mistrim to be reasonably expected in service will be a pilot judgment.

21. SECTION 23.55 (as added by amendment 23-34) ACCELERATE-STOP DISTANCE.

a. Explanation. This section describes test demonstrations necessary to determine accelerate-stop distances for airplane performance required to be published in the Performance Section of the AFM.

b. Procedures.

(1) Accelerate-stop tests should be determined in accordance with the provisions of this paragraph.

(i) A sufficient number of test runs should be conducted for each airplane configuration desired by the applicant, in order to establish a representative distance that would be required in the event of a rejected takeoff at or below the takeoff decision speed V_1.

(ii) The procedures outlined in paragraph 21b(12), as required by § 23.45(f)(5), apply appropriate time delays for the execution of retarding means related to the accelerate-stop operation procedures and for expansion of accelerate-stop data to be incorporated in the AFM.

(iii) The stopping portion of the accelerate-stop test may not utilize propeller reverse thrust unless the thrust reverser system is shown to be safe, reliable, and capable of giving repeatable results.

NOTE: In past airplane certifications, reverse thrust has not been considered sufficiently safe and reliable to permit accelerate-stop or landing distances to be predicated on its use. This policy will be reviewed when evidence is presented that reverse mechanism reliability is sufficiently high.

(2) Accelerate-stop runs at different airport elevations can be simulated at one airport elevation provided the braking speeds used include the entire energy range to be absorbed by the brakes. In scheduling the data for the AFM, the brake energy assumed should not exceed the maximum demonstrated in these tests.

(3) The braking speeds referred to herein are scheduled test speeds and need not correspond to the values to be scheduled in the AFM, since it is necessary to increase or decrease the braking speed to simulate the energy range and weight envelope.

(4) Number of Runs. At least two test runs are necessary for each configuration when multiple aerodynamic configurations are being shown to have the same braking coefficient of friction, unless sufficient data is available for the airplane model to account for variation of braking performance with weight, kinetic energy, lift, drag, ground speed, torque limit, etc. These runs should be made with the airplane weight and knetic energy varying throughout the range for which takeoff data is scheduled. This will usually require at least six test runs. These tests are usually conducted on hard surfaced, dry runways.

(5) Alternate Approvals. For an alternate approval with antiskid inoperative, nose wheel brakes or one main wheel brake inoperative, autobraking systems, etc., a full set of tests, as mentioned in paragraph 21b(4), should normally be conducted. A lesser number of tests may be accepted for "equal or better" demonstrations, or to establish small increments, or if adequate conservatism is used during testing.

(6) Maximum Energy Stop. A brake energy demonstration is needed to show compliance with the brake energy requirements. A maximum energy stop (or some lesser brake energy) is used to establish a distance that can be associated with the demonstrated kinetic energy. An applicant can choose any level of energy for demonstration providing that the AFM does not show performance beyond the demonstrated kinetic energy. The demonstratration should be conducted at not less than maximum takeoff weight and should be preceded by a 3-mile taxi, including three full stops using normal braking and all engines operating. Propeller pitch controls should be applied in a manner which is consistent with procedures to be normally used in service. Following the stop at the maximum kinetic energy level demonstration, it is not necessary for the airplane to demonstrate its ability to taxi. The maximum kinetic airplane energy at which performance data is scheduled should not exceed the value for which a satisfactory afterstop condition exists or the kinetic energy capacity value documented under Technical Standard Order (TSO) C26c, whichever value is less. A satisfactory afterstop condition is defined as one in which fires are confined to tires, wheels, and brakes, and which would not result in progressive engulfment of the remaining airplane during the time of passenger and crew evacuation. The application of fire fighting means or artificial coolants should not be required for a period of five minutes following the stop.

(7) Maximum Energy Stop from a Landing. In the event the applicant proposes to conduct the maximum energy RTO demonstration from a landing, a satisfactory accounting of the brake and tire temperatures that would have been generated during taxi and acceleration, required by paragraph 21b(6), should be made.

(8) Either ground or airborne instrumentation should include a means to determine the horizontal distance-time history.

(9) Wind Speed. The wind speed and direction relative to the active runway should be determined. The height of the wind measurement should be noted, to facilitate corrections to airplane wing level.

(10) Configurations. The accelerate-stop tests should be conducted in the following configurations:

(i) Heavy to light weight as required.

(ii) Most critical c.g. position.

(iii) Wing flaps in the takeoff position(s).

(iv) Tire pressure: before taxi and with cold tires, set to the highest value appropriate for the takeoff weight for which approval is being sought.

(v) Engine: set r.p.m. at applicant's recommended upper idle power limit, or the effect of maximum idle power may be accounted for in data analyses. Propeller condition should also be considered. See discussion in subparagraph (11), Engine Power.

(11) Engine Power. Engine power should be appropriate to each segment of the rejected takeoff and account for thrust decay times. See discussion of § 23.57(a)(2) in paragraph 22c(1). At the selected speed that corresponds to the required energy, the airplane is brought to a stop employing the acceptable braking means. The critical engine's propeller should be in the position it would normally assume when an engine fails and the power levers are closed. The high drag position (not reverse) of the remaining engines' propellers may be utilized provided adequate directional control can be demonstrated on a wet runway. Simulating wet runway controllability by disconnecting the nose wheel steering may be used. The use of the higher propeller drag position (i.e., ground fine) is conditional on the presence of a throttle position which incorporates tactile feel that can consistently be selected in service by a pilot with average skill. It should be determined whether the throttle motions from takeoff power to this ground fine position are one or two distinctive motions. If it is deemed to be two separate motions, then accelerate-stop time delays should be determined accordingly and applied to expansion of data.

(12) Accelerate-Stop Time Delays. Figure 21-1 is an illustration of the accelerate-stop time delays considered acceptable for compliance with § 23.45:

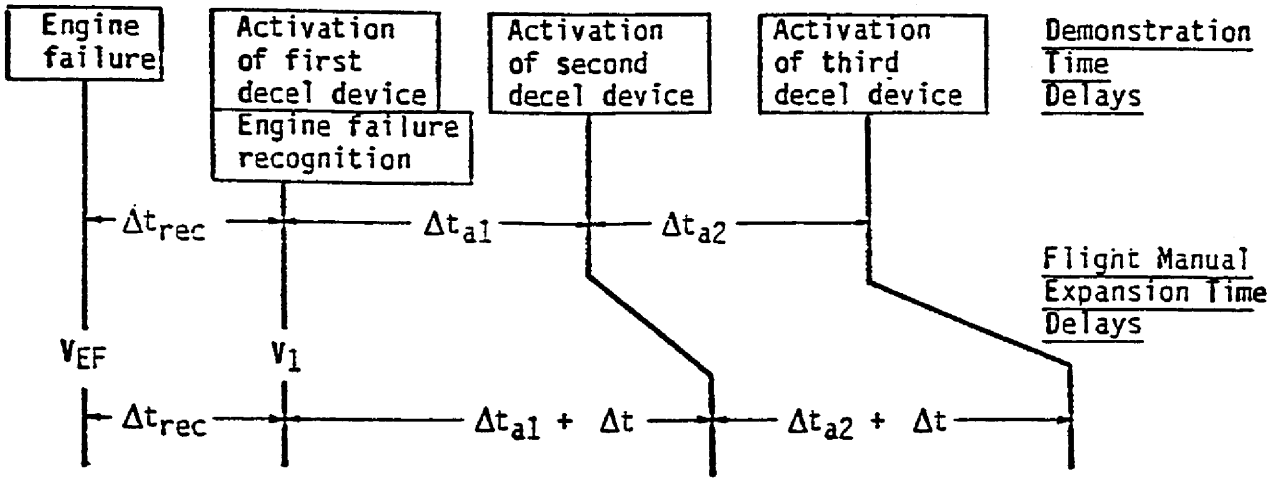


Figure 21-1 - ACCELERATE-STOP TIME DELAYS

(i) Δt_{rec} = engine failure recognition time. The demonstrated time from engine failure to pilot action indicating recognition of the engine failure. For AFM data expansion purposes, it has been found practical to use the demonstrated time or 1 second, whichever is greater, in order to allow a time which can be executed consistently in service.

(ii) Δt_{a1} = the demonstrated time interval between activation of the first and second deceleration devices.

(iii) Δt_{a2} = the demonstrated time interval between activation of the second and third deceleration devices.

(iv) Δt = a 1-second reaction time delay to account for in-service variations. If a command is required for another crewmember to actuate a deceleration device, a 2-second delay, in lieu of the 1-second delay, should be applied for each action. For automatic deceleration devices which are approved for performance credit for AFM data expansion, established times determined during certification testing may be used without the application of additional time delays required by this paragraph.

(v) The sequence for activation of deceleration devices may be selected by the applicant. If, on occasion, the desired sequence is not achieved during testing, the test need not be repeated; however, the demonstrated time interval may be used.

(13) The procedures used to determine accelerate-stop distance should be described in the Performance Information Section of the AFM.

22. SECTION 23.57 (as added by amendment 23-34) TAKEOFF PATH.

a. Section 23.57(a).

(1) Explanation.

(i) The takeoff path requirements of § 23.57 and the reductions required by § 23.61 are established so that the AFM performance can be used in making the necessary decisions relative to takeoff weights when obstacles are present. Net takeoff flight path data should be presented in the AFM for information; however, its use is only required for Part 135 operations (reference FAR 135.398(b)).

(ii) The required performance is provided in the AFM by either pictorial paths at various power-to-weight conditions with corrections for wind, or by a series of charts for each segment along with a procedure for connecting these segments into a continuous path.

(2) Procedures.

(i) Section 23.57(a) requires that the takeoff path extend to the higher of where the airplane is 1500 feet above the takeoff surface or to the altitude at which the transition to en route configuration is complete and a speed is reached at which compliance with § 23.67(e)(2) is shown.

(ii) Section 135.398 requires the airplane not be banked before reaching a height of 50 feet as shown by the net takeoff flight path data.

(iii) The AFM should contain information required to show compliance with the climb requirements of §§ 23.57 and 23.67(e)(2). This should include information related to the transition from the takeoff configuration and speed to the en route configuration and speed. The effects of changes from takeoff power to maximum continuous power should also be included.

(iv) Generally, the AFM shows takeoff paths which at low power to weight include acceleration segments between 400 and 1500 feet and end at 1500 feet, and at high power to weight extending considerably higher than 1500 feet above the takeoff surface. On some airplanes, the takeoff speed schedules and/or flap configuration do not require acceleration below 1500 feet, even at limiting performance gradients.

b. Section 23.57(a)(1) - Takeoff Path Power Conditions.

(1) Explanation. The takeoff path established from continuous demonstrated takeoffs should represent the actual expected performance at all points. If the path is constructed by the segmental method, in accordance with §§ 23.57(d)(2) and 23.57(d)(4), it should be conservative and should be supported by at least one demonstrated fly-out to the completed en route configuration. This is necessary to ensure all required crew actions do not adversely impact the required gradients.

(2) Procedures.

(i) To substantiate that the predicted takeoff path is representative of actual performance, the power used in its construction must comply with § 23.45. This requires, in part, that the power for any particular flight condition be that for the particular ambient atmospheric conditions that are assumed to exist along the path. The standard lapse rate for ambient temperature is specified in Part 1 of the FAR under "Standard Atmosphere" and should be used for power determination associated with each pressure altitude during the climb.

(ii) Section 23.57(c)(4) requires that the power up to 400 feet above the takeoff surface represents the power available along the path resulting from the power lever setting established during the initial ground roll in accordance with AFM procedures. This resulting power should represent the normal expected variations throughout the acceleration and climb to 400 feet and should not exceed the limits for takeoff power at any point.

(iii) A sufficient number of takeoffs, to at least the altitude above the takeoff surface scheduled for V_2 climb, should be made to establish the power lapse resulting from a fixed power lever. An analysis may be used to account for various engine bleeds, e.g., ice protection, air conditioning, etc. In some airplanes, the power growth characteristics are such that less than full rated power is required to be used for AFM takeoff power limitations and performance.

(iv) Engine power lapse with speed and altitude during the takeoff and climb, at fixed power lever settings, may be affected by takeoff pressure altitude.

(v) Most turboprop engines are sensitive to increasing airspeed during the takeoff roll. The applicant's procedure should be evaluated and, if acceptable, the procedure should be reflected in the AFM. The AFM takeoff field length and takeoff power setting charts are based on the approved procedure. Approved procedures should be ones that can be accomplished in service by pilots of normal skill. For example, if a power adjustment is to be made after brake release, the power should be adjustable without undue attention. Only one adjustment is allowed.

(vi) A typical "non-rolling" takeoff procedure is as follows:

(A) After stopping on the runway, adjust all engines to a static takeoff power setting (selected by the applicant).

(B) Release brakes.

(C) Upon reaching 50 to 60 knots, adjust power levers to maintain torque and temperatures within limits. Only one adjustment is allowed.

(vii) A typical "rolling takeoff" procedure is as follows:

(A) Release brakes.

(B) Adjust power levers to takeoff power in a smooth motion.

(C) As speed increases, make a small adjustment as necessary to preclude exceeding torque or temperature limits.

c. Section 23.57(a)(2) - Engine Failure.

(1) Explanation. Propeller thrust/drag characteristics should represent conditions which occur when the engine is actually failed. The power time history used for data reduction and expansion should be substantiated by test results.

(2) Procedures. Sufficient tests should be conducted utilizing actual fuel cuts to establish the propeller thrust decay history.

d. Section 23.57(c)(1) - Takeoff Path Slope.

(1) Explanation. For showing compliance with the positive slope required by § 23.57(c)(1), the establishment of a horizontal segment, as part of the takeoff flight path, is considered to be acceptable, in accordance with § 23.61(c). See figure 24-2. See paragraph 24b(2) for further discussion.

(2) Procedures.

(i) The level acceleration segment in the AFM net takeoff profile should begin at the horizontal distance along the takeoff flight path that the net climb segment reaches the AFM specified acceleration height. See figure 24-2.

(ii) The AFM acceleration height should be presented in terms of pressure altitude increment above the takeoff surface. This information should allow the establishment of the pressure altitude "increment" (Hp) for off-standard ambient temperature so that the geometric height required for obstacle clearance is assured. For example:

Given:

- Takeoff surface pressure altitude (Hp) = 2000 feet
- Airport std. temp. abs. (T_S) = $11^{\circ}C+273.2 = 284.2^{\circ}k$
- Airport ambient temp. abs. (T_{AM}) = $-20^{\circ}C+273.2 = 253.2^{\circ}k$
- ΔGeometric height required ($_{\Delta}h$) = 1500 feet above the takeoff surface

Find:

- Pressure altitude increment (ΔHp) above the takeoff surface
  $\Delta Hp = \Delta h(T_S/T_{AM})$ = 1500 feet ($284.2^{\circ}k/253.2^{\circ}k$)
  ΔHp = 1684 feet

e. Section 23.57(c)(2) - Takeoff Path Speed.

(1) Explanation.

(i) It is intended that the airplane be flown at a constant indicated airspeed to at least 400 feet above the takeoff surface. This speed should meet the constraints on V_2 of § 23.53(c)(2).

(ii) The specific wording of § 23.57(c)(2) should not be construed to imply that above 400 feet the airspeed may be reduced below V_2, but instead that acceleration may be commenced.

(2) Procedures. None.

f. Section 23.57(c)(4) - Configuration Changes.

(1) Explanation.

(i) The intent of this requirement is to permit only those crew actions that are conducted routinely to be used in establishing the engine-inoperative takeoff path. The power levers may only be adjusted early during the takeoff roll, as discussed under § 23.57(a)(1) (paragraph 22b(2)(ii)), and then left fixed until at least 400 feet above the takeoff surface.

(ii) Simulation studies and accident investigations have shown that when heavy workload occurs in the cockpit, as with an engine loss during takeoff, the crew might not advance the operative engines to avoid the ground even if the crew knows the operative engines have been set at reduced power. This same finding applies to manually feathering a propeller. The landing gear may be retracted, because this is accomplished routinely, once a positive rate of climb is observed. This also establishes the delay time to be used for data expansion purposes.

(2) Procedures.

(i) To permit the takeoff to be conducted using less than rated power, automatic power advance devices have been approved. These devices are discussed in a proposed change to Part 23 and various special conditions.

(ii) To permit the takeoff to be based on a feathered propeller up to 400 feet above the takeoff surface, automatic propeller feathering devices have been approved if adequate system reliability has been shown in accordance with § 23.1309. Other automatic systems such as one which minimizes drag of the inoperative propeller by sensing negative torque have also been approved. Drag reduction for a manually feathered propeller is permitted for flight path calculations only after reaching 400 feet above the takeoff surface.

g. Section 23.57(d) - Takeoff Path Construction.

(1) Explanation. This regulation should not be construed to mean that the takeoff path be constructed entirely from a continuous demonstration or entirely from segments. To take advantage of ground effect, typical AFM takeoff paths utilize a continuous takeoff path from V_{LOF} to the gear-up point, covering the range of power-to-weight ratios. From that point, free air performance, in accordance with § 23.57(d)(2), is added segmentally. This methodology may yield an AFM flight path that is steeper with the gear down than up. Section 135.398(e) requires that for net takeoff flight path, the airplane not be banked before reaching a height of 50 feet as shown by the net takeoff flight path. This requires determination of climb data in the wings level condition.

(2) Procedures. The AFM should include the procedures necessary to achieve this performance.

h. Section 23.57(d)(2) - Takeoff Path Segment Conditions.

(1) Explanation. Section 23.57(d)(2) requires that the weight of the airplane, the configuration, and the power setting must be constant throughout each segment and must correspond to the most critical condition prevailing in the segment. The intent is that for simplified analysis, the performance be based on that available at the most critical point in time during the segment, not that the individual variables (weight, approximate power setting, etc.) should each be picked at its most critical value and then combined to produce the performance for the segment.

(2) Procedures. The performance during the takeoff path segments should be obtained using one of the following methods

(i) The critical level of performance as explained in paragraph 22h(1).

(ii) The actual performance variation during the segment.

i. Section 23.57(d)(3) - Segmented Takeoff Path Ground Effect.

(1) Explanation. See explanation under § 23.57(d). Additionally, this requirement does not intend that the entire flight path necessarily be based upon out-of-ground-effect performance simply because the continuous takeoff demonstrations have been broken into sections for data reduction expediency. For example, if the engine-inoperative acceleration from V_{EF} to V_R is separated into a power decay portion and a windmilling drag portion, the climb from 35 feet to gear up does not necessarily need to be based upon out-of-ground-effect performance, as would be indicated by § 23.57(d)(3), if, in fact, the climb from 35 feet to gear up is within ground effect, as defined by § 23.57(d)(5).

(2) Procedures. None.

j. Section 23.57(d)(4) - Segmented Takeoff Path Check.

(1) Explanation. None.

(2) Procedures. If the construction of the takeoff path from brake release to out-of-ground-effect contains any portions that have been segmented (e.g., airplane acceleration segments of all engines and one-engine inoperative), the path should be checked by continuous demonstrated takeoffs. A sufficient number of these, using the AFM established takeoff procedures and speeds and covering the range of power-to-weight ratios, should be made to ensure the validity of the segmented takeoff path. The continuous takeoff data should be compared to takeoff data calculated by AFM data procedures but using test engine power and test speeds.

k. Turboprop Reduced Power Takeoffs.

(1) Reduced takeoff power is a power less than approved takeoff power for which power setting and airplane performance is established by corrections to the approved power setting and performance. When operating with reduced takeoff power, the power setting which establishes power for takeoff is not considered a limitation.

(2) It is acceptable to establish and use a takeoff power setting that is less than the approved takeoff power if

(i) The establishment of the reduced power takeoff data is handled through the type certification process and contained in the AFM.

(ii) The reduced takeoff power setting

(A) Does not result in loss of systems or functions that are normally operative for takeoff such as engine failure warning, configuration warning, autofeather, automatic throttles, rudder boost, automatic ignition, or any other safety-related system dependent upon a minimum takeoff power setting.

(B) Is based on an approved engine takeoff power rating for which airplane performance data is approved.

(C) Does not introduce difficulties in airplane controllability or engine response/operation in the event that approved takeoff power is applied at any point in the takeoff path.

(D) Is at least 75% of the approved takeoff power for the ambient conditions.

(E) Is predicated on a careful analysis of propeller efficiency variation at all applicable conditions.

(iii) Relevant speeds used for reduced power takeoffs are not less than those which will show compliance with the required controllability margins with the approved takeoff power for the ambient conditions.

(iv) The AFM states, as a limitation, that reduced takeoff power settings may not be used

(A) Unless the operator establishes a means to periodically check the availability of approved takeoff power such that deteriorated engines are not used.

(B) When the antiskid system (if installed) is inoperative.

(C) On wet runways and runways contaminated with snow, slush, or ice, unless suitable performance accountability is made to the increased acceleration and stopping distances on these surfaces.

(v) Procedures for reliably determining and applying the reduced takeoff power value are simple, and the pilot is provided with information to obtain both the reduced power and approved takeoff power for each ambient condition.

(vi) The AFM provides adequate information to conduct a power check, using the approved takeoff power.

(vii) Procedures are given to the use of reduced power.

(viii) Application of reduced power in service is always at the discretion of the pilot.

23. SECTION 23.59 (as added by amendment 23-34) TAKEOFF DISTANCE AND TAKEOFF RUN.

a. Takeoff Distance - Section 23.59(a).

(1) Explanation. The takeoff distance is either of the two distances depicted in paragraph 23a(1)(i) or (ii), whichever is greater. The distances indicated below are measured horizontally from the main landing gears at initial brake release to that same point on the airplane when the lowest part of the departing airplane is 35 feet above the surface of the runway and accomplished in accordance with the procedures developed for § 23.57.

(i) The distance measured to 35 feet with a critical engine failure recognized at V_1. See figure 23-1.

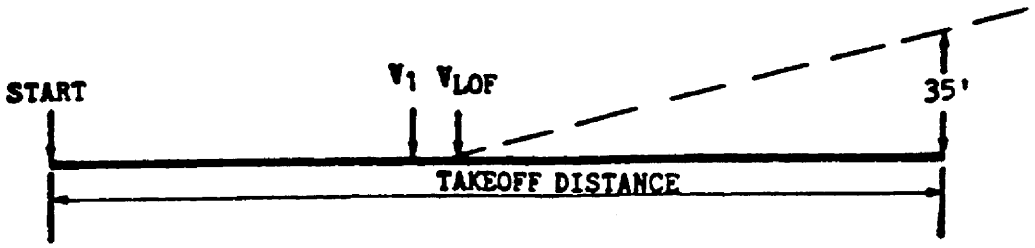


Figure 23-1 - TAKEOFF DISTANCE
Critical Engine Failure Recognized at V_1

(ii) One hundred fifteen percent (115%) of the distance measured to 35 feet with all engines operating. See figure 23-2.

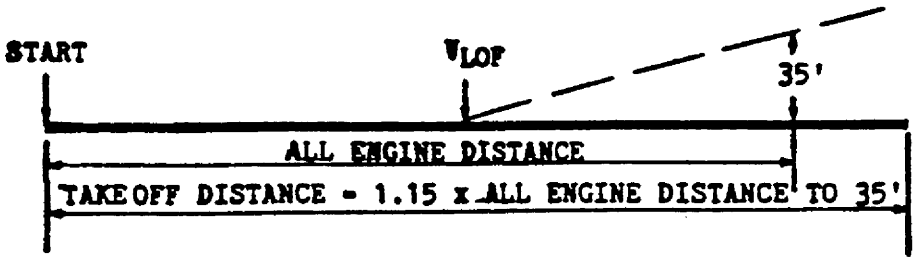


Figure 23-2 - TAKEOFF DISTANCE
All Engines Operating

b. Takeoff Run - Section 23.59(b).

(1) Explanation.

(i) Takeoff run is a term used for the runway length when the takeoff distance includes a clearway (i.e., where the accelerate-go distance does not remain entirely over the runway), and the takeoff run is either of the two distances depicted in paragraph 23b(1)(i)(A) or (B), whichever is greater. These distances are measured as described in § 23.59(a). Clearways are only defined for turbine-powered airplanes. When using a clearway to determine the takeoff run, no more than one-half of the air distance from V_{LOF} to the 35 foot point may be flown over the clearway.

(A) The distance from start of takeoff roll to the mid-point between liftoff and the point at which the airplane attains a height of 35 feet above the takeoff surface, with a critical engine failure recognized at V_1. See figure 23-3.

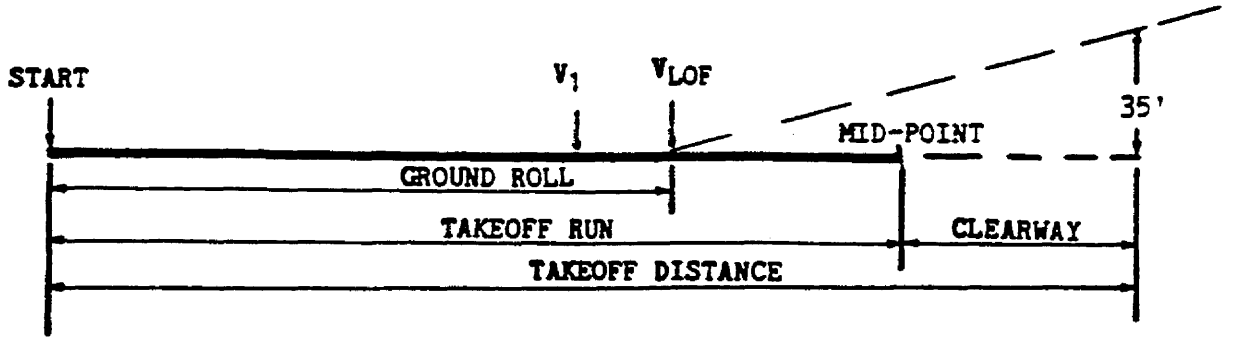


Figure 23-3 - TAKEOFF RUN
Critical Engine Failure Recognized at V_1

(B) One hundred fifteen percent (115%) of the distance from start of roll to the mid-point between liftoff and the point at which the airplane attains a height of 35 feet above the takeoff surface, with all engines operating. See figure 23-4.

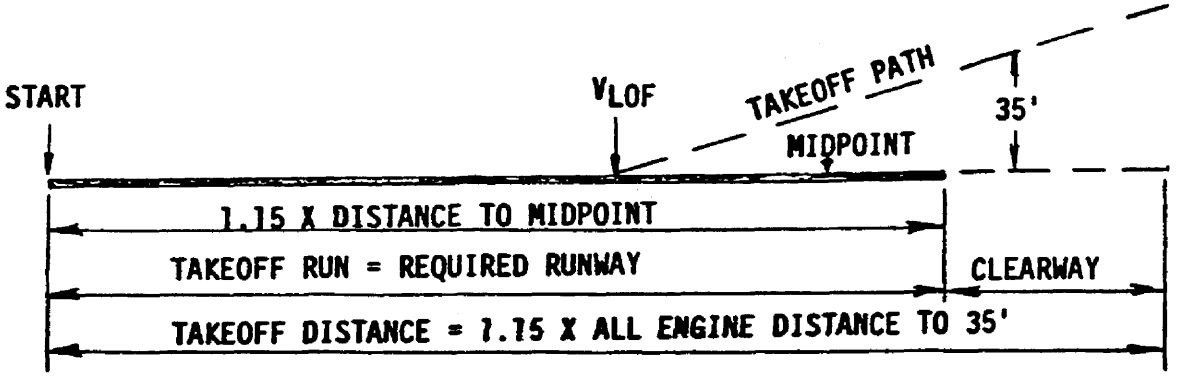


Figure 23-4 - TAKEOFF RUN
All Engines Operating

(ii) There may be situations in which the one-engine-inoperative condition (paragraph 23b(1)(i)(A)) would dictate one of the distance criteria, takeoff run (required runway) or takeoff distance (required runway plus clearway), while the all-engines operating condition (paragraph 23b(1)(i)(B)) would dictate the other. Therefore, both conditions should be considered.

(iii) For the purpose of establishing takeoff distances and takeoff runs, the clearway plane is defined in Part 1 of the FAR for turbine-powered engines. The clearway is considered to be part of the takeoff surface, and a height of 35 feet may be measured from that surface. See figure 23-5.

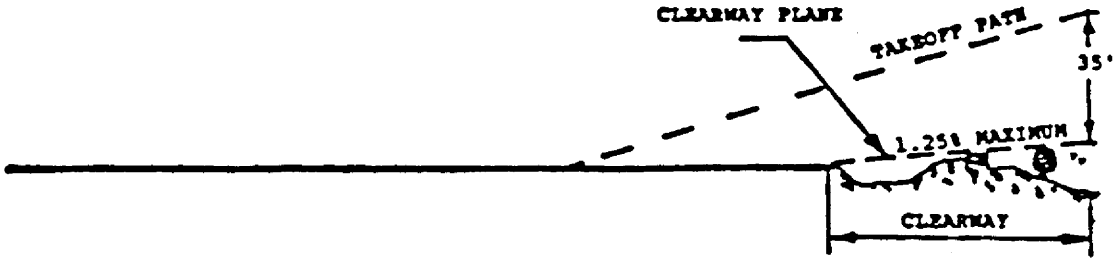


Figure 23-5 - CLEARWAY PROFILES

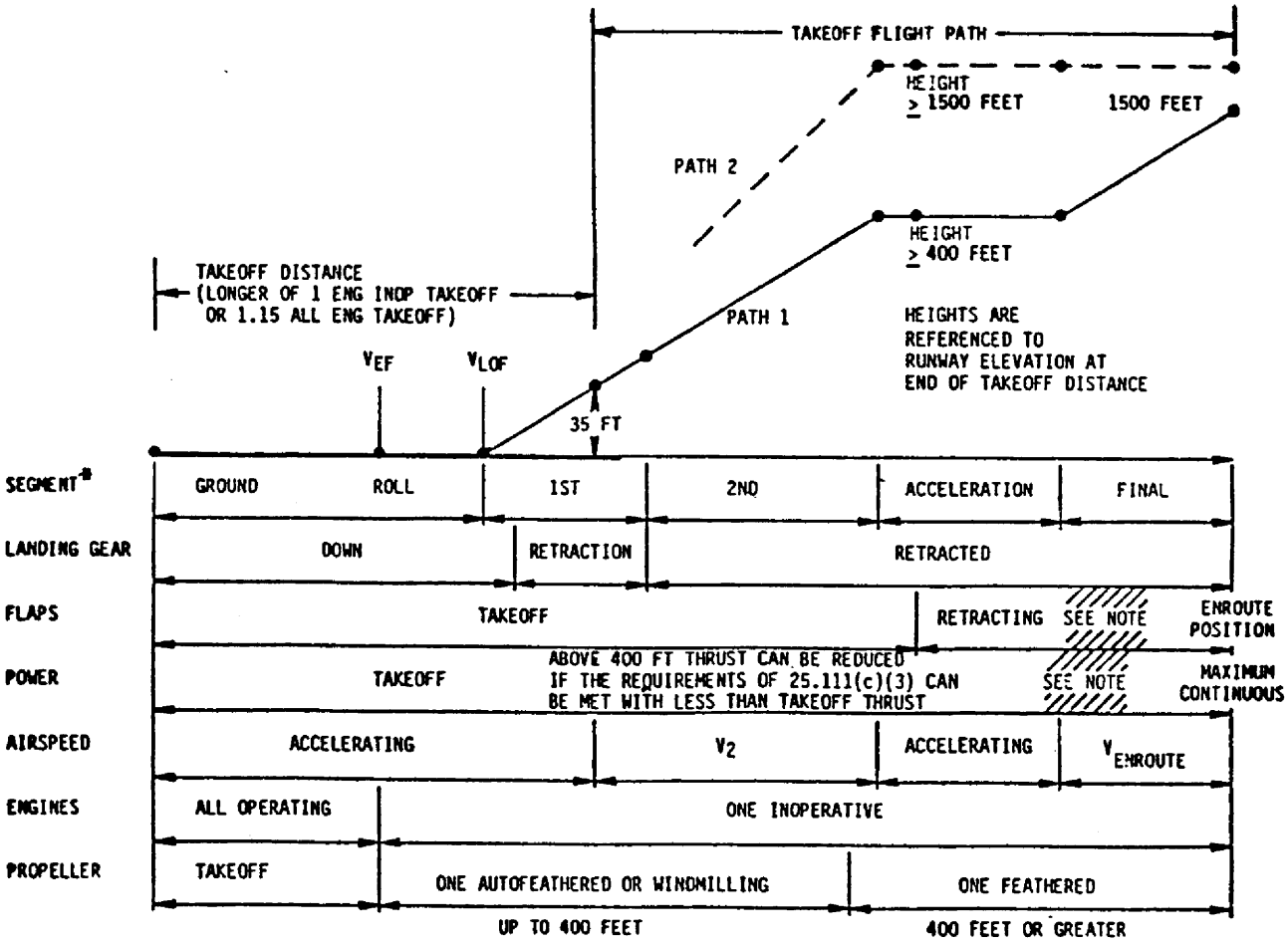
24. SECTION 23.61 (as added by amendment 23-34) TAKEOFF FLIGHT PATH.

a. Takeoff Flight Path - Section 23.61(a). The takeoff flight path begins 35 feet above the takeoff surface at the end of the takeoff distance determined in accordance with § 23.59 and ends when the airplane's height is the higher of 1500 feet above the takeoff surface or at an altitude at which the configuration and speed have been achieved in accordance with § 23.67(e)(2). See figure 24-1.

b. Net Takeoff Flight Path - Section 23.61(b) and (c).

(1) The net takeoff flight path is the actual path diminished by a gradient of 0.8 percent for two-engine airplanes, 0.9 percent for three-engine airplanes, and 1.0 percent for four-engine airplanes. See figure 24-2.

(2) The net takeoff flight path is the flight path used to determine the airplane obstacle clearance for Part 135 operations. Section 23.61(b) states the required climb gradient reduction to be applied throughout the flight path for the determination of the net flight path, including the level flight acceleration segment. Rather than decrease the level flight path by the amount required by § 23.61(b), § 23.61(c) allows the airplane to maintain a level net flight path during acceleration but with a reduction in acceleration equal to the gradient decrement required by § 23.61(b). By this method, the applicant exchanges altitude reduction for increased distance to accelerate in level flight in determination of the level flight portion of the net takeoff path.



NOTE: The en route takeoff segment usually begins with the airplane in the en route configuration and with maximum continuous thrust, but it is not required that these conditions exist until the end of the takeoff path when compliance with § 23.67(e)(2) is shown. The time limit on takeoff thrust cannot be exceeded.

*Segments as defined by § 23.67.

Figure 24-1 - TAKEOFF SEGMENTS AND NOMENCLATURE

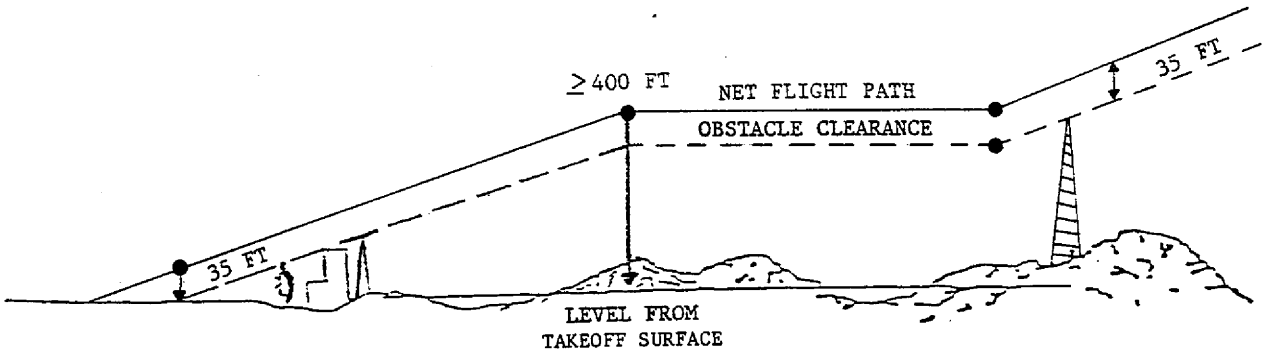


Figure 24-2 - NET TAKEOFF FLIGHT PATH

25. SECTION 23.65 (as amended by amendment 23-34) CLIMB: ALL ENGINES OPERATING.

a. Explanation.

(1) Objectives. The climb tests associated with this requirement are performed to establish the airplane's all-engine performance capability for altitudes between sea level and not less than 8000 feet with wing flaps set to the takeoff position. This is necessary to enable comparison with the minimum climb performance required, and also for AFM presentation of climb performance data of § 23.1587(a)(7) and the effect of altitude and temperature (see § 23.1587(a)(8)) and the effect of weight for commuter category airplanes.

(2) Cooling Climbs. Applicants with single engine reciprocating powered airplanes may vary the climb speeds to meet the requirements of § 23.1047. If variations in climb speeds are required to meet the cooling tests, the applicant may wish to establish the variation of rate of climb with speed.

(3) Sawtooth Climbs. A common method of determining climb performance is sawtooth climbs. A series of climbs, known as sawtooth climbs, should be conducted at several constant indicated airspeeds using a constant power setting and a prescribed configuration. A minimum of three series of sawtooth climbs should be conducted. The mean altitudes through which the sawtooth climbs are conducted should be:

(i) As near sea level as practical.

(ii) Close to the ceiling (where 100 feet/minute can be maintained) for sea level engines.

(iii) An intermediate altitude, taking into consideration the power characteristics of the engine.

b. Procedures - Sawtooth Climbs.

(1) Climb Technique. With the altimeter adjusted to a setting of 29.92 inches Hg (pressure altitude), the series of climbs should be initiated at a chosen altitude. Stabilize airspeed and power prior to recording data. The time at the beginning of each run should be recorded for weight-accounting purposes, and the stabilized climb should be continued for 3 minutes or 3000 feet minimum while holding airspeed substantially constant. Climbs should be conducted 90^{o} to the wind, and alternately, on reciprocal headings to minimize the effects of windshear. Since the rate at which the altitude changes is the primary consideration of the test, particular care should be taken to observe the precise altimeter indication at precise time intervals. Time intervals of not more than 30 seconds are recommended for altimeter readings. Airspeed, ambient temperatures, r.p.m. and other engine power parameters also should be recorded, permissibly at longer intervals. Rates-of-climb/sink observed for test conditions should be greater than $\pm$100 ft./min. Rates of climb near zero tend to be unreliable. A running plot of altitude-versus-time provides an effective means of monitoring acceptability of test data as the run progresses, and a running plot of the observed rate of climb obtained for each airspeed enables similar monitoring of the sawtooth program. This procedure is recommended because of the opportunity it affords for promptly observing and economically rectifying questionable test results.

(2) Air Quality. In order to obtain accurate results, it is essential that the sawtooth climbs be conducted in smooth air. In general, the effects of turbulence are more pronounced in test data obtained at lower rates of climb and, when testing for compliance with minimum climb requirements, even slight turbulence may produce errors in observed climbs of such magnitude as to render the data inconclusive with respect both to rate of climb and best climb speed. Less obvious but equally unacceptable for climb testing is the presence of an inverse gradient in the ambient temperature.

(3) Test Airspeeds. The airspeeds selected for the sawtooth should bracket the best climb speed, which for preliminary purposes may be estimated as 140% of the power-off stalling speed. The lowest climb test speed should be as near the stalling speed as can be flown without evidence of buffeting, or necessity for abnormally frequent or excessive control movements, which might penalize the climb performance. Although the example shown in figure 25-1 has 10 knot intervals, the interval between test speeds should be smaller at the lowspeed end of the range, and should increase as the speed increases. Suggested intervals are 5 knots at the low end, varying to 15 knots at the high end. In addition, the maximum level flight speed and V_S (or V_{MIN}) at the approximate midrange test altitude provide a useful aid in defining the curves in figure 25-2.

(4) Data Plotting. Sawtooth climb data is plotted on a graph using altitude and time as the basic parameters as shown in figure 25-1. After the sawtooth data has been plotted, draw in the mean altitude line. A tangent line can now be drawn to each of the sawtooth climb curves at the mean altitude intersection. By determining the slope of the tangent lines, the observed rate of climb at the mean altitude for each sawtooth can be determined.

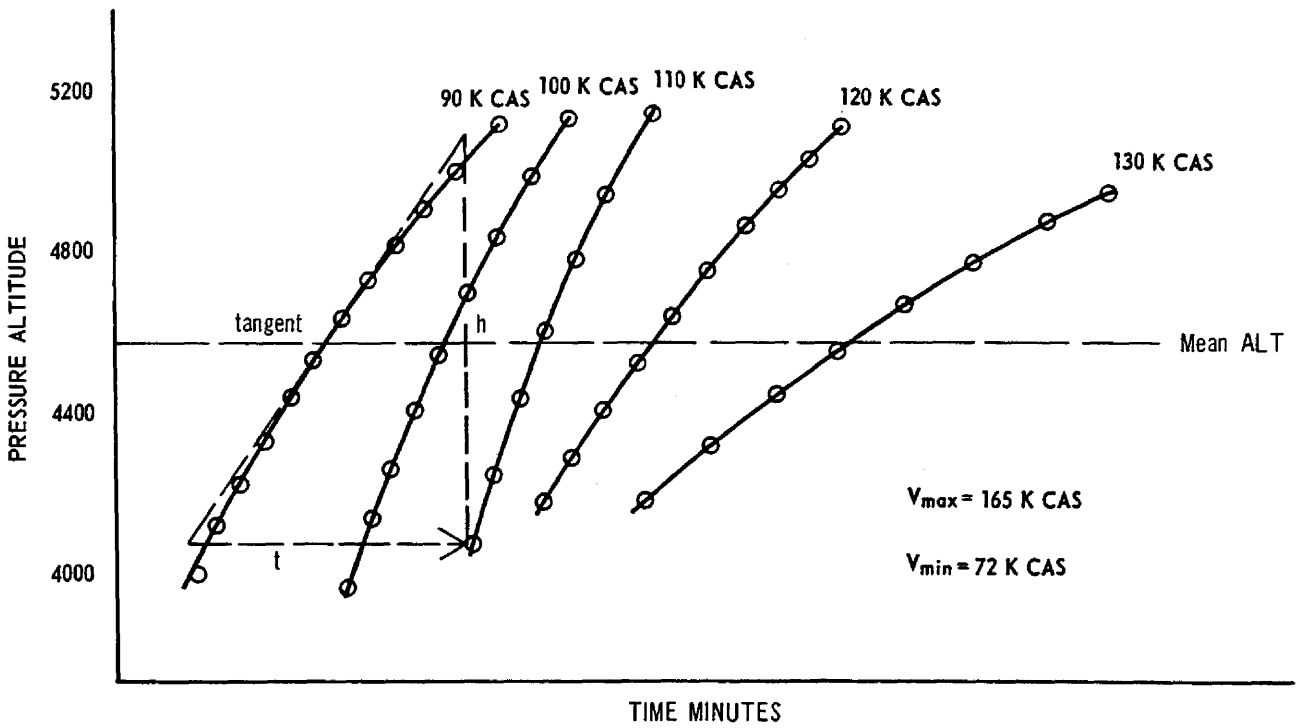


Figure 25-1 - OBSERVED DATA

(5) Data Corrections. For the density altitude method of data reduction (see appendix 2), it is necessary to correct the data to standard atmospheric conditions, maximum weight, and chart brake horsepower before proceeding any further with the observed data. These corrections sometimes change the observed data a significant amount. The maximum level flight speed (V_{MAX}) data points should also be corrected to assist in defining the curves in figure 25-2.

(6) Plotting of Corrected Data. After the observed data has been corrected to the desired standards, it can be plotted as shown in figure 25-2 with the rate of climb versus calibrated airspeed at various density altitudes.

(7) Speed Schedule Data Points. From the curves of figure 25-2, it is now possible to determine the airplane's best rate of climb speed schedule, V_Y. This is done by drawing a straight line through the peaks (highest rate of climb point) of each of the previously drawn curves of R/C vs. CAS. Also, it is possible to obtain from this graph the best angle of climb speed schedule V_X. This is done by drawing tangent lines to the R/C vs. CAS curves from the graph origin and connecting each of the tangent intersect points with a straight line. It should be noted that the V_X and V_Y speed lines intersect at "zero" rate of climb. This is because zero rate of climb occurs at the airplane's absolute ceiling and V_X, V_Y and V_{MIN} and V_{MAX} are all the same speed at this point.

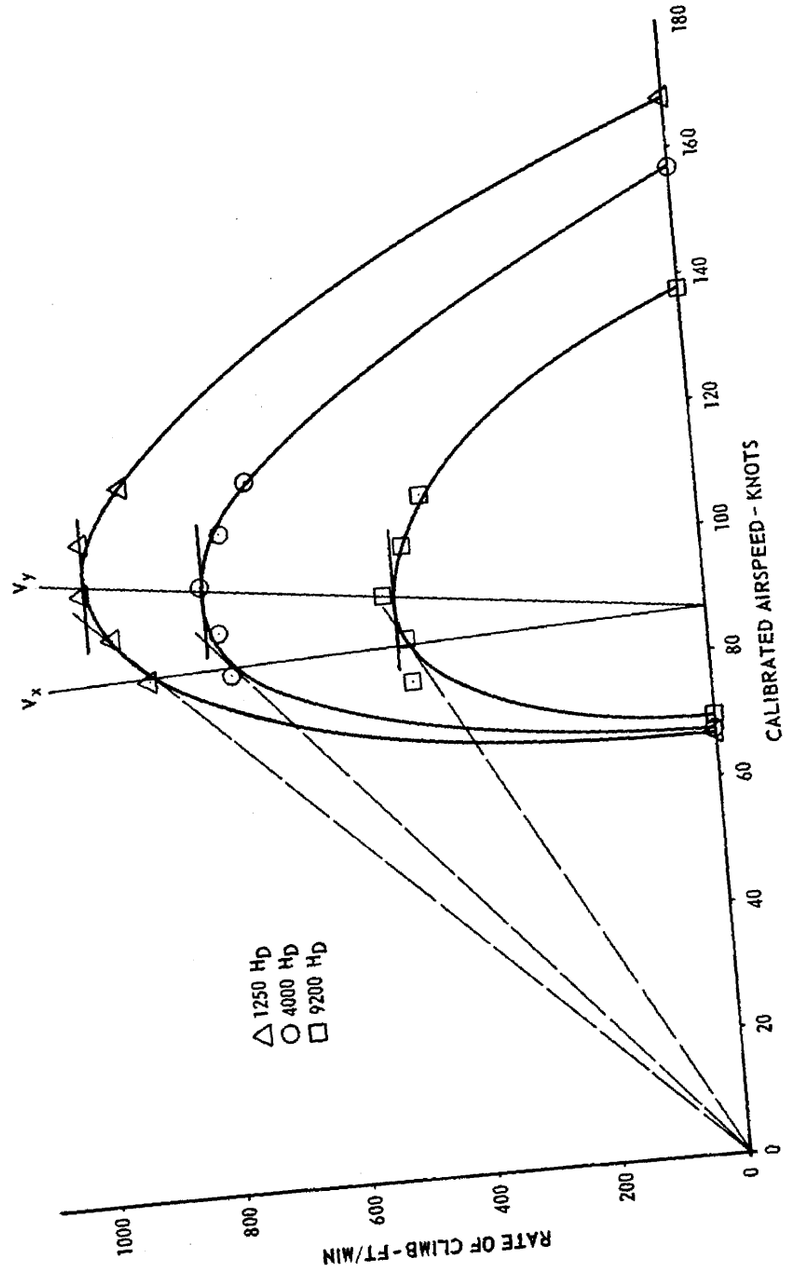


Figure 25-2 - RATE OF CLIMB VS. AIRSPEED

(8) Speed and Rate of Climb. Directly from information obtained from figure 25-2, it is possible to plot the climb performance of the airplane into a more usable form. By reading the rates of climb at the V_Y intersect points and plotting them against altitude as shown in figure 25-3, it is possible to determine the rate of climb from sea level to the absolute ceiling.

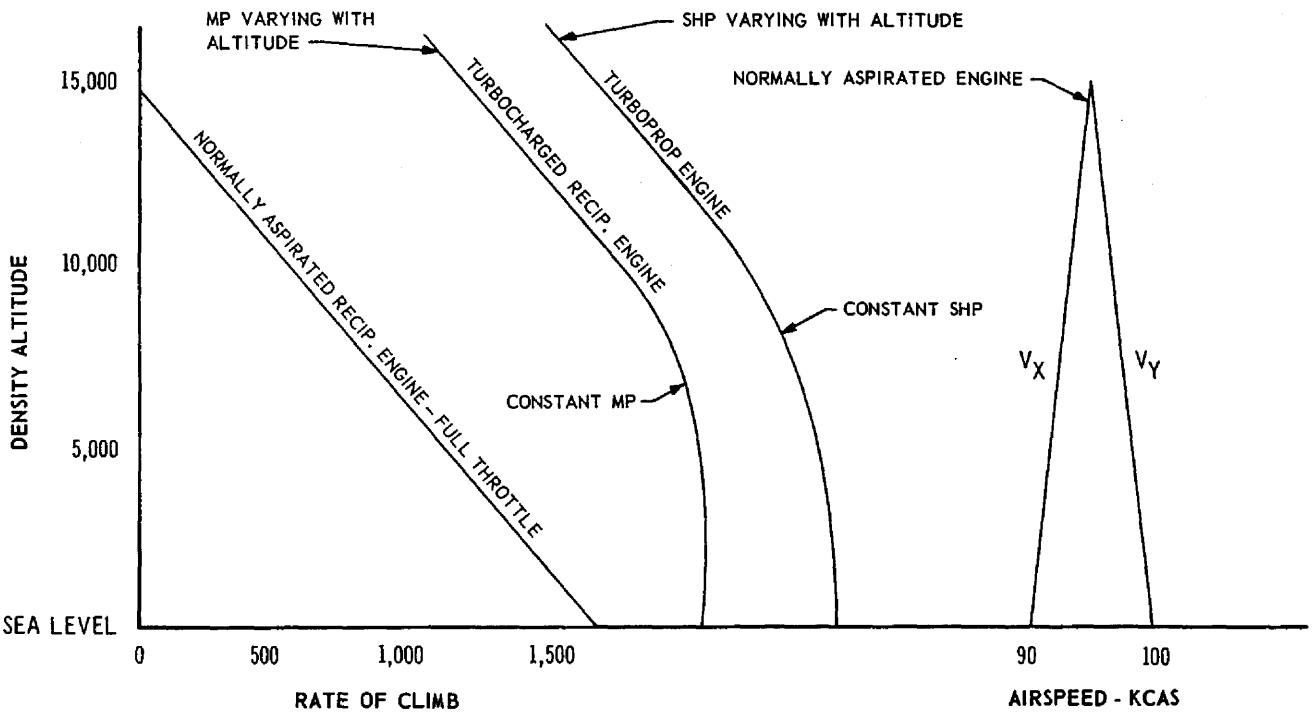


Figure 25-3 - RATE OF CLIMB AND SPEEDS

(9) Cowl Flap and Mixture. Cowl flaps should be in the position used for cooling tests. The mixture setting should be set to that used during the cooling test.

(10) Weight and C.G. For climb performance tests, the airplane's test weight, load distribution and engine power should be recorded. Usually, forward c.g. is critical for climb performance.

c. Continuous Climb. For engine changes where the objective is to determine that new climb performance is equal to or better than the old climb performance and the all-engine climb performance is obviously in excess of the requirements of § 23.65, a continuous climb may be used to obtain the data. The rate of climb data at a convenient number of points should be reduced to standard day conditions.

d. Extrapolation of Climb Data. The climb data expansion required by § 23.1587(a)(8) to 8000 feet and ISA + 40°F - 60°F can be accomplished by the methods in appendix 2. Normally, the same method used for data reduction should be used for data expansion. Use caution in extrapolating beyond altitudes that have not been verified by flight tests. Generally, data should not be extrapolated more than 3000 feet in altitude.

e. Special Equipment or Instrumentation. Climb performance tests require an airspeed indicator, sensitive altimeter, total air temperature indicator with a known recovery factor, induction air temperature gauge, engine tachometer, manifold pressure gauge and cylinder head temperature indicator if appropriate for each reciprocating engine, or appropriate indicators of power parameters for turbine engines. A fuel counter and/or fuel flowmeter is useful. All instruments should be calibrated, and the calibration data should be included with the test records. In addition, a stopwatch and appropriate data recording board and forms are required.

26. SECTION 23.67 (as amended by amendment 23-34) CLIMB: ONE ENGINE INOPERATIVE.

a. Normal, Utility, and Acrobatic Category Airplanes.

(1) Performance Matrix. For all multiengine airplanes, § 23.67 requires the one-engine-inoperative climb performance be determined in the specified configuration. The requirements of § 23.67 are summarized in the following table:

Regulation	§23.67(a)	§23.67(b)(1)	§23.67(b)(2)	§23.67(c)
Eng. Type	recip.	recip.	recip.	turbine
Weight (lbs)	over 6000	6000 or less	6000 or less	(all)
V_{SO} (kts)	(all)	over 61	61 or less	(all)
Required R/C (fpm)	.027 V_{SO}^2 at 5000 ft.	.027 V_{SO}^2 at 5000 ft.	no minimum required, but must be determined	*

*(i) 1.2% gradient or .027 V_{SO}^2 if greater, at 5000 feet Hp and 41°F (ISA) and

(ii) 0.6% gradient or .014 V_{SO}^2 if greater, at 5000 feet Hp and 81°F (ISA + 40°F).

(iii) The minimum climb gradients of (i) and (ii) must vary linearly between 40°F and 81°F and must change at the same rate up to the maximum operating temperature approved for the airplane.

(2) Range of Tests. The primary objective of the climb tests associated with this requirement is to establish the airplane's climb performance capability with one engine inoperative for altitudes between sea level and 8000 feet or higher and temperatures from ISA - 60°F to ISA + 40°F. This is necessary to enable comparison with the prescribed climb requirement at 5000 feet altitude, and also for AFM presentation of climb performance data for altitudes and temperatures as prescribed in § 23.1587(c)(5). Secondary objectives are to establish the climb

speed to be used in the cooling tests required by §§ 23.1041 through 23.1047, including the appropriate speed variation with altitude, and to establish the speed for best rate of climb (or for minimum descent, as appropriate) which, irrespective of the speed used in demonstrating compliance with climb and cooling requirements, is required for presentation in the AFM in accordance with § 23.1587(c)(2).

(3) Turbine-Powered Airplane Off-load. For turbine-powered airplanes, offloading is permitted to meet the performance requirements. See discussion in paragraph 8 of this AC.

b. Procedure.

(1) Critical Engine. To accomplish these objectives, it is necessary that sawtooth climbs be conducted with the critical engine inoperative and with the prescribed configuration and power condition. The "critical-inoperative-engine" for performance considerations is that engine which, when inoperative, results in the lowest rate of climb. The critical engine should be determined by conducting a set of sawtooth climbs, one engine at a time. The relative power or thrust capabilities of each engine should be established so that comparative climb performance data can be corrected to equal engine powers.

(2) Test Technique. One-engine-inoperative climb tests should be conducted at airspeeds and at altitudes as outlined for all-engine climbs under § 23.65. The test technique and other considerations noted under § 23.65 also apply. In climb tests with one engine inoperative, however, trim drag can be a significant factor and one-engine-inoperative climb tests should be conducted on a steady heading with the wings laterally level or, at the option of the applicant, with not more than 5^{o} bank into the good engine in an effort to achieve zero sideslip. A yaw string or yaw vane is needed to detect zero sideslip. The AFM should describe the method used, and the approximate ball position required to achieve the AFM performance.

c. Commuter Category Airplanes.

(1) Climb Gradient. The required climb gradients are specified in § 23.67(e).

(2) Climb Performance Methods. Climb performance should be determined wings level, in the configurations necessary, to construct the net takeoff flight path. See paragraph 22g(1). If full rudder with wings level cannot maintain constant heading, small bank angles into the operating engine(s), with full rudder, should be used to maintain constant heading. For all other conditions, climb performance may be determined with up to 5^{o} bank into the good engine. Two methods for establishing the critical one-engine-inoperative climb performance follow:

(i) Method No. 1. Reciprocal heading climbs are conducted at several thrust-to-weight conditions from which the performance for the AFM is extracted.

(ii) Method No. 2. Drag polars and engine-out yaw drag data are obtained for expansion into AFM climb performance. See appendix 2. Reciprocal heading check climbs are conducted to verify the predicted climb performance.

(3) Landing Gear Position. The climb performance tests with landing gear extended in accordance with § 23.67(e)(1)(i) should be conducted with the landing gear and gear doors extended in the most unfavorable in-transit drag position. It has been acceptable to consider that the critical configuration is associated with the largest frontal area. For the landing gear, it usually exists with no weight on the landing gear. For gear doors, it is usually with all the gear doors open. If it is evident that a more critical transitional configuration exists, such as directional rotation of the gear, testing should be conducted in that configuration. In all cases where the critical configuration occurs during a transition phase which cannot be maintained except by special or extraordinary procedures, it is permissible to apply corrections based on other test data or acceptable analysis.

(4) Cooling Air. If means, such as variable intake doors, are provided to control powerplant cooling air supply during takeoff, climb, and en route flight, they should be set in a position which will maintain the temperature of major powerplant components, engine fluids, etc., within the established limits. The effect of these procedures should be included in the climb performance of the airplane. These provisions apply for all ambient temperatures up to the highest operational temperature limit for which approval is desired.

(5) Power. See paragraph 22b.

27. SECTION 23.75 (as amended by amendment 23-34) LANDING.

a. Explanation.

(1) Purpose. The purpose of this requirement is to evaluate the landing characteristics and to determine the landing distance. The landing distance is the horizontal distance from a point along the flight path 50 feet above the landing surface to the point where the airplane has come to a complete stop, or to a speed of 3 knots for seaplanes or amphibians on water.

(2) Companion Requirements. Sections 23.143(a)(5), 23.153, 23.231, and 23.233 are companion requirements, and normally, tests to determine compliance would be accomplished at the same time. Additionally, the requirements of § 23.473 should be considered.

(3) Approach. The steady gliding approach, the pilot skill, the conditions, the vertical accelerations, and the airplane actions in § 23.75(a), (b), and (c) are concerned primarily with not requiring particularly skillful or abrupt maneuvers after passing the 50-foot point. The phrase "steady gliding approach," taken in its strictest sense, means power off. However, it has generally been considered that some power may be used during a steady gliding approach to maintain at least 1.3 V_{S1} and control sink rate on final approach. For those airplanes using power during approach, power may be decreased after passing the 50-foot point and there should be no nose depression by use of the longitudinal control. For those airplanes approaching with power off, the longitudinal control may be used as necessary to maintain a safe speed for flare. In both cases, there should be no change in configuration and power should not be increased. The landing distance and the procedure specified in the AFM are then based on the power used for the demonstration. The power used and the technique used to achieve the landing distances should be clearly stated in the AFM. This applies to portions of the approach prior to and after the 50-foot height.

(4) Landing Gear Loads. Sink rate at touchdown during landing distance determination should be considered and should not exceed the design landing gear loads established by § 23.473(d).

(5) Landing Distance Credit for Disking Drag. Most turboprop installations embody provisions for reduction of propeller blade pitch from the "flight" regime to a "ground" regime to produce a significant level of disking drag and/or reverse thrust following touchdown on landing. For purposes of this discussion, disking drag is defined as not less than zero thrust at zero airspeed. Section 23.75(f) permits the use of "means other than wheelbrakes" when the conditions specified in § 23.75(f) are met.

(6) Landing Distance Credit for Reverse Thrust. In past certifications, reverse thrust has not been considered sufficiently safe and reliable to permit landing distances to be predicated on its use. This policy will be reviewed when evidence is presented that reverse mechanism reliability is sufficiently high.

(7) Multiengine Installations with Flight Idle and Ground Idle. Symmetrical power/thrust may be used, with power levers at flight-idle position during air run, and at ground-idle position after touchdown. Procedures for consistently achieving ground idle should be established to ensure that the operational pilot gets the power lever back to ground idle, and thus providing consistent results in service. Two of the designs that have been found acceptable for ground-idle positioning are a dedicated throttle gate or tactile positioning of the throttle. In effecting thrust changes following touchdown, allowance should be made for any time delays that reasonably may be expected in service, or which may be necessary to assure that the airplane is firmly on the surface. See subparagraph b(2) for commuter category time delays. Associated procedures should be included in the AFM. The pitch changing mechanisms should be sufficiently safe and reliable to prevent hazards. If the disking drag or some other powerplant-related device has significant effect on the landing distance, the effect of an inoperative engine should be determined and published in the AFM Performance Section. The airplane should be satisfactorily controllable when landing under the most unfavorable conditions expected to be encountered in service, including crosswinds, wet runway surfaces and one engine inoperative.

(8) Single-Engine Installations with Flight Idle and Ground Idle. Landing distances should be determined with the power levers at flight-idle position during air run, and at ground-idle position after touchdown. Procedures for consistently achieving ground idle should be established. Two of the designs that have been found acceptable for ground-idle positioning are a dedicated throttle gate or tactile positioning of the throttle. In effecting thrust changes following touchdown, allowance should be made for any time delays that reasonably may be expected in service, or which may be necessary to assure that the airplane is firmly on the surface. Associated procedures should be included in the AFM. The pitch changing mechanisms should be sufficiently safe and reliable to minimize hazards. The airplane should be satisfactorily controllable when landing under the most unfavorable conditions expected to be encountered in service, including crosswinds, and wet runway surfaces.

(9) Balked Landing Transition. For the power conditions selected for the landing demonstration (except one engine inoperative) and other steady state conditions of speed and rate of sink that are established during the landing

approach, it should be possible, at the 50-foot point, to make a satisfactory transition to the balked landing climb requirement of § 23.77 using average piloting skill without encountering any unsafe conditions.

(10) Commuter Category.

(i) Temperature. Section 23.75(g)(1) requires landing distances be determined at standard temperature for the approved range of weights, altitudes, and wind conditions.

(ii) Wind Corrections. Correction for headwind and tailwind should be made in accordance with § 23.75(g)(3).

(iii) Expansion of Landing Data for a Range of Airport Elevations. When the basic landing tests are accomplished between sea level and approximately 3000 feet, the maximum allowable extrapolation limits are 6000 feet above and 3000 feet below the test field elevation. If it is desired to extrapolate beyond these limits, one of two procedures may be employed. These procedures are given in paragraph 19c(3)(i) and (ii).

b. Procedures.

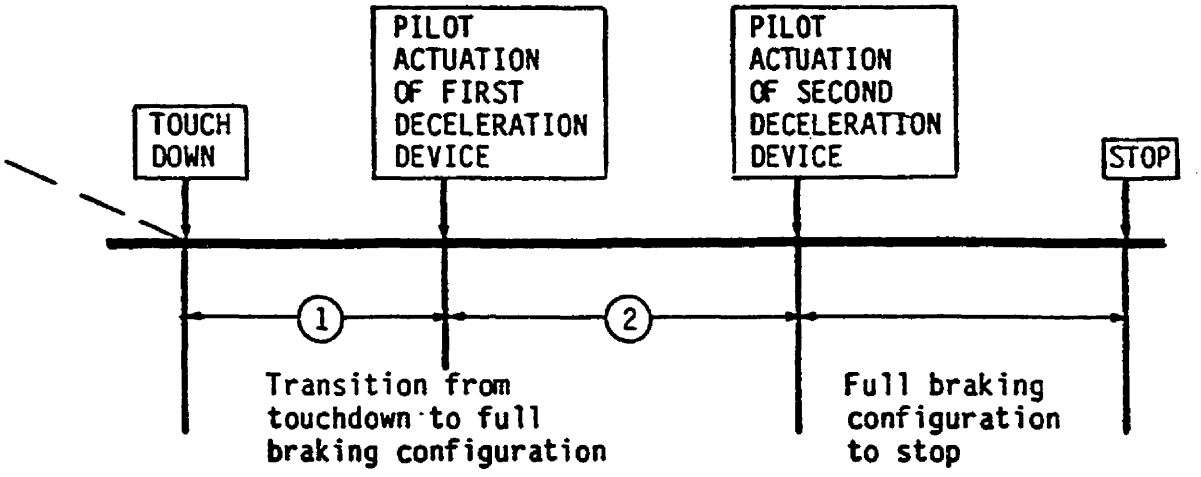
(1) Technique. The landing approach should be stabilized on target speed, power, and the airplane in the landing configuration prior to reaching the 50-foot height to assure stabilized conditions when the airplane passes through the reference height. The engine fuel control should be adjusted to the maximum flight-idle fuel flow permitted on airplanes in service unless it is shown that the range of adjustment has no effect on landing distance. A smooth flare should be made to the touchdown point. The landing roll should be as straight as possible and the airplane brought to a complete stop (or 3 knots for seaplanes) for each landing test. Normal pilot reaction times should be used for power reduction, brake application, and use of other drag/deceleration devices. See subparagraph b(2) for commuter category time delays. These reaction times should be established by a deliberate application of appropriate controls as would be used by a normal pilot in service. They should not represent the minimum times associated with the reactions of a highly trained test pilot.

(2) Commuter Category Time Delays.

(i) The time delays shown in figure 27-1 should be used.

(ii) For approved automatic deceleration devices (e.g., autospoilers, etc.) for which performance credit is sought for AFM data expansion, established times determined during certification testing may be used without the application of the 1-second minimum time delay required in the appropriate segment above.

(3) Applicant's Procedures. The procedures to be followed should be those recommended by the applicant.



① - This segment represents the flight test measured average time from touchdown to pilot actuation of the first deceleration device. For AFM data expansion, use 1 second or the test time, whichever is longer.

② - This segment represents the flight test measured average test time from pilot actuation of the first deceleration device to pilot actuation of the second deceleration device. For AFM data expansion, see item ① above.

Step ② is repeated until pilot actuation of all deceleration devices has been completed and the airplane is in the full braking configuration.

Figure 27-1 - LANDING TIME DELAYS

(4) Number of Landings. For airplanes of more than 6000 pounds gross weight, at least six landings should be conducted on the same wheels, tires, and brakes to establish the proper functioning required by § 21.35(b). Six landings on the same wheels, tires, and brakes are recommended for airplanes of 6000 pounds or less.

(5) Winds. Wind velocity and direction should be measured adjacent to the runway during the time interval of each test run. See paragraph 6a(5) of this AC for wind velocity and direction tolerances.

(6) Weight. Landing tests should be conducted at maximum landing weight.

(7) Approach Angles Greater than 3°. For commuter category airplanes, if the applicant chooses an approach angle greater than 3°, landing distances which result from utilizing a 3° approach angle should be determined and published in the AFM to enable operators to comply with related operating rules.

c. Data Acquisition.

(1) The data to be recorded for landing distance tests are:

(i) Vertical and horizontal path of the airplane relative to the runway. Two methods that have been used are runway observers and time histories. Sink rate at touchdown and descent gradients may be computed from time histories.

(ii) Pressure altitude.

(iii) Ambient air temperature.

(iv) Airplane weight (fuel used or time since engine start).

(v) Engine power or thrust data.

(vi) Cowl flap position.

(vii) Wing flap position.

(viii) Runway slope.

(ix) Direction of landing run.

(x) Wind direction and velocity at a height of 6 feet adjacent to the runway near the touchdown point.

(xi) Landing procedures noted for inclusion in the AFM.

(2) Means of acquiring the required data are listed below:

(i) Time history data is obtained by use of a takeoff and landing camera, electronic equipment, or a phototheodolite having a known surveyed location. If landing gear loads are a concern, sink rate at touchdown may be computed, or alternately, vertical load factor may be measured by an accelerometer at the c.g.

(ii) Pressure altitude may be obtained with a calibrated sensitive altimeter.

(iii) Ambient air temperature should be obtained with a calibrated temperature sensor.

(iv) The airplane weight may be computed from a known weight at start of test minus the fuel used to the time of test.

(v) Engine power or thrust data may be determined using calibrated airplane powerplant instruments to provide the basic parameters required.

(vi) Cowl flap position may be obtained from a calibrated indicator or a measured position.

(vii) Wing flap position may be obtained from a calibrated indicator or a measured position.

(viii) Slope of the runway can be obtained from the official runway survey or other suitable data obtained using accepted survey practices.

(ix) Direction of the landing run will be the direction of the runway used, or an accurate compass indication.

(x) The wind direction and velocity should be obtained with an accurate compass and a calibrated anemometer. Wind data obtained from airport control towers should not be used.

28. SECTION 23.77 (as amended by amendment 23-34) BALKED LANDING CLIMB.

a. Explanation (Normal, Utility, and Acrobatic Category).

(1) Purpose. The configuration that is specified for this climb requirement ordinarily is used in the final stages of an approach for landing, and the objective of requiring the prescribed climb capability is to ensure that the descent may readily be arrested, and that the airplane will be able to "go around" for another attempt at landing, in the event conditions beyond control of the pilot make such action advisable or necessary. The turbine-powered requirement of § 23.77(b) is to ensure that the effects of altitude and temperature do not inordinately deteriorate the airplane performance.

(2) Flap Retraction. As an alternative to having the flaps in the landing position, compliance with the balked landing climb requirement may be demonstrated with flaps in the retracted position, provided the flaps are capable of being retracted in 2 seconds or less and also provided the airplane's flight characteristics during flap retraction satisfy the constraints imposed by the regulation; that is, flaps must be retracted with safety, without loss of altitude, without sudden change in angle of attack, and without need for exceptional piloting skill. Evaluation should include satisfactory demonstration of ability to promptly arrest the descent by application of takeoff power in conjunction with rapid retraction of the flaps during final approach to landing.

(3) Flaps That Will Not Fully Retract in Two (2) Seconds. If the flaps will not fully retract in 2 seconds, the climb available with the flap position at the end of 2 seconds may be used as a consideration in an equivalent level of safety finding. Other considerations should include flight characteristics, ease of operation and reliability. If the flap is nonmechanical, the flap mechanism should be reliable in order to receive credit for a partially retracted flap.

b. Procedures. Climb performance tests are conducted to establish compliance with the prescribed climb requirement and for inclusion in the AFM. The procedures outlined under § 23.65 are equally applicable to the balked landing climb, except that the cooling and other considerations that recommend exploration of a speed range by conducting sawtooth climbs do not apply to the balked landing climb. In lieu of sawtooth climbs, the balked landing climb performance may be established as the average of not less than three continuous run pairs at the climb speed selected by the applicant.

c. Explanation (Commuter Category). Section 23.77(c)(1) states that the engines are to be set at the power or thrust that is available 8 seconds after initiation of movement of the power controls from minimum flight idle to the takeoff position. The procedures given are for the determination of this maximum power for showing compliance with the climb requirements of § 23.77.

d. Procedures (Commuter Category).

(1) Engine Trim. Trim turboprop engines to the minimum idle speed/power to be defined in the airplane maintenance manual.

(2) Engine Power Tests. Engine power tests should be conducted at the most adverse landing elevation and temperature condition, or the range of landing altitude and temperature conditions if the most adverse cannot be readily determined.

(i) In the critical air bleed configuration, stabilize the airplane in level flight with symmetrical power on all engines, landing gear down, flaps in the landing position, at a speed of 1.3 V_{SO}, at an altitude sufficiently above the selected test altitude so that time for descent to the test altitude with all throttles closed will result in minimum flight-idle power at test altitude.

(ii) Retard throttles to flight idle and descend at 1.3 V_S to approximately the test altitude. When the appropriate time has elapsed, advance throttle(s) in less than 1 second to obtain takeoff power.

(iii) The power that is available 8 seconds after the initiation of movement of the power controls from the minimum flight idle position is the maximum permitted for showing compliance with the landing climb of § 23.77 for each of the bleed combinations tested.

(iv) If AFM performance is presented so there is no accountability for various bleed conditions, the power obtained with the most critical air bleed should be used for landing climb performance for all operations, including the effects of anti-ice bleed.

e. Data Acquisition and Reduction. The information presented under § 23.65 applies to the balked landing climb.

29.-38. RESERVED.

Section 3. FLIGHT CHARACTERISTICS

39. SECTION 23.141 (as amended by amendment 23-17) GENERAL.

a. Explanation.

(1) Minimum Flight Characteristics. The purpose of these requirements is to specify minimum flight characteristics which are considered essential to safety for any airplane. This section deals primarily with controllability and maneuverability. A flight characteristic is an attribute, a quality, or a feature