U.S. Department of Transportation

Federal Aviation Administration

Advisory Circular

Subject: FLIGHT TEST GUIDE FOR CERTIFICATION OF PART 23 AIRPLANES	**Date:** 11/16/2011 **Initiated By:** ACE-100	**AC No:** 23-8C **Change:**

1. Purpose.

a. This advisory circular (AC) sets forth an acceptable means, but not the only means, of showing compliance with Title 14 of the Code of Federal Regulations (14 CFR) part 23 concerning flight tests and pilot judgements. Material in this AC is neither mandatory nor regulatory in nature and does not constitute a regulation.

b. This AC is one method being utilized to achieve national standardization in normal, utility, acrobatic, and commuter category airplanes. This AC applies to Subpart B and various sections under Subparts A, D, E, F and G from § 23.1 through § 23.1589. This AC consolidates existing policy documents, and certain ACs that cover specific paragraphs of the regulations, into a single document.

c. This material is intended as a ready reference for part 23 airplane manufacturers, modifiers, Federal Aviation Administration (FAA) design evaluation engineers, flight test engineers, and engineering flight test pilots, including Organization Delegation Option (DOA).

2. Applicability.

a. The methods and procedures contained in this AC are available for use during all normal, utility, acrobatic, and commuter category airplane flight test certification activities. This material does not have any legal status and must be treated accordingly. The procedures set forth are one acceptable means of compliance with applicable sections of part 23.

b. Like all AC material, these guidelines are not mandatory and do not constitute a regulation. They came from previous FAA experience in finding compliance with the airworthiness requirements. They represent the methods and procedures found acceptable by that experience. Since these methods and procedures are only one acceptable means of compliance, individuals should be guided by the intent of the methods provided in this AC.

Any alternate means proposed by the applicant will be given due consideration. Applicants should contact their aircraft certification office (ACO) to determine the acceptability of proposed methods.

c. This AC covers the latest part 23 amendments through Amendment 23-62. Each paragraph has the applicable part 23 amendment shown in the title. Prior amendments may require separate procedures and guidance. Applicants should contact their ACO for information concerning policies applicable to prior amendments of part 23 and Civil Air Regulations (CAR 3).

d. Sections entitled "Reserved" will be filled in when the material is developed.

e. This AC is applicable only to the original applicant seeking issuance of a type certificate (TC), an amended TC, or a supplemental type certificate (STC) for the initial approval of the new type design or a change in the approved type design. This material is not to be construed as having any legal status and should be treated accordingly. This version of the AC covers policy available through November 16, 2011. Policy that became available after that date will be covered in future amendments to the AC.

3. Cancellation. The following AC is cancelled: AC 23-8B**,** Flight Test Guide for Certification of Part 23 Airplanes.

4. General. This AC covers flight test items of interest during type certification. Other engineering disciplines, such as airframe, systems and equipment, and propulsion are addressed as they pertain to flight test criteria.

5. Background.

a. AC 23-8, Flight Test Guide for Certification of Normal, Utility, and Acrobatic Category Airplanes, was published to replace FAA Order 8110.7, Engineering Flight Test Guide for Small Airplanes, dated June 20, 1972, and to consolidate existing flight test policy. AC 23-8 did not cover commuter category airplanes. AC 23-8A updated the original AC 23-8 by adding information and guidance for commuter airplanes. AC 23-8B updated the Flight Test Guide to incorporate information and guidance through 14 CFR part 23, Amendment 23-51. The AC also incorporated material harmonized with the European Joint Aviation Authorities (JAA).

b. The latest revision to the Flight Test Guide, AC 23-8C, contains guidance material for turbojets certificated under part 23. For almost two decades, part 23 jets used extensive special conditions to address the special issues associated with high performance, high altitude turbojet airplanes. However, in the past five years, the number of new jet certification programs in part 23 has increased more than 100 percent over the program numbers of the past three decades. The need to incorporate these special conditions into part 23 stems not only from the existing number of new jet programs, but expected future programs. This AC is updated to accompany the addition of jet requirements to part 23.

6. Paragraphs Keyed to Part 23. Each paragraph has the applicable part 23 amendment shown in the title. As part 23 changes occur, the appropriate revisions will be made to the affected paragraphs of this AC.

7. Related Publications. Certification personnel should be familiar with FAA Order 8110.4 "Type Certification," and FAA Order 8100.5A, "Aircraft Certification Service Mission, Responsibilities, Relationships, and Programs." In this AC, reference is made to other FAA ACs which provide guidance on various aspects of type certification and supplemental type certification. The documents listed below are provided as a quick reference source of documents that are acceptable for use in 14 CFR part 23 certification programs/projects.

a. Copies of current FAA ACs are available on the Internet at http://www.faa.gov/regulations_policies/advisory_circulars/

(1) 20-67 Airborne VHF Communications Equipment Installations

(2) 20-124 Water Ingestion Testing for Turbine Powered Airplanes

(3) 20-118 Emergency Evacuation Demonstration

(4) 20-138B Airworthiness Approval of Positioning and Navigation Systems

(5) 23.629-1 Means of Compliance with Section 23.629, Flutter

(6) 23-1309-1 System Safety Analysis and Assessment for Part 23 Airplanes

(7) 23-1419-2 Certification of Part 23 Airplanes for Flight in Icing Conditions

(8) 90-79 Recommended Practices and Procedures for the Use of Electronic Long-Range Navigation Equipment

(9) 91-49 General Aviation Procedures for Flight in North Atlantic Minimum Navigation Performance Specifications Airspace

(10) 121-13 Self-Contained Navigation Systems (Long Range)

(11) 20-88 Guidelines on Marking Aircraft Powerplant Instruments (Displays)

(12) 23-16 Powerplant Guide for Certification of Part 23 Airplanes and Airships

(13) 23-17 Systems and Equipment Guide for Certification of Part 23 Airplanes and Airships

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Chapter 1. Subpart A--General

1. § 23.1 Applicability.

a. Explanation.

(1) *Airplane Categories*. Section 23.1(a) is introductory and prescribes the airplane categories eligible for certification under 14 CFR part 23. Applicants should refer to 14 CFR part 21 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.

b. Procedures. None.

2. § 23.3 Airplane Categories.

a. Explanation. For normal/utility category as well as for commuter category airplanes, stalls (except whip stalls) are approved maneuvers. In this context, approved stalls are to be understood to be stalls as defined in §§ 23.49, 23.201, and 23.203.

b. Procedures. None.

Chapter 2 Subpart B – Flight

Section 1. General

1. § 23.21 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, and so forth, necessary to define the envelope and show compliance within. These engineering tests should define the limits of the entire operating envelope and establish compliance with the regulations. If compliance cannot be established between these points, additional testing should be conducted to determine compliance. The applicant could also apply for an equivalent level of safety (ELOS) or an exemption to the regulation if warranted by new designs or technology. 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. 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) *Additional acceptable tolerances.* Additional acceptable tolerances appear in table 1 below:

Table 1 - Tolerances

Item	Tolerance
Airspeed	3 knots or ±3 percent (%), whichever is greater
Power	±5 percent
Wind (takeoff and, landing tests, not for crosswind component testing)	As low as possible, but not to exceed approximately 12 percent 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 unsmooth flight conditions.

(6) *Corrections to a standard value.* Cases in which corrections to a standard value of the parameter are normally allowed appear in table 2 below:

Table 2 - Corrections to Standard Value Parameter

Test	Weight	Density	Power/ Thrust	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
Glide Performance	X	X	-	X	
V_{MC}	—	X	X	—	

(7) *Function and Reliability (F&R) Test.* Section 21.35(b)(2) specifies the requirements of F&R tests, which are required for aircraft with a maximum certificated weight over 6,000 pounds (lbs) (2730 kilograms (kg)). (Complex airplanes that include features like Full Authority Digital Engine Control (FADEC) engines, pressurization, and avionics integrated with flight

management software (FMS) and autopilot capability should consider a comprehensive F&R testing program regardless of weight.)

b. Procedures.

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

(2) *Instrument Calibration.* Test instrumentation (transducers, indicators, and other installed instrumentation) should be calibrated (removed from the airplane and bench checked by an approved method in an approved facility) within six months of the tests. When electronic recording devices are used, such as oscillographs, data loggers, and other electronic data acquisition devices, preflight and post-flight 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 in table 3, 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 at an approved facility. For example, performing a pitot-static/air data system leak check to "calibrate" an airspeed indicator, whether in or out of the airplane, is not acceptable.

Table 3 – Sample Portion of Airspeed Indicator Calibration

XYZ INSTRUMENT SERVICE, INC. ABC CITY AIRPORT APPROVED REPAIR STATION - NO. 1234		
	8/12/80 P/N 1701DX8-04 S/N AF55-17044	
A/S Indicator	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 several 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, and so forth).

(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, if considered, can be accomplished and be located at a point that will produce a significant c.g. shift to a less critical c.g. location. Applicants should perform a simple structural analysis for complex load installations that have the potential to interfere with safe flight and landing if there was a failure of the supporting structure. 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.

(4) *Function and Reliability (F&R) Tests for Airplanes over 6,000 pounds Maximum Certificated Weight.* While § 21.35(b)(2) does not require F&R testing for airplanes weighing less than 6000 lbs., the Small Airplane Directorate's policy is to require (via special conditions) a comprehensive Function and Reliability testing program regardless of weight for complex airplanes that include features like FADEC controlled engines, pressurization, and avionics integrated with FMS and autopilot capability.

(i) A comprehensive and systematic check of all aircraft components must be made to assure that they perform their intended function and are reliable.

(ii) F&R certification testing must be accomplished on an aircraft that is in conformity with the approved type design. Furthermore, the number of airplanes used should be limited to meet the intent of F&R testing. F&R certification testing should follow the type certification testing. This is to assure that significant changes resulting from type certification tests can be incorporated on the aircraft and successfully retested prior to the F&R tests.

(a) A certain portion of the F&R test program should emphasize systems, operational conditions, or environments found particularly marginal during type certification tests. Applicants should put the aircraft in as many different environments as possible (for example, cold, hot, rain, etc.) as well as different types of airports to exercise the systems as they will be in the field.

> Note: It is important to perform F&R testing with the configuration the manufacturer is planning to deliver to the customer (this may be different than what is configured at the end of initial certification). This is especially important in the case of software and post-TC changes.

(iii) All components of the aircraft should be periodically operated in sequences and combinations likely to occur in service. Ground inspection should be made at appropriate intervals to identify potential failure conditions; however, no special maintenance beyond that described in the Aircraft Maintenance Manual should be allowed.

(iv) A complete record of defects and failures should be maintained along with required servicing of aircraft fluid levels. Results of this record should be consistent with inspection and servicing information provided in the Aircraft Maintenance Manual.

2. § 23.23 Load Distribution Limits.

a. Explanation.

(1) *C.G. Envelope*. The test tolerance of ±7 percent of the total c.g. range (given in § 23.21) is intended to allow some practical relief for in-flight c.g. movement. This relief is only acceptable when the test data general scatter is on either side of 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 flight characteristics be present, the limits of the envelope should be reduced to ensure safe margins. Where variation in the c.g. position may have a significant effect on the result of a test (for example, spins and V_{MC}), the result should be corrected to the most critical c.g. position within the operating limits to be approved. If such a correction is impractical or may be unreliable, the actual test should ensure that the measured characteristics represent the critical value.

(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 possible loading conditions can result in a significant variation of the lateral c.g., this lateral range of c.g. must be established by:

(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 loadings. When investigating the effects of asymmetric lateral loads, the following sections in this flight test guide (FTG) represent applicable flights requirements:

(a) § 23.143 Controllability and Maneuverability, General.
(b) § 23.147 Directional and lateral control.
(c) § 23.149 Minimum control speed.
(d) § 23.151 Acrobatic maneuvers.
(e) § 23.157 Rate of roll.
(f) § 23.161 Trim.
(g) § 23.201 Wings level stall.
(h) § 23.203 Turning flight and accelerated turning stalls.
(i) § 23.221 Spinning.
(j) § 23.233 Directional stability and control.
(k) § 23.701 Flap interconnection.

b. Procedures. None.

3. § 23.25 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 allow an exception 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. (Refer to Advisory Circular (AC) 23-7 if the airplane is being modified for an increase in maximum weight.) Due to changes in the operational requirements of an owner/operator, in many cases the need arises to modify and substantiate the structure for an increase in maximum weight and maximum landing weight. Any one of these increases affects the airplane's basic loads and structural integrity, and they could affect the limitations and performance.

(i) If an airplane was certificated with maximum landing weight equal to maximum weight, some applicants take advantage of the five percent difference between design landing and design maximum weight permitted by § 23.473(b). These applicants use the STC process. In these cases, re-substantiation of the landing gear for landing loads is not required when increasing the maximum weight by as much as five percent. For those programs involving more than a five percent increase in maximum weight, some re-substantiation of the landing gear should be accomplished.

(ii) Other applicants are replacing piston engines with turbopropeller engines, thus requiring that gasoline be replaced with jet fuel, which weighs as much as 17 percent more. In some cases, the quantity of fuel is being increased at the same time as engine replacement, but the maximum zero fuel weight remains the same.

(iii) All the above types of modifications should be investigated to verify that critical loads have not increased or that those loads that have increased are capable of being carried by the existing or modified structure.

(3) *Weight, Altitude, Temperature (WAT).* For all airplanes with a maximum takeoff weight exceeding 6,000 pounds and turbine engine airplanes, a WAT chart may be used as a maximum weight limitation.

(4) *Ramp Weight.* The applicant may elect to use a "ramp weight" provided compliance is shown with each applicable section of part 23. Ramp weight is the takeoff weight at brake release plus an increment of fuel weight consumed during engine start, taxiing, and run-up. Generally, this increment of fuel should not exceed one percent of the maximum permissible flight weight up to 125 pounds. 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 run-up will be sufficiently close to an amount fixed such that taxi can be considered as the only variable. If the pilot is provided with taxi fuel burn rate in

pounds per 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 is limited by altitude, temperature, or other criteria. The maximum ramp weight should be shown as a limitation on the TC Data Sheet and in the AFM.

(5) *Lowest Maximum Weight*. Sections 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. This has to be shown with the most critical combinations of required equipment for the type of operation for which certification is requested.

(6) *Placarding of Seats*. When establishing a maximum weight in accordance with § 23.25(a)(2)(i), one or more seats may be placarded to a weight of less than 170 pounds (or less than 190 pounds for utility and acrobatic category airplanes). An associated requirement is § 23.1557(b). The AFM loading instructions, required by § 23.1589(b), should be specific in addressing the use of the placarded seats.

b. Procedures. None.

4. § 23.29 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 with an equipment list that 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. Normally, the test crew will verify the calculations.

5. § 23.31 Removable Ballast.

a. Explanation. This regulation is associated only with ballast that 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 3, of this AC.

b. Fluid Cargo. For those airplanes configured to carry fluid cargo (such as agricultural chemical tanks, minnow tanks, slurry tanks, and so forth), airplane handling qualities should be evaluated for controllability and non-exceedance of the limitations at the full and the most critical partial fluid loads. When so equipped, the effects of in-flight jettison or dumping of the fluid load should be evaluated to establish that the pilot is able to exercise sufficient control to prevent unacceptably large flight path excursions or exceedance of operational/structural limits.

6. § 23.33 Propeller Speed and Pitch Limits.

a. Explanation. 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.

(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. Applicants should account for altitude and temperature effects in the TCDS. 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 percent 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 all-engine(s)-operating 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 percent 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 propeller 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 all-engine(s)-operating climb speed.

(ii) *Static r.p.m.* With the propeller governor made inoperative by mechanical means, obtain a no-wind static r.p.m.

(a) *Reciprocating Engines*. Determine that the maximum power static r.p.m., with the propeller blade operating against the low pitch stop, does not exceed 103 percent of the rated takeoff r.p.m. of the engine.

(b) *Turbopropeller Engines.* Although this rule references manifold pressure, it has been considered to be applicable to turbopropeller installations. With the governor inoperative, the propeller blades at the lowest possible pitch, with takeoff power, the airplane stationary, and no wind, ensure that the propeller speed does not exceed the maximum approved engine and propeller r.p.m. limits. 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} with full power, although within the normal operating range, is not a normal operating procedure. Engine r.p.m., with the 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 normal operating limits for the propeller are not exceeded.

(4) *Data Acquisition and Reduction*. Outside air temperature and altitude needs to be considered for the ground tests. 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.

Section 2. Performance

1. § 23.45 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, and so forth. This is essential to obtaining good data and repeatable results. Non-standard conditions of temperature, pressure, and so forth, 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) *Reciprocating Engine-Powered Airplanes Below 6,000 pounds (2730 kg) Maximum Weight*. Performance tests will normally be conducted in non-standard atmospheric conditions, but ideally for accuracy in data reduction and expansion, tests should be conducted in atmospheric conditions as near those of a standard atmosphere as possible. Accounting for winds and non-standard conditions requires testing procedures and data reduction methods that reduce the data to standard atmospheric conditions.

(ii) *Reciprocating Engine-Powered Airplanes of More Than 6,000 pounds (2730 kg) Maximum Weight and Turbine-engine Powered Airplanes.* Performance tests should be conducted in the range of atmospheric conditions that will show compliance with the selected weight, altitude, and temperature limits. Refer to § 23.53 of this AC for guidance on extrapolation of takeoff data and § 23.75 for extrapolation of landing data.

(2) *Standard Atmosphere*. The 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 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, based on the power approved during airplane certification. 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) *Propeller Cutoff*. In general, if the airplane will be approved with an allowable cutoff for the propeller, then the performance flight testing should be done using the most critical propeller diameter. In most cases, this is expected to be the minimum diameter propeller allowed.

(i) For normal, utility, and acrobatic category airplanes only, a two percent margin was the allowed reduction in propeller diameter. Historically, the two percent margin was selected as being the maximum permissible reduction in diameter of a given propeller that will not noticeably reduce performance. Service history has shown this to be an acceptable margin without additional flight testing.

(5) *Flight Procedures.* The flight procedures must not be unduly sensitive to less than ideal atmospheric conditions. The atmospheric conditions "reasonably expected to be encountered in service" may be different depending on the class of aircraft, but should cover at least the maximum demonstrated crosswind component established in compliance with § 23.233(a).

(6) *Flight Test Data*. For calibrated engines, test day power is 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; however, the upper tolerance chart brake horsepower for reciprocating engines using 14 CFR part 33 tolerances of +5 percent, -0 percent may lead to unrealistic performance. Historically, the two major reciprocating engine manufacturer's engines have tolerances closer to +2 percent, -0 percent. Refer to appendix 1 for further information. 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.

(7) *Humidity Correction.* Refer to appendix 1.

b. Procedures. Refer to appendix 1.

c. Operation on Unpaved Runways.

(1) *Small airplane operations from grass runways.* For airplanes less than 6,000 pounds (2730 kg) maximum weight, the factors given below may be quoted in the flight manual, as an alternative to the scheduling of data derived from testing or calculation. It should be noted that these factors are intended to cover the range of airplane types in this category and are necessarily conservative. Manufacturers are, therefore, encouraged to produce and schedule their own data in accordance with (1) and (2) above to obtain optimized performance for their airplane.

Table 4 - Smooth, Flat Runway

	Takeoff	Landing
Dry Grass	1.2	1.2
Wet Grass	1.3	1.6

Note: If the runway is not smooth, the grass is very long or very short, higher factors may be warranted.

Very short grass = golf course length
Very long grass = unmowed field or high interstate highway median grass length

(2) *Airplanes with 6,000 pounds (2730 kg) maximum weight or more*. The following guidance was developed to include high performance multiengine airplanes. The level of detail should be scaled back to that appropriate for the airplane. Simple, single-engine turbine bush airplanes, for example, do not need the level of detail discussed here.

Operations on other than smooth, dry, hard runway surfaces may require specific approval and the scheduling of information on the effect of those surfaces on takeoff and landing distances in the flight manual. Applicants may use the factors for grass runways in paragraph (1). These factors would, in many cases, result in such conservative distances that operational utility may be compromised. Applicants may propose their own factors if accompanied with supporting data. To obtain approval for takeoff and landing operations on unpaved runway surfaces, compliance with the following should be shown:

(i) Each type of surface must be defined so that it can be recognized in operations in service including conditions such as day or wet.

(ii) It must be determined that the airplane can be operated on each defined surface without hazard from likely impingement or engine ingestion of any foreign objects that constitute parts of the surface.

(iii) If any special procedures or techniques are found to be necessary, these must also be determined and scheduled.

(iv) The takeoff and landing performance on each defined surface must be determined in accordance with §§ 23.53 and 23.75, as modified in (3) below.

(3) *Takeoff and Landing Data*. Takeoff and landing data must be determined for each type of unpaved surface for which approval is requested.

(i) The test runways on which the takeoff and landing distance measurements are conducted should be chosen to be representative of the worst characteristics (that is, high rolling friction, low braking friction) of each of the types of runway under consideration.

(ii) In establishing the operation limitations for a particular type of unpaved runway, the runway's load bearing characteristics, rolling and braking friction, and impingement and ingestion characteristics, should be considered.

e. Wet and Contaminated Runways. Reserved.

2. § 23.49 Stalling Speed.

a. Explanation.

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

(2) *Background*. Since many of the regulations pertain to performance, handling qualities, airspeed indicator markings, and other variables that 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_{S0} and V_{S1} speeds to be determined using the procedures specified in § 23.201. Refer to 14 CFR part 1 and § 23.49 for definitions of V_{S0} and V_{S1}. "Landing configuration" in part 23 is gear down and full flaps. Section 23.201(b) defines when the airplane can be considered stalled for airplane certification purposes when one of three conditions occurs, whichever occurs first. The conditions are:

(i) Uncontrollable downward pitching motion;

(ii) Downward pitching motion resulting from the activation of a device (for example, stick pusher); or,

(iii) The control reaches the stop.

(a) 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. Refer to figure 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 a minimum of two seconds and consistent with the time against the stop for stall characteristics testing in § 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 is not necessarily the first indication of nose-down pitch.

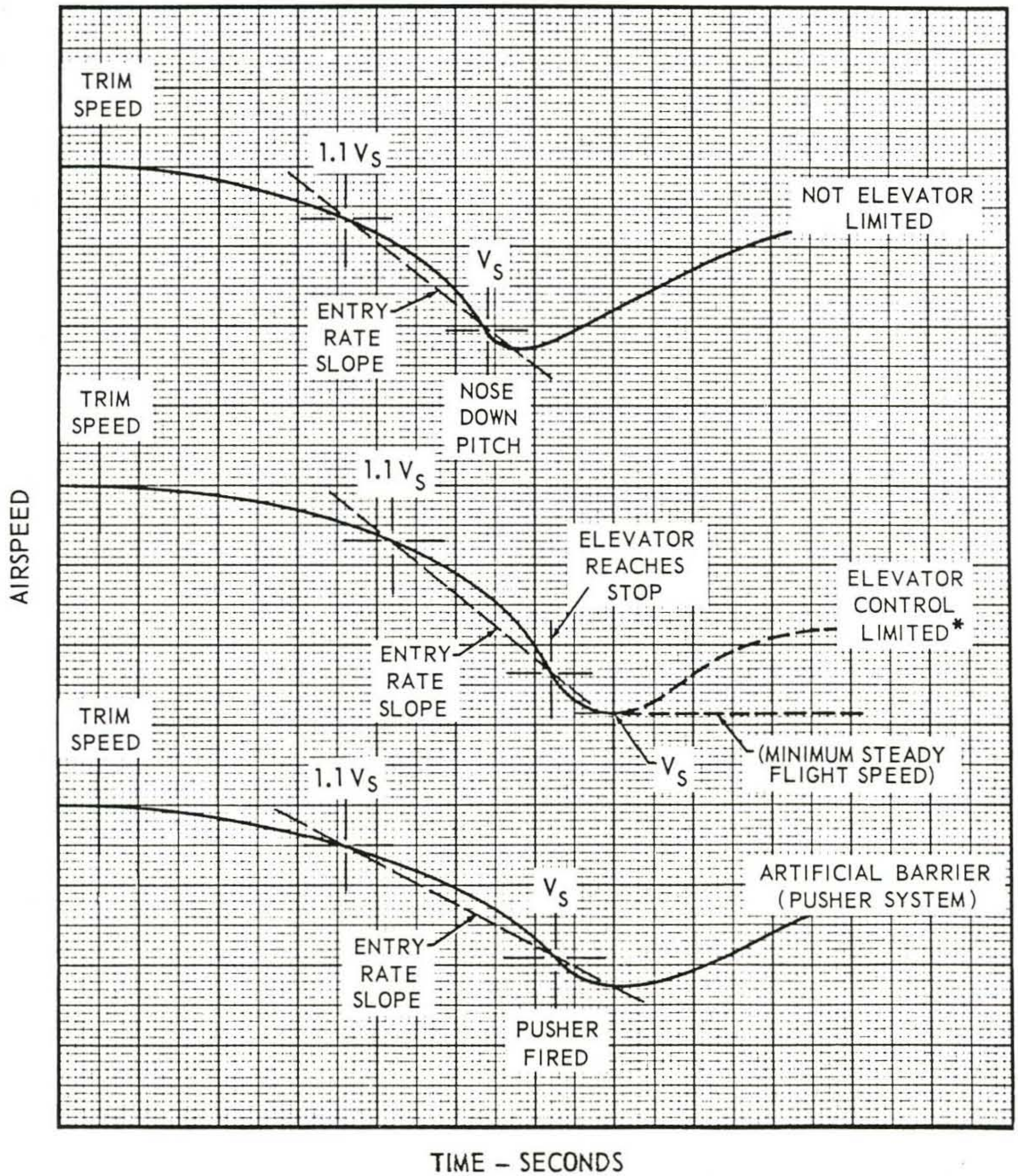
(4) *Reciprocating Engine Throttle Position*. For reciprocating engine airplanes, the stalling speed is that obtainable with the propellers in the takeoff position and the engines idling with throttles closed. As an alternative to "throttles closed," the regulations allow the use of sufficient power to produce zero propeller thrust at a speed not more than 10 percent 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, a dependable method of determining inflight thrust, 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 paragraph (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 2, where:

C_T = thrust coefficient
C_P = power coefficient
ß = blade angle setting
J = advance ratio

Figure 1 Stall Speed



(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 3.

(iv) Another approach is to use the prop rake method. In some cases this may be easier to use and more accurate.

(6) *Turbopropeller Thrust.* For turbopropeller airplanes, § 23.49(a)(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).

(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 5,000 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.

(i) 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 re-evaluated at low altitudes on all fixed shaft turboprops to assure that the stall speeds have not increased.

Figure 2 Propeller Coefficients

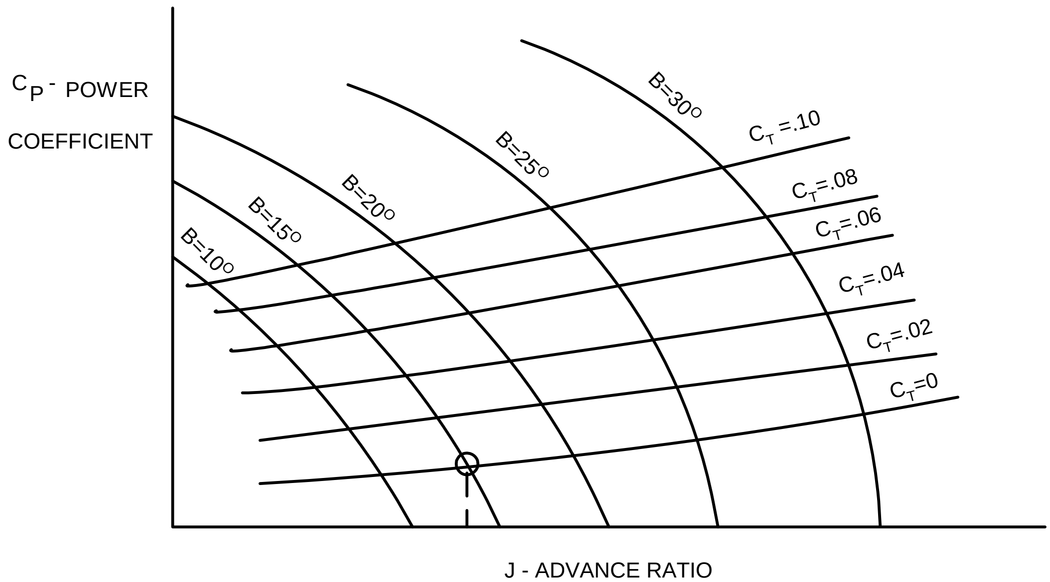
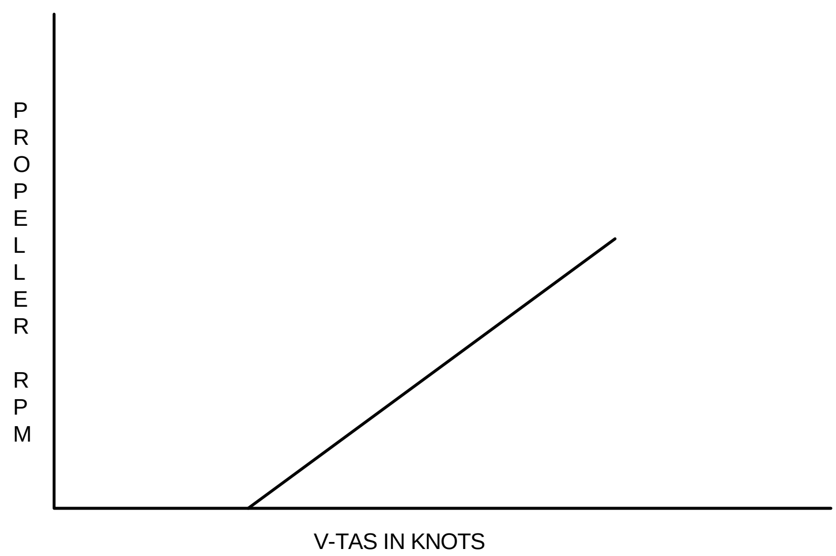


Figure 3 Zero Thrust



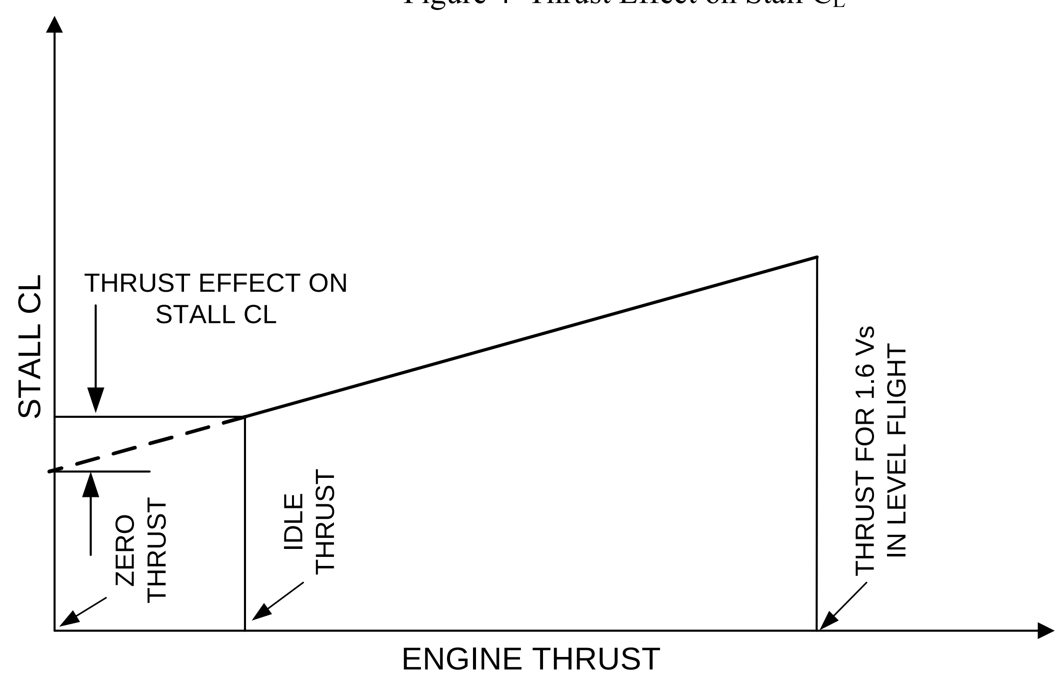
(8) *Turbojets and turbofans.*

(i) Stall speeds are normally defined with the thrust levers at idle; however, it is necessary to verify by test or analysis that engine idle thrust does not affect stall speeds to an extent that they are appreciably lower than would be experienced at zero thrust. Negative thrust at the stall, which slightly increases stall speeds, is acceptable.

(ii) To determine whether thrust effects on stall speed are significant, at least three stalls should be conducted at one flap setting, with thrust set to approximately the value required to maintain level flight at 1.6 V_S in the selected configuration.

(iii) These data may then be extrapolated to a zero thrust condition to eliminate the effects of idle thrust on stall speeds (refer to figure 4). If the difference between idle thrust and zero thrust stall speed is 0.5 knots or less, the effect may be considered insignificant.

Figure 4 Thrust Effect on Stall C_L



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.

(a) 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, but are not limited to the following:

1. *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. Another way to make the fixed pitot work for stall speeds is to mount the boom at a negative incidence angle biased for the stall angle of attack. 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.

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

3. *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 either speed or altitude, or both, 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 2,000 to 3,000 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 of accounting for lag errors is described in NASA Reference Publication 1046, "Measurement of Aircraft Speed and Altitude," by W. Gracey, May 1980. A lag correction is unnecessary if it can be shown that the system lag is small enough to be considered insignificant.

(iv) *Transducer Location*. The instrumentation should account for any difference in the installed location of the pressure transducers used in the cone, boom, or bomb and the aircraft system.

(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 1. The indicated airspeed at the stall should be noted, using the production airspeed system. Both the IAS 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 to determine the critical condition. 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 (pounds)
W_T = Test weight (pounds)

(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.

3. § 23.51 Takeoff Speeds.

a. Explanation. The primary objective of this section is to determine the normal takeoff speeds for non-weight, altitude, and temperature limited airplanes. For WAT limited airplanes, the objective is to determine the takeoff speed schedules for all takeoff configurations at weight, altitude, and temperature conditions within the operational limits selected by the applicant.

b. Procedures. For normal, utility, and acrobatic category airplanes, the rotation speed, (V_R) in terms of calibrated airspeed, must be selected by the applicant. V_R is constrained by § 23.51(a), as follows:

(1) *For multiengine landplanes.* V_R must not be less than the greater of 1.05 V_{MC} or 1.10 V_{S1};

(2) *For single-engine landplanes.* V_R must not be less than V_{S1}; and

(3) *For seaplanes and amphibians taking off from water.* V_R may be any speed that is shown to be safe under all reasonably expected conditions, including turbulence and complete failure of the critical engine.

c. Procedures. For normal, utility, and acrobatic category airplanes, the speed at 50 feet should be determined by:

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

(i) A speed that is shown to be safe for continued flight (or land back, if applicable) under all reasonably expected conditions, including turbulence and complete engine failure; or

(ii) 1.1 V_{MC}; or

(iii) 1.2 V_{S1}.

(2) *Single Engine 50-foot Speed*. For single-engine airplanes, § 23.51(b)(2) requires the speed at the 50-foot point to be the higher of the following:

(i) A speed that is shown to be safe under all reasonably expected conditions, including turbulence and complete engine failure; or

(ii) 1.2 V_{S1}.

(3) *Takeoff Speed Investigations - General*. 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 imbalance.

(4) *Single-engine Airplane Takeoff Speeds*. The takeoff speed investigation should include a demonstration that controllability and maneuverability following engine failure at any time between lift-off and the 50-foot point are adequate for safe landing.

(5) *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. Rotation speed should be scheduled so that the speed at 50 feet is in accordance with § 23.51(b)(1).

(6) *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 that decrease as the weight decreases, the investigations of paragraph (3) 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(b)(1) should include demonstration of acceptable characteristics following engine failure at any time between liftoff and the 50-foot point during takeoff in accordance with the established takeoff procedures.

(7) *Complete Engine Failure*. The term "complete engine failure" has been consistently interpreted to require that, for multiengine airplanes that meet the powerplant isolation requirements of § 23.903(c) in the takeoff configuration, only one engine needs to be made inoperative in the specified investigations.

d. Jets Over 6,000 Pounds Maximum Weight and Commuter Category Airplanes.

(1) *Takeoff Speeds*. The following speed definitions are given in terms of CAS. The AFM presentations are required, by § 23.1581(d), in IAS.

(i) *Section 23.51(c)(1) - Engine Failure Speed (V_{EF}).* The engine failure speed V_{EF} is defined as the CAS at which the critical engine is assumed to fail and must be selected by the applicant. V_{EF} cannot be less than 1.05 V_{MC}, as determined in § 23.149. Ground controllability should also be determined to be adequate at V_{EF} to ensure meeting the requirements of § 23.51(c)(1), that is, speed adequate to safely continue the takeoff. During the demonstration, the airplane's ground run should not deviate more than 30 feet from the pre-engine-cut projected ground track. V_{MCG} determined under 14 CFR part 25, § 25.149(f) is acceptable in lieu of 1.05 V_{MC}. 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 nose wheel steering is an integral part of the rudder system and is required to be operative, then nose wheel steering may be active. Otherwise, control of the airplane should be accomplished by use of the rudder only. If the applicant elects to use V_{MCG}, then the nosewheel steering must be disconnected as required in § 25.149(d). 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 be avoided.

(ii) *Section 23.51(c)(l) - 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, and so forth, during accelerate-stop tests. The applicant may choose the sequence of events. V_1 should include any airspeed system errors determined during accelerate-takeoff ground runs. Refer to the requirements of § 23.1323(c).

(iii) *Section 23.51(c)(2)- Rotation Speed (V_R).*

(a) The rotation speed, V_R in terms of in-ground effect CAS, must be selected by the applicant. V_R is constrained by § 23.51(c)(2) as follows:

1 V_1; or

2 1.05 V_{MC} determined under § 23.149(b); or

3 1.10 V_{S1}; or

4 The speed that allows attaining the initial climbout speed, V_2, before reaching a height of 35 feet above the takeoff surface in accordance with § 23.57(c)(2).

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

1 In showing compliance with § 23.51(c)(5), 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 paragraphs 2 and 3 below.

2 In conducting the flight tests required by § 23.51(c)(5), 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 five 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 (that is, 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 re-conducting the tests, to analytically adjust the test distance to account for the excessive speed decrement.

(c) *All-engines-operating abuse tests.*

1 Section 23.51(c)(6) 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:

(aa) An abuse at rotation speed, and

(bb) 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 five percent 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 percent 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 seven percent, whichever is less, below the scheduled V_R. Tests should be conducted at a rapid rotation rate or should include an over-rotation of two degrees above normal attitude after liftoff. Rapid rotation should be taken to mean significantly above the normal pitch rate of rotation. It should be noted that four or five degrees per second have previously proved satisfactory. Tail strikes, should they occur during this demonstration, are acceptable only if a fault analysis (structural, electrical, hydraulic, and so forth) 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, some things should be shown -. With the airplane mis-trimmed, 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. The amount of mis-trim 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.

(iv) *Lift-off Speed (V_{LOF}).* V_{LOF} is the CAS at which the airplane first becomes airborne.

(v) *Section 23.51(c)(4) - Takeoff Safety Speed (V_2).* V_2 is the CAS 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 23.51(c)(4) requires V_2 not be less than 1.1 V_{MC} or 1.2 V_{S1}. Attainment of V_2 by 35 feet should be substantiated by use of procedures consistent with those used in service. If auto feather is required, then auto feather should be activated as an integral part of testing.

4. § 23.53 Takeoff Performance.

a. Explanation.

(1) *Normal, Utility, and Acrobatic Category Airplanes*.

(i) *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.

(ii) *AFM Takeoff Distance*. Section 23.1587(c)(1) requires the takeoff distance determined under this section be furnished in the AFM. The data should be furnished at the most critical c.g. (usually forward). Section 23.1587 further requires the effect of altitude from sea level to 10,000 feet and the following:

(a) Temperature from standard to 30 °C above standard; or

(b) For airplanes greater than 6,000 pounds (2730 kg) and turbine-powered airplanes, the AFM should furnish temperature from standard to 30 °C above standard, or the maximum ambient atmospheric temperature at which compliance with the cooling provisions of § 23.1041 to § 23.1047 is shown, if lower. 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.

(iii) *AFM Takeoff Technique*. For multiengine airplanes, § 23.1585(d)(1) requires the AFM to furnish the procedures for the § 23.53 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.

(iv) *Tire Speed Limits.* If tires approved through the technical standard order (TSO) process are used, it should be determined, 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 tire speed limit should be established as an operating limitation. In compliance with § 23.1581(a)(2), a maximum takeoff weight limited by tire speed chart should also be included in the AFM performance section.

b. Procedures.

(1) *Takeoff Distance Tests*. The takeoff distance should be established by test. It 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, Global Positioning System (GPS), 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. Some airplanes may not be able to safely remain on the runway above flying speed. It is acceptable to allow the airplane to fly in ground effect without climbing. 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. Refer to § 23.65 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_{L0F}, 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_{L0F} to the 50-foot speed. For those airplanes with retractable gear, the landing gear should be extended throughout or an alternative method of retraction may be initiated at a speed corresponding to a safe speed for gear retraction following liftoff 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 ±0.5 percent weight tolerance is observed.

(4) *Nose wheel/tail wheel*. In the absence of evidence to the contrary, the "critical" c.g. position for takeoff distance tests may be assumed to be forward. However, the applicant should determine the critical c.g. for the aircraft configuration as well as for the runway distance.

(5) *Wind*. Wind velocity and direction should be measured adjacent to the runway during the time interval of each test run. Refer to section 23.21a(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:

$$S_G = S_{GW}$$

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)

Note 1 + is used for headwind and - for tailwind

Note 2 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 as follows:

$$S_G = \frac{S_{GS1}}{1 \pm \left(\frac{2gS_{GS1}}{(V_{TO})^2} \right) \sin\theta}$$

Where: S_{GS1} = 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

(7) *Expansion of Takeoff Data for a Range of Airport Elevations.*

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

(ii) 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:

(a) When the basic takeoff tests are accomplished between sea level and approximately 3,000 feet, the maximum allowable extrapolation limits are 6,000 feet above and 3,000 feet below the test field elevation. If it is desired to extrapolate beyond these limits, one of two procedures may be employed.

(b) *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 verifying 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 elevation by an amount equal to zero percent for the highest airport elevation approved on the results of the basic tests Also, it should result in an additional cumulative two percent incremental factor for each

1,000 feet of elevation above the highest airport elevation approved for zero percent conservatism. The two 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:

1 Previously established calculation procedures should be used, taking into account all known variables.

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

3 The brake kinetic energy limits established by airplane ground tests should not be exceeded.

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

1 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.

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

3 If verifying tests substantiate the expanded takeoff data, the data may be further expanded up to 6,000 feet above the altitude at which the verifying tests were conducted. At altitudes higher than 6,000 feet above the verifying test altitude, the two percent per 1,000 feet cumulative factor discussed in paragraph (b) above should be applied starting at zero percent at the verifying test altitude plus 6,000 feet.

c. Jets Over 6,000 Pounds Maximum Takeoff Weight and Commuter Category Airplanes.

(1) *Objective of Takeoff Requirement.* Section 23.53(c) 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.

(2) *Takeoff Profile*. Tests are required to determine the performance throughout the takeoff path as specifically defined by § 23.55 through § 23.59, and as discussed in the following sections of this AC.

5. § 23.55 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*. Accelerate-stop tests should be determined in accordance with the provisions of this paragraph.

(i) *Number of Test Runs*. 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) *Time Delays*. The procedures outlined in paragraph 23.55b(12), apply appropriate time delays for the execution of retarding means related to the accelerate-stop operational procedures and for expansion of accelerate-stop data to be incorporated in the AFM.

(iii) *Reverse Thrust*. The stopping portion of the accelerate-stop test may not utilize reverse thrust unless the thrust reverser system is shown to be safe, reliable, and capable of giving repeatable results. Refer to paragraph 23.55c.

(2) *Airport Elevation*. 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) *Braking Speeds*. 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, and so forth. These runs should be made with the airplane weight and kinetic 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, auto braking systems, and so forth, a full set of tests, as mentioned in paragraph 23.55b(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 demonstration 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. If installed, the propeller pitch controls should be applied in a manner that 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 after-stop condition exists. A satisfactory after-stop condition is defined as one in which fires are confined to tires, wheels, and brakes, and which would not result in a 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 rejected take-off (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 23.55b(6), should be made.

(8) *Instrumentation.* 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. For propeller equipped aircraft, the propeller condition should also be considered. Refer to information in subparagraph (11), Engine Power.

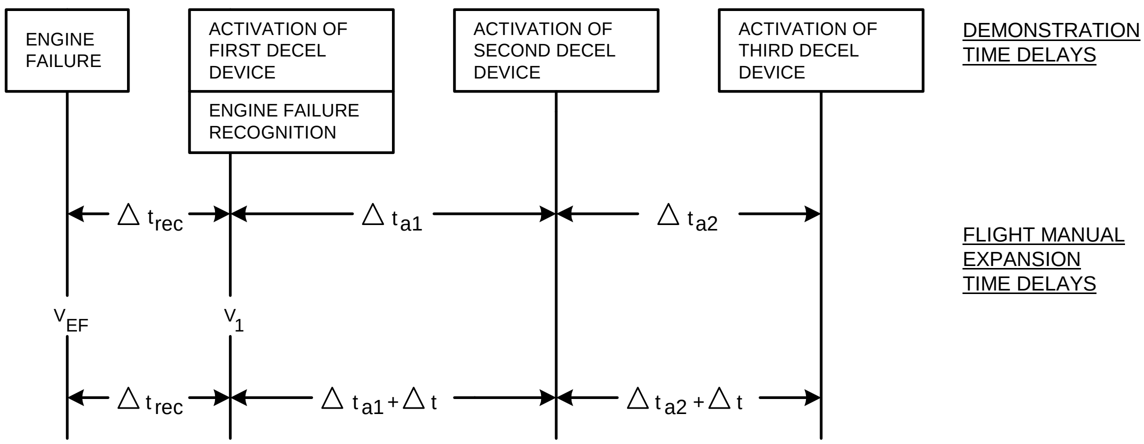
(11) *Engine Power.* Engine power should be appropriate to each segment of the rejected takeoff and account for thrust decay times. Refer to information in § 23.57(a)(2) in paragraph 23.55c(1). At the selected speed that corresponds to the required energy, the airplane is brought to a stop employing the acceptable braking means. For propeller equipped aircraft, the critical engine's propeller should be in the position it would normally assume when an engine fails and the power lever is closed. For turbojet aircraft, the critical engine’s power lever should be left in the position it is in when the engine fails unless there is an automatic system that moves it.

(i) *High-Drag Propeller Position (for propeller equipped aircraft).* 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, that is, ground fine, is conditional on the presence of a throttle position that 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.

(ii) *Reverse Thrust.* Refer to paragraph 23.55c for other guidance on when reverse thrust may be used for propeller driven airplanes. Demonstration of full single engine reverse controllability on a wet runway and in a 10-knot adverse crosswind will be required. Control down to zero speed is not essential, but a cancellation speed based on controllability can be declared and credit given for use of reverse thrust above that speed. The use of reverse thrust on one engine on a wet runway requires that the reverse thrust component be equally matched by a braking component and rudder use on the other side. Experience has shown that using reverse thrust with one engine inoperative requires brakes to be modulated differently between left and right while applying only partial reverse thrust, even on dry pavement. Disconnecting nose wheel steering will not adequately simulate a wet runway for a full reverse condition. The use of a reverse thrust propeller position 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. Selection of reverse thrust from takeoff power typically requires the power lever to be retarded to idle, a gate or latching mechanism to be overcome, and the power lever to be further retarded into the ground/reverse range. This is interpreted as three "distinctive motions," with each regarded as activation of a separate deceleration device. Accelerate-stop time delays should be determined accordingly and applied to expansion of data. Experience has shown that single engine thrust reverse, due to rudder blanking, may not be as critical as two-engine reverse, for controllability. If brake modulation is required and allowed for steering, then the reduced braking must be accounted for in the stopping performance.

(12) *Accelerate-Stop Time Delays.* Figure 5 is an illustration of the accelerate-stop time delays considered acceptable for compliance with § 23.45:

Figure 5 - 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 one second, whichever is greater, in order to allow a time that 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 one-second reaction time delay to account for in-service variations. For AFM calculations, airplane deceleration is not allowed during the reaction time delays. If a command is required for another crewmember to actuate a deceleration device, a two-second delay, in lieu of the one-second delay, should be applied for each action. For automatic deceleration devices that 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 normal and/or the emergency procedures section of the AFM. The procedures should also be repeated in the performance information section of the AFM so pilots clearly understand how aggressively the maneuver is performed in flight test so they can meet the published distances.

c. Use of Reverse Thrust. Section 23.55(b) permits means other than wheel brakes to be used in determining the stopping distance, when the conditions specified in § 23.55(b) are met. One of the conditions is that the means be safe and reliable.

(1) *Reliable.* Compliance with the "reliable" provision of the rule may be accomplished by an evaluation of the pitch changing/reversing system in accordance with § 23.1309. The methods of AC 23.1309-1 should be used in the evaluation, even though type-certificated engine or propeller systems may not have been subjected to the AC 23.1309-1 analysis during certification. Additionally, Society of Automotive Engineers (SAE) document ARP-926A, "Fault/Failure Analysis Procedure," will assist in conducting reliability and hazard assessments. Additionally, § 23.1309(d) requires the system to be designed to safeguard against hazards to the airplane in the event the system or any component thereof malfunctions or fails. An acceptable means for showing compliance with the requirement would be to conduct a Failure Modes and Effects Analysis (FMEA) of the system. An acceptable analysis would show that the effects of any system or component malfunction or failure would not result in a hazard to the airplane and that the propeller reversing system is reliable. SAE document, ARP-926A, contains acceptable criteria for conducting such an analysis.

(2) *Safe*. Compliance with the "safe" provisions of §§ 23.55 (b)(2) and 23.75(f)(1) will require an evaluation of the complete system, including operational aspects, to ensure no unsafe feature exists.

(i) Safe and reliable also means that it is extremely improbable that the system can mislead the flight crew or will allow gross asymmetric power settings, for example, forward thrust on one engine versus reverse thrust on the other. In achieving this level of reliability, the system should not increase crew workload or require excessive crew attention during a very dynamic time period. Also, the approved performance data should be such that the average pilot can duplicate this performance by following the AFM procedures.

6. § 23.57 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 as required by § 23.1587(d)(6).

(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(c)(3) is shown.

(ii) Section 23.66 requires the airplane not to 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(c)(3). 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 at low power to weight that include acceleration segments between 400 and 1500 feet and end at 1500 feet. At high power to weight, these takeoff paths extend considerably higher than 1500 feet above the takeoff surface. On some airplanes, either the takeoff speed schedules or the flap configuration, or both, 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 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 appendix 7 of this AC 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, for example, ice protection, air conditioning, and so forth. 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/thrust levers to maintain torque/N1 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/N1 or temperature limits.

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

(1) *Explanation*. Propeller or jet thrust/drag characteristics should represent conditions that occur when the engine is fails. 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/jet engine 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). Refer to figure 12. Refer to paragraph 23.61b(2) for further guidance.

(2) *Procedures*.

(i) The level acceleration segment in the AFM net takeoff profile should begin at the horizontal distance along the takeoff flight path where the net climb segment reaches the AFM specified acceleration height. Refer to figure 12.

(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:

Table 5 - AFM Acceleration Height

Given	
Takeoff surface pressure altitude (Hp)	= 2,000 feet
Airport standard temperature absolute (T_S)	= 11°C+273.2 = 284.2°k
Airport ambient temperature absolute (T_{AM})	= -20°C+273.2 = 253.2°k
Geometric height required (Δh)	= 1,500 feet above takeoff surface
Find:	
Pressure altitude increment (ΔHp) above the takeoff surface	
	$\Delta Hp = \Delta h(T_S/T_{AM})$ = 1500 feet (284.2°k/253.2°k)
	ΔHp = 1684 feet

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

(l) *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 § 23.51(c)(4).

(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.

(l) *Explanation*.

(i) The intent of this requirement is to permit only routine crew actions to establish the engine-inoperative takeoff path. The power levers may only be adjusted early during the takeoff roll, as discussed under § 23.57(a)(1), 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 based on a feathered propeller up to 400 feet above the takeoff surface, automatic propeller feathering devices may be approved if adequate system reliability is shown in accordance with § 23.1309. Other automatic systems such as one which minimizes drag of the inoperative propeller by sensing negative torque may also be approved. Drag reduction for a manually feathered propeller is permitted for flight path calculations only after reaching 400 feet above the takeoff surface.

(ii) For flap retraction above 400 feet, a speed of not less than the lesser of 1.1 V_{MC} or 1.2 V_{S1} should be maintained.

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

(1) *Explanation*. To take advantage of ground effect, AFM takeoff paths utilize a continuous takeoff path from V_{LOF} to 35 feet, covering the range of power-to-weight ratios. From that point, free air performance, in accordance with § 23.57(e), is added segmentally. This methodology may yield an AFM flight path that is steeper with the gear down than up. The airplane should 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(e)(2) - Takeoff Path Segment Conditions.

(l) *Explanation*. Section 23.57(e)(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, and so forth) 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 (l); or

(ii) The actual performance variation during the segment.

i. 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 that 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 provided the following:

(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 percent of the approved takeoff power.

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

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

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

(a) When the antiskid system (if installed) is inoperative;

(b) On runways contaminated with standing water, snow, slush or ice;

(c) On wet runways unless suitable performance accountability is made to the increased acceleration and stopping distances on these surfaces; or

(d) Where items affecting performance cause a significant increase in crew workload. Examples are inoperative equipment (for example, inoperative engine gauges, reversers or engine systems resulting in the need for additional performance corrections) or non-standard operations (that is, any situation requiring a non-standard takeoff technique).

(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 and, if necessary, establish a time interval.

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

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

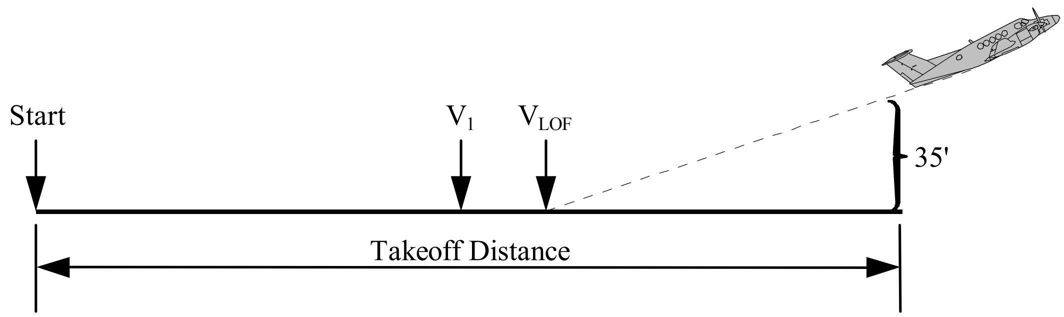
7. § 23.59 Takeoff Distance and Takeoff Run.

a. Takeoff Distance - Section 23.59(a).

(1) *Explanation*. The takeoff distance is either of the two distances depicted in figures 6 and 7 and discussed in paragraph b(l)(a) or (b), whichever yields the higher value. 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.

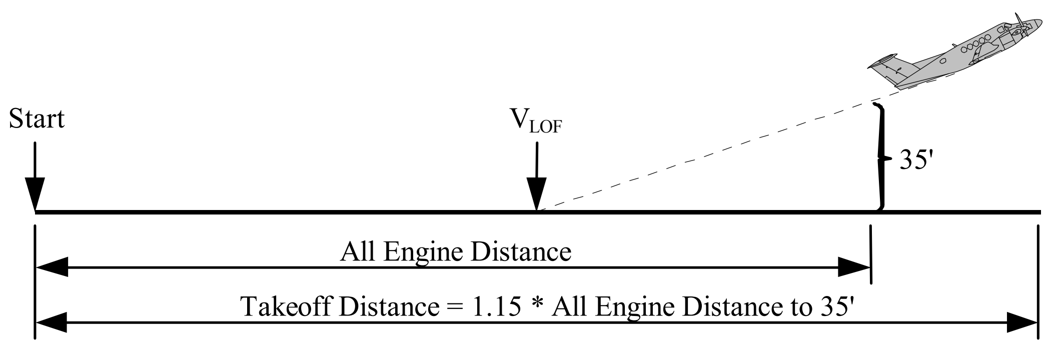
(i) The distance measured to 35 feet with a critical engine failure recognized at V_1. Refer to figure 6.

Figure 6 Takeoff Distance Critical Engine Failure Recognized at V_1



(ii) 115 percent of the distance measured to 35 feet with all engines operating. Refer to figure 7.

Figure 7 - Takeoff Distance - All Engines Operating



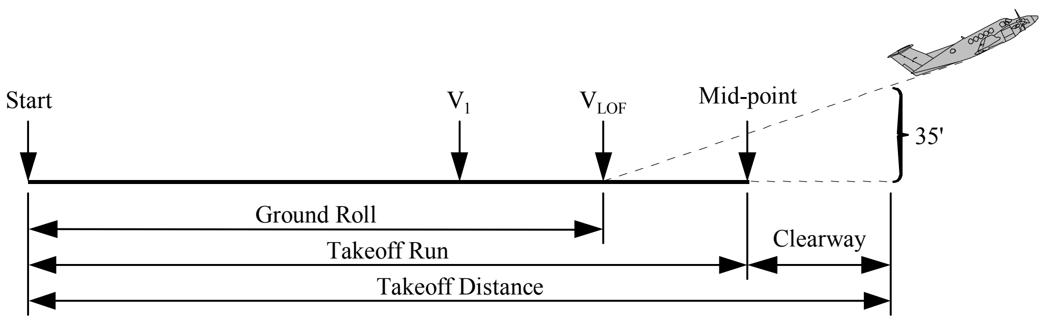
b. Takeoff Run - Section 23.59(b).

(1) *Explanation.*

(i) Takeoff run is a term used for the runway length when the takeoff distance includes a clearway and the takeoff run is either of the two distances depicted in figure 6 and 7, and discussed in paragraph b(1)(i)(a) and (b), whichever yields the higher value. A clearway is where the accelerate-go distance does not remain entirely over the runway. These distances are measured as described in § 23.59(a). 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.

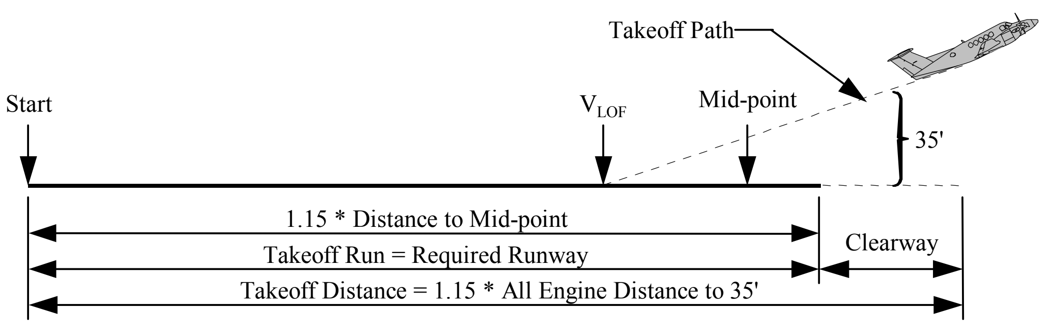
(a) The distance from start of takeoff roll to the mid-point between liftoff and the point at which the airplane attains a height of 35 feet above the takeoff surface, with a critical engine failure recognized at V_1. Refer to figure 8.

Figure 8 - Takeoff Run - Critical Engine Failure Recognized at V_1



(b) 115 percent 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. Refer to figure 9.

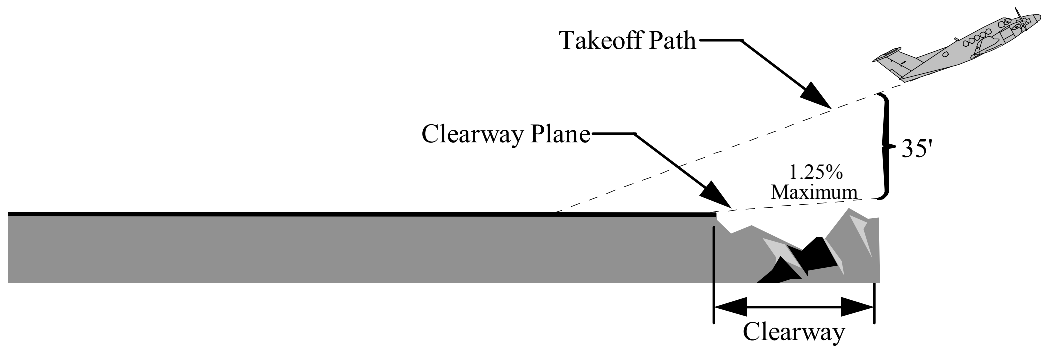
Figure 9 - Takeoff Run - All Engines Operating



(ii) There may be situations in which the one-engine-inoperative condition (paragraph b(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 b(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. The clearway is considered to be part of the takeoff surface, and a height of 35 feet may be measured from that surface. Refer to figure 10.

Figure 10 - Clearway Profiles



8. § 23.61 Takeoff Flight Path.

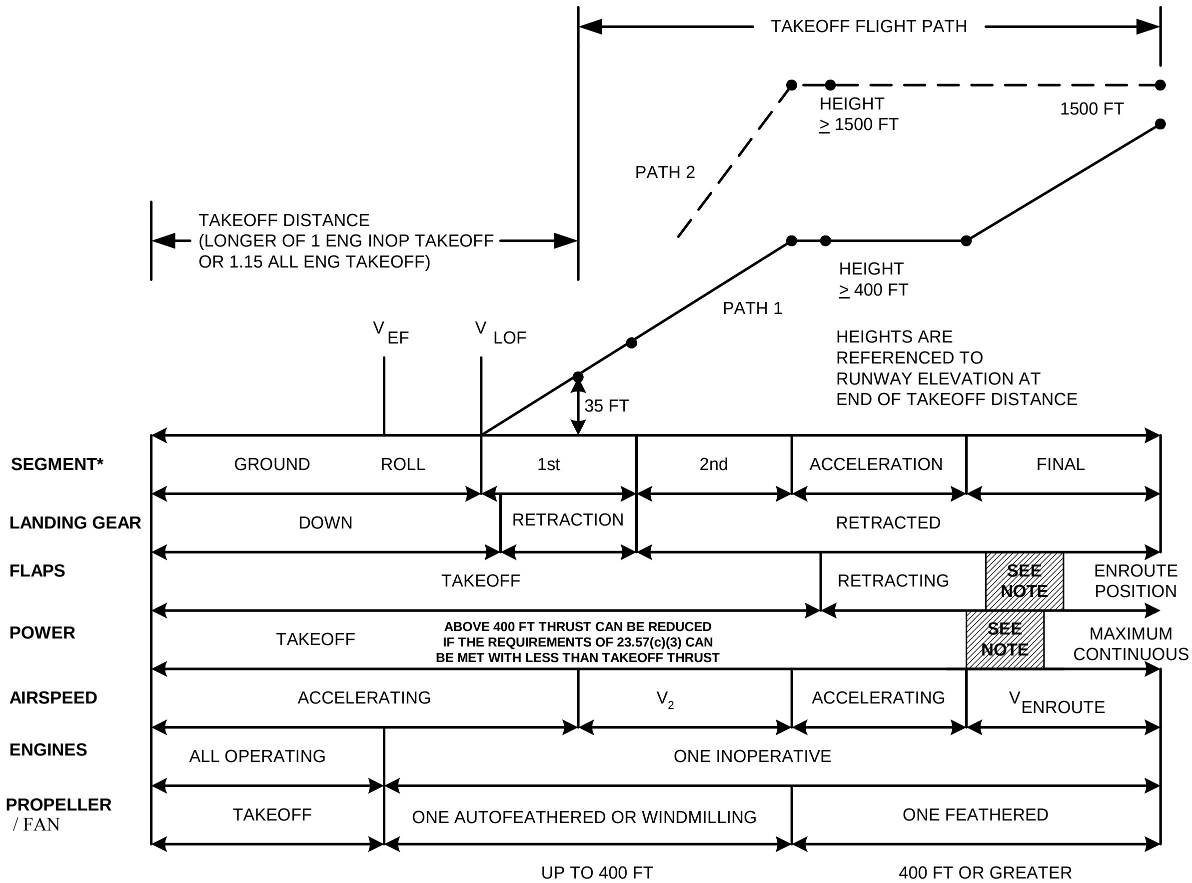
a. Takeoff Flight Path - Section 23.61(a). The takeoff flight path begins 35 feet above the takeoff surface at the end of the takeoff distance determined in accordance with § 23.59. The takeoff flight path ends when the airplane's height is the higher of 1,500 feet above the takeoff surface or at an altitude at which the configuration and speed have been achieved in accordance with § 23.67(c)(3). Refer to figure 11.

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. Refer to figure 12.

(2) The net takeoff flight path is the flight path used to determine the airplane obstacle clearance. Section 23.61(b) states the required climb gradient reduction to be applied throughout the flight path to determine 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.

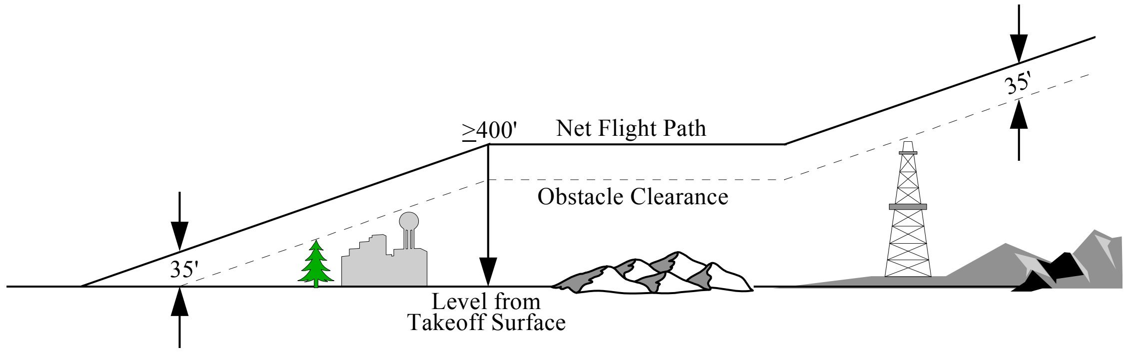
Figure 11 - Takeoff Segments and Nomenclature



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(c)(3) is shown. The time limit on takeoff thrust cannot be exceeded.

*Segments as defined by § 23.67.

Figure 12- Net Takeoff Flight Path



9. § 23.65 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 10,000 feet with wing flaps set to the takeoff position. This is necessary to enable comparison with the minimum climb performance required and for AFM presentation of climb performance data of 10,000 feet including the effect of altitude and temperature (refer to § 23.1587) and including the effect of weight for aircraft over 6,000 pounds maximum takeoff weight (MTOW) and turbine engine aircraft.

(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; and

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

(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 three minutes or 3,000 feet minimum while holding airspeed substantially constant. Climbs should be conducted 90 degrees 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 feet-per-minute. 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 it affords opportunity 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.

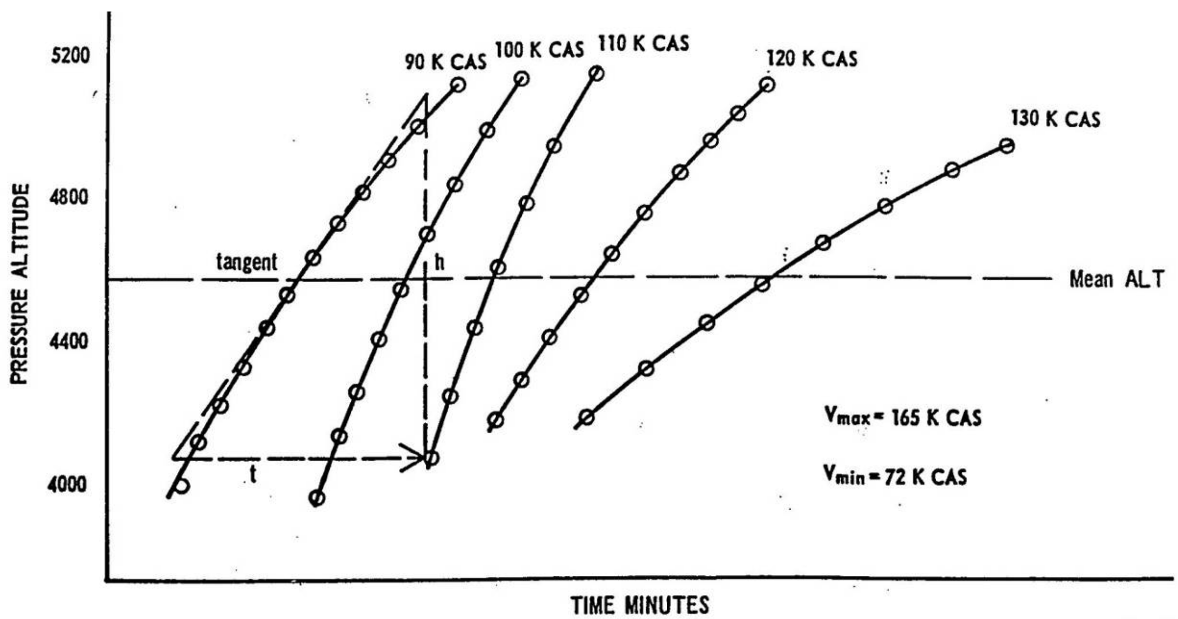
(3) *Test Airspeeds*. The airspeeds selected for the sawtooth should bracket the best climb speed, which for preliminary purposes may be estimated as 140 percent of the power-off stalling speed. The lowest climb test speed should be as near the stalling speed as can be flown without evidence of buffeting or necessity for abnormally frequent or excessive control movements, which might penalize the climb performance. Although the example shown in figure 13 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 five 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 mid-range test altitude provide a useful aid in defining the curves in figure 14.

(4) *Data Plotting*. Sawtooth climb data is plotted on a graph using altitude and time as the basic parameters as shown in figure 13. 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.

(5) *Data Corrections*. For the density altitude method of data reduction (refer to 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 14.

(6) *Plotting of Corrected Data.* After the observed data has been corrected to the desired standards, it can be plotted as shown in figure 14 with the rate of climb versus CAS at various density altitudes. It should be noted that the stall speed points are not usually true stabilized zero rate-of-climb data points. However, the stall speed points are useful in defining the asymptotic character of the left hand part of the curve.

Figure 13 - Observed Data



(7) *Speed Schedule Data Points.* From the curves of figure 14, 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 rate-of-climb 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 rate-of-climb 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, V_{MIN}, and V_{MAX} are all the same speed at this point. (Note: V_{MIN} as used here is not related to the V_{MIN} in stall testing.)

(8) *Speed and Rate of Climb.* Directly from information obtained from figure 14, 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 15, it is possible to determine the rate of climb from sea level to the absolute ceiling.

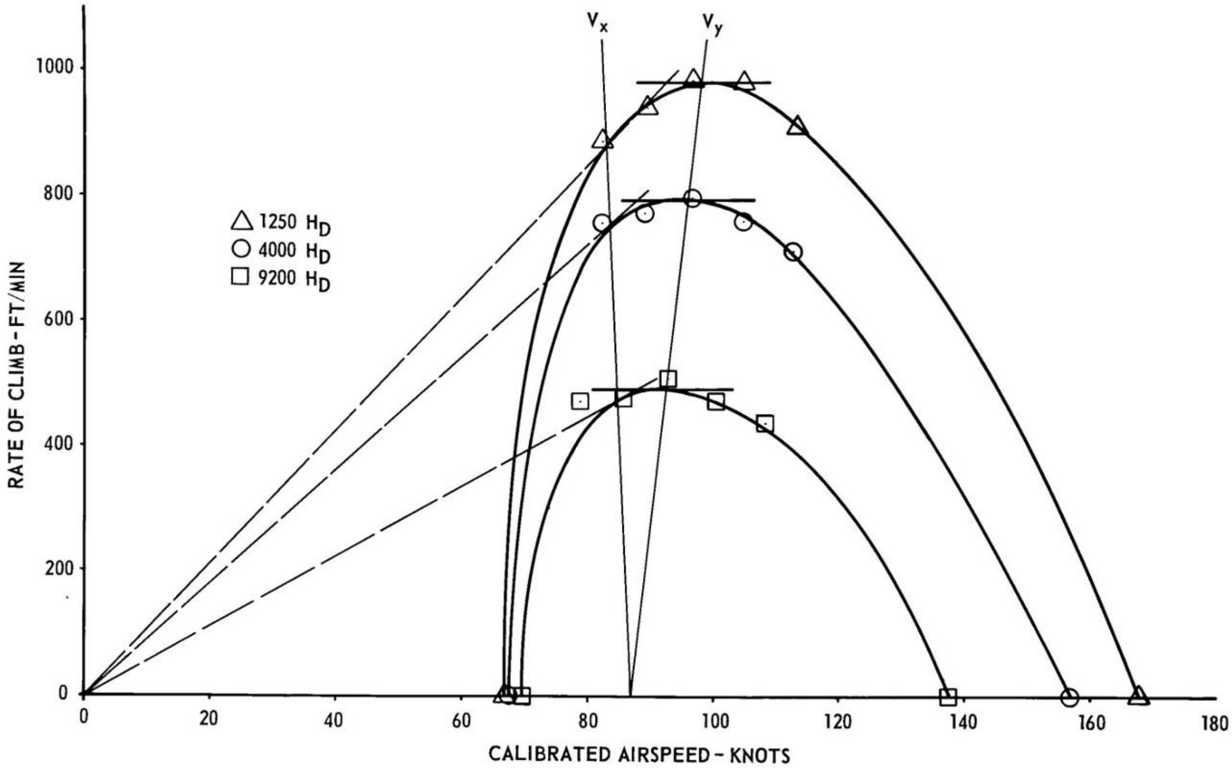
(9) *Cowl Flap and Mixture*. For propeller equipped aircraft, cowl flaps should be in the position used for cooling tests. The mixture setting should be set to that used during the cooling test.

(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 from sea level to 10,000 feet and from ISA to ISA + 30 °C 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.

Figure 14 - Rate of Climb vs. Airspeed

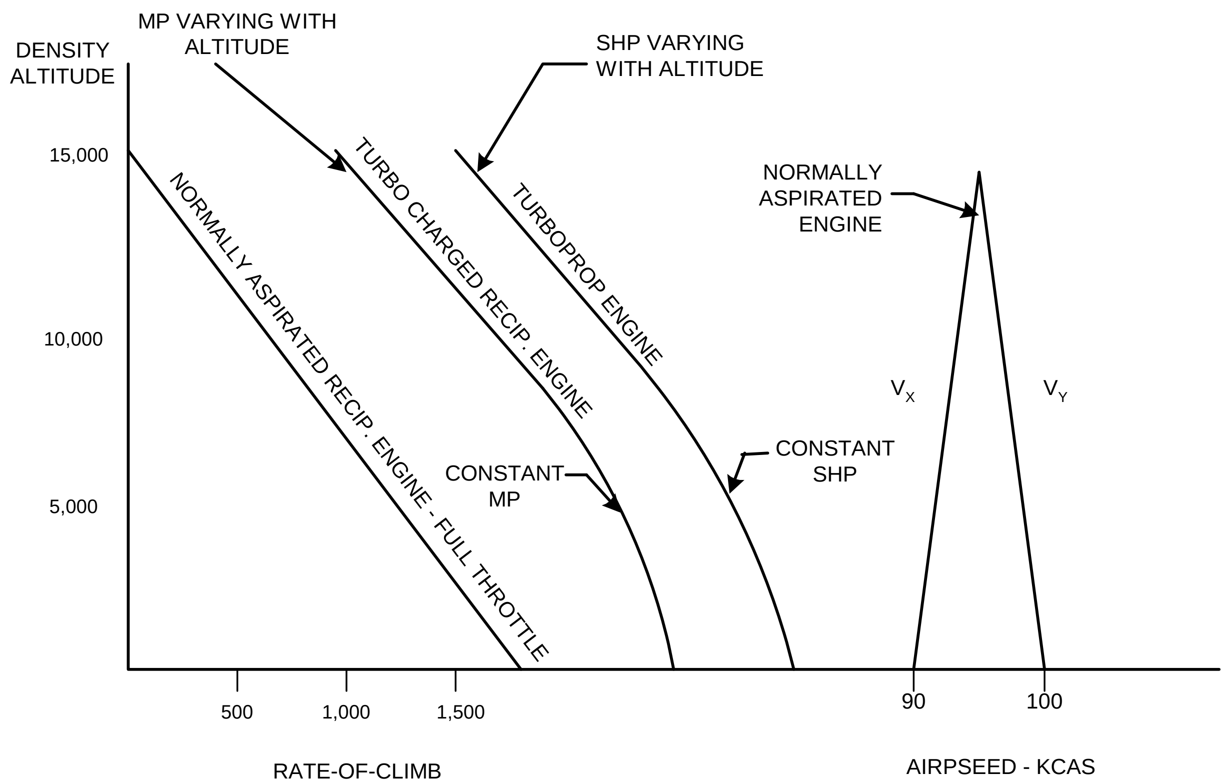


e. Special Equipment or Instrumentation. Climb performance tests require an airspeed indicator, sensitive altimeter, and total air temperature indicator with a known recovery factor. For reciprocating engine-powered airplanes, an induction air temperature gauge, engine tachometer, manifold pressure gauge, and cylinder head temperature indicator may be appropriate. For turbine-powered airplanes, indicators of power parameters, such as torque meter, exhaust gas temperature (EGT), N1, N2, and propeller r.p.m., may be appropriate. Either a fuel counter or fuel flowmeter, or both, 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.

f. Climb Performance After STC Modifications. Reserved.

10. § 23.66 Takeoff Climb, One Engine Inoperative. Section 23.66(1) for normal, utility, and acrobatic category airplanes greater than 6,000 pounds and turbine-engine powered airplanes in the normal, utility, and acrobatic category requires the propeller of the inoperative engine to be in the position it "rapidly and automatically assumes" for the determination of one-engine inoperative takeoff climb performance. This allows performance credit for a reliable system that rapidly drives the propeller to a low drag setting with no action from the pilot. If no such system is fitted, the propeller should be assumed to be in the most critical condition.

Figure 15 - Rate of Climb and Speeds



11. § 23.67 Climb: One Engine Inoperative.

a. Explanation.

(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 Table 6.

(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 10,000 feet or higher and temperatures from ISA to ISA + 30 °C. This is necessary to enable comparison with the prescribed climb requirement at 5,000 feet altitude and for AFM presentation of climb performance data for altitudes and temperatures as prescribed in § 23.1587. Secondary objectives are:

(i) 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

(ii) To establish the speed for best rate of climb (or for minimum descent, as appropriate) that, regardless 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)(5).

(3) *WAT Charts*. For airplanes with an MTOW greater than 6,000 pounds and all turbine-powered airplanes, a WAT chart is an acceptable means to meet the performance requirements. Refer to Table 6 for specific climb requirements summary.

Table 6 - WAT Chart

Regulation	23.67(a)(1)	23.67(a)(2)	23.67(b)(1)	23.67(b)(2)	23.67(c)(1)	23.67(c)(2)	23.67(d)(1)	23.67(d)(2)	23.67(d)(3)	23.67(d)(4)
Category	Normal, Utility, and Aerobatic						Normal, Utility, and Aerobatic Turbojets > 6,000 lbs and Commuter			
Engine Type and Airplane Weight	Recip 6,000 lbs or less		Recips > 6,000 lbs and Turboprops		Turbojets 6,000 lbs or less					
V_{SO} (kts)	>61	≤61								
Power On Operative Engine	≤ MCP	≤MCP	MTOP	≤MCP	MTOP	≤MCP	MTOP	MTOP	≤MCP	MTOP
Configuration	Flap and gear retracted	Flap and gear retracted	Take-off flap, gear retracted	Flap and gear retracted	Take-off flap, gear retracted	Flap and gear retracted	Take-off flap, gear extended	Take-off flap, gear retracted	Flap and gear retracted	Approach flap[1], gear retracted
Propeller Position on Inop Engine	Minimum drag	Minimum drag	Minimum drag	Minimum drag			Position it automatically and rapidly assumes	Position it automatically and rapidly assumes	Minimum drag	Minimum drag
Attitude							Wings level			
Climb Speed	≥$1.2V_{S1}$	≥$1.2V_{S1}$	Equal to that achieved at 50ft demon-strating 23.53	≥$1.2V_{S1}$	Equal to that achieved at 50ft demon-strating 23.53	≥$1.2V_{S1}$	V_2	V_2	≥$1.2V_{S1}$	As in procedures but ≥$1.5V_{S1}$
Altitude (ft)	5,000	5,000	400	1,500	400	1,500	Take-off surface	400	1,500	400
Required Climb Gradient (%)	≥1.50	No minimum but must determine steady climb/ descent gradient	≥ 1.00	≥0.75	≥ 1.20	≥0.75	Measurably positive[2]	≥2.00[3]	≥1.20[4]	≥2.10[5]

Notes:

1 Approach position(s) in which V_{S1} does not exceed 110 percent of the V_{S1} for the related all-engines-operating landing positions.

2 Measured positively for two-engine airplanes, ≥ 0.3 percent for three-engine airplanes, or ≥ 0.5 percent for four-engine airplanes.

3 ≥2.0 percent for two-engine airplanes, ≥2.3 percent for three-engine airplanes, ≥2.6 percent for four-engine airplanes.

4 ≥1.2 percent for two-engine airplanes, ≥1.5 percent for three-engine airplanes, ≥1.7 percent for four-engine airplanes.

5 ≥2.1 percent for two-engine airplanes, ≥2.4 percent for three-engine airplanes, ≥2.7 percent for four-engine airplanes.

6 MCP is maximum continuous power

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.

(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 a five-degree 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. Jet Aircraft > 6,000 pounds and Commuter Category Airplanes.

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

(2) *Climb Performance Methods.* Climb performance should be determined in the configurations necessary to construct the net takeoff flight path and to show compliance with the approach climb requirements of § 23.67(d). Some net takeoff flight path conditions will require wings level climb data. Refer to paragraph 23.57g(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 a constant heading. For all other conditions, climb performance may be determined with up to a five-degree 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. Refer to 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(d) 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 that 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 that will maintain the temperature of major powerplant components, engine fluids, and so forth, 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*. Refer to paragraph 23.57b.

12. § 23.71 Glide (Single-Engine Airplanes).

a. Explanation.

(1) *Gliding Performance*. Section 23.71 requires the optimum gliding performance to be scheduled, with the landing gear and wing flaps in the most favorable position and the propeller in the minimum drag position.

(2) *Background*. The primary purpose of this information is to provide the pilot with the airplane gliding performance. Such data will be used as an approximate guide to the gliding range that can be achieved, but they will not be used to the same degree of accuracy or commercial significance as many other aspects of performance information. Hence, some reasonable approximation in its derivation is acceptable.

b. Means of compliance.

(1) *Engine-inoperative Tests.* Clearly the simplest way of obtaining accurate data is to perform actual engine-inoperative glides. These tests should be carried out over an airfield, thereby permitting a safe landing to be made if the engine does not restart at the end of the test.

(i) *Fixed-Pitch Propeller*. Most likely, the propeller will be windmilling after the fuel is shut off. If this is the case and the propeller does not stop after slowing to the best glide speed, then the gliding performance should be based on a windmilling propeller. Stalling the airplane to stop the propeller from windmilling is not an acceptable method of determining performance because the procedure could cause the average pilot to divert attention away from the primary flight task of gliding to a safe landing.

(ii) *Constant-speed/Variable-pitch Propeller Airplanes.* For these propellers, the applicant may assume that the means to change propeller pitch is still operational and, therefore, the propeller should be set at the minimum drag configuration. For most installations, this will be coarse pitch or feather.

(iii) *Turbojet airplanes*. Reserved.

(2) *Sawtooth Glides*. A method of determining glide performance is sawtooth glides. These glides can be flown using the same basic procedures in § 23.65 of this AC minus the power considerations. For simplification, the test need only be flown at an intermediate altitude and gross weight generating one speed for the pilot to use. The best lift over drag speed is frequently higher than the best rate of climb speed; therefore, the airspeed range to flight test may be bracketed around a speed 10 to 15 percent higher than the best rate of climb speed.

(3) *Performance Data*. A chart or table should be constructed for the AFM that presents the literal (over-the-ground) gliding distances for the altitude range expected in service, at the best demonstrated glide speed. As a minimum, a statement of nautical miles (NM) per 1,000 feet loss of altitude at the demonstrated configuration and speed at MTOW, standard day, no wind, should be given.

13. § 23.75 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 three knots for seaplanes or amphibians on water.

(2) *Companion Requirements*. Sections 23.143(a)(6), 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 and Landing*. The steady 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. It has generally been considered that some power may be used during a steady gliding approach to maintain at least 1.3 V_{S1} 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 abrupt maneuvers using 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) *Adverse Landing Conditions*. The airplane should be satisfactorily controllable when landing under the most unfavorable conditions to be encountered in service, including crosswinds, wet runway surfaces, and with one engine inoperative. Demonstration of landing with an adverse crosswind of at least 0.2 V_{SO} is addressed in § 23.233. Operations on wet (but not contaminated) runway surfaces have been simulated by disconnecting the nosewheel steering on large part 23 airplanes. The effect of weight on the landing distance due to its influence on controllability of reverse thrust should be considered. The criticality of the adverse landing conditions should guide the level of complexity applicants use in determining controllability. Existing flight test practices have proven adequate for propeller driven part 23 airplanes, but they may not be adequate for small jets. Additional guidance may be found in AC 25-7B. Part 23 jets typically have higher landing speeds and little drag to help slow the airplane. Landing

accidents dominate the non-fatal accidents for small jets. This is a critical phase of flight for small jets and adequate attention should be given to adverse landing conditions such as wet runways.

(5) *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).

(6) *Landing Distance Credit for Disking Drag and Reverse Thrust*. Most turboprop installations embody provisions for reduction of propeller blade pitch from the "flight" regime to a "ground" regime to produce either a significant level of disking drag or reverse thrust or both, 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 means other than wheel brakes to be used in determining landing distance, when the conditions specified in § 23.75(f) are met. Such disking drag or reverse thrust may be acceptable in showing compliance with § 23.75(f) provided the means is safe and reliable.

(i) *Reliable*. Compliance with the "reliable" provision of the rule may be accomplished by an evaluation of the pitch changing/reversing system in accordance with § 23.1309. The methods of AC 23.1309-1 should be used in the evaluation even though type-certificated engine or propeller systems may not have been subjected to the AC 23.1309-1 analysis during certification. Additionally, Society of Automotive Engineers (SAE) document ARP-926A, "Fault/Failure Analysis Procedure," will assist in conducting reliability and hazard assessments.

(a) For commuter category airplanes, § 23.1309 requires the system to be designed to safeguard against hazards to the airplane in the event the system or any component thereof malfunctions or fails. An acceptable means for showing compliance with the requirement would be to conduct a FMEA of the system. An acceptable analysis would show that the effects of any system or component malfunction or failure would not result in a hazard to the airplane and that the propeller reversing system is reliable. SAE document, ARP-926A, contains acceptable criteria for conducting such an analysis.

(b) Safe and reliable should also mean that it is extremely improbable that the system can mislead the flight crew or will allow asymmetric power settings, that is, forward thrust on one engine versus reverse thrust on the other. In achieving this level of reliability, the system should not increase crew workload or require excessive crew attention during a very dynamic time in the landing phase. Also, the approved performance data should be such that the average pilot can duplicate this performance by following the AFM procedures.

(ii) *Safe*. Compliance with the "safe" provisions of § 23.75(f)(1) will require an evaluation of the complete system, including operational aspects, to ensure no unsafe feature exists.

(iii) *Disking Drag for 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, 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. Refer to b(2) for commuter category time delays. Associated procedures should be included in the AFM. If the disking drag or some other powerplant-related device has a significant effect on the landing distance, the effect of an inoperative engine should be determined and published in the AFM performance section.

(iv) *Disking Drag for 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.

(v) *Reverse Thrust for Multiengine Airplanes*. In the approval of reverse thrust for turboprop and turbojet airplanes, due consideration should be given for thrust settings allowed, the number of operating engines, and control of the aircraft with one engine inoperative. If the landing distance depends on the operation of any engine and the landing distance would be noticeably increased (2 percent has been found acceptable) when a landing is made with that engine inoperative, then the landing distance should be determined with that engine inoperative. However, if the use of compensating means (such as reverse thrust on the operating engine) will result in a landing distance not more than that with each engine operating, then the landing distance does not need to be determined with that engine inoperative. This assumes that there are no other changes in configuration, for example, flap setting associated with one engine inoperative, that will cause an increase in landing distance. 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. Refer to b(2) for commuter category time delays. Associated procedures should be included in the AFM.

(vi) *Reverse Thrust for Single-Engine Airplanes*. 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.

(7) *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.

(8) *Expansion of Landing Data for a Range of Airport Elevations*. When the basic landing tests are accomplished between sea level and approximately 3,000 feet, the maximum allowable extrapolation limits are 6,000 feet above and 3,000 feet below the test field elevation. If you desire to extrapolate beyond these limits, one of two procedures may be employed. These procedures are given in paragraph 23.53b(7).

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 three 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. Refer to 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.

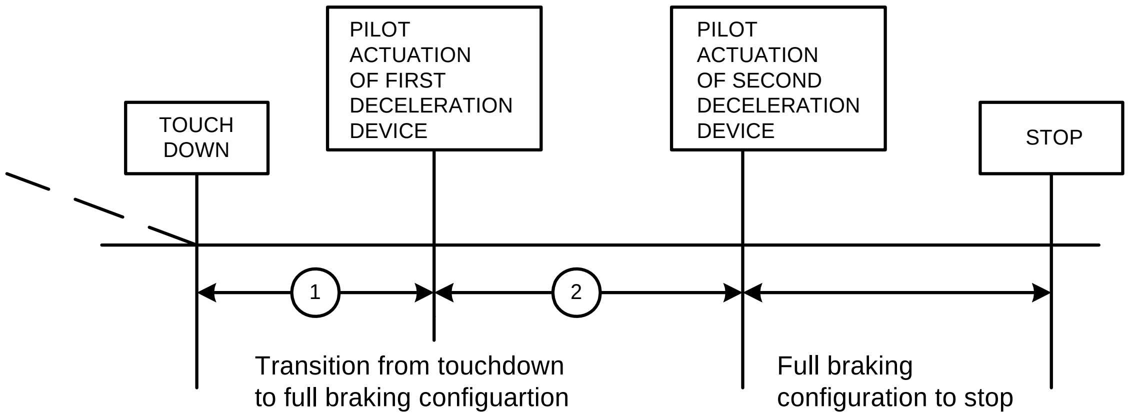
(2) *Commuter Category Time Delays.*

(i) The time delays shown in figure 16 should be used.

(ii) For approved automatic deceleration devices (for example, 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 one-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.

Figure 16 - Landing Time Delays



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 one 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, refer to item ① above.

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

(4) *Number of Landings*. At least six landings should be conducted on the same wheels, tires, and brakes to establish the proper functioning required by § 21.35(b).

(5) *Winds*. Wind velocity and direction should be measured adjacent to the runway during the time interval of each test run. Refer to paragraph 23.21a(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 Three Degrees.* If the applicant chooses an approach angle greater than three degrees, landing distances that result from utilizing a three-degree approach angle should be determined and published in the AFM to enable operators to comply with related operational 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 1) runway observers and 2) time histories, though runway observers are typically used for small, simple airplanes. 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.

(vii) Runway slope.

(ix) Direction of landing run.

(x) Wind direction and velocity at a height of six 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 such as differential GPS, 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.

14. § 23.77 Balked Landing Climb.

a. Explanation (Normal, Utility, and Acrobatic Category). Reciprocating engine airplanes with a MTOW of 6,000 pounds (2730 kg) or less.

(1) *Purpose*. The configuration that is specified for this climb requirement ordinarily is used in the final stages of an approach for landing. 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.

(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 two seconds or less. 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 Seconds*. If the flaps will not fully retract in two seconds, the climb available with the flap position at the end of two seconds may be used and the position noted in the AFM. Other considerations should include flight characteristics, ease of operation and reliability. If the flap is not mechanical, 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 (Normal, Utility and Acrobatic Aircraft with MTOW greater than 6,000 pounds (2730 kg) and Turbine Engine Aircraft and Commuter Category Aircraft)**.** Sections 23.77(b)(1) and 23.77(c)(1) state that the engines are to be set at the power or thrust that is available eight 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. (Aircraft with a MTOW greater than 6,000 pounds and turbine-engine aircraft.)

(1) *Engine Trim*. Trim 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, if applicable, stabilize the airplane in level flight with symmetrical power on all engines, landing gear down, flaps in the landing position, at a speed of V_{REF} 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 V_{REF}, as defined in § 23.73, to approximately the test altitude. When power has stabilized, advance throttle(s) in less than one second to obtain takeoff power.

(iii) The power that is available eight 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 of the regulation applies to the balked landing climb.

Section 3. Flight Characteristics of 14 CFR § 23.141

1. § 23.141 General

a. Explanation.

(1) *Minimum Flight Characteristics*. The purpose of these requirements is to specify minimum flight characteristics that 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 of the fundamental nature of the airplane that is assumed to exist because the airplane behaves in flight in a certain consistent manner when the controls are placed in certain positions or are manipulated in a certain manner. In some cases, measurements of forces, control surface positions, or acceleration in pitch, roll, and yaw may be made to support a decision but, normally, it will be a pass/fail judgement by the Civil Aviation Authority's/FAA test pilot.

(2) *Exceptional Skills*. The phrase "exceptional piloting skill, alertness, or strength," is used repeatedly throughout the regulations and requires highly qualitative judgments on the part of the test pilot. The judgments should be based on the pilot's estimate of the skill and experience of the pilots who normally fly the type of airplane under consideration (that is, private pilot, commercial pilot, or airline transport pilot skill levels). Exceptional alertness or strength requires additional judgment factors when the control forces are deemed marginal or when a condition exists that requires rapid recognition and reaction to be coped with successfully.

b. Procedures. None.

Section 4. Controllability and Maneuverability

1. § 23.143 General.

a. Explanation.

(1) *Temporary Control Forces*. Temporary application, as specified in the table in § 23.143(c)(1), may be defined as the period of time necessary to perform the necessary pilot motions to relieve the forces, such as trimming or reducing power. The values in the table under § 23.143 of part 23 are maximums. There may be circumstances where a lower force is required for safety. If it is found that a lower force is necessary for safety, then that lower force should be established under § 21.21(b)(2).

(2) *Prolonged Control Forces*. Prolonged application would be for some condition that could not be trimmed out, such as a forward c.g. landing. The time of application would be for the final approach only if the airplane could be flown in trim to that point. Section 23.689 includes discussion concerning a failed cable. .

(3) *Controllability*. Controllability is the ability of the pilot, through a proper manipulation of the controls, to establish and maintain or alter the attitude of the airplane with respect to its flight path. It is intended in the design of the airplane that it be possible to "control" the attitude about each of the three axes, the longitudinal, the lateral, and the vertical axes. Angular displacements about the longitudinal axis are called "roll." Those about the lateral axis are called "pitch" and those about the directional axis are called "yaw." Controllability should be defined as "satisfactory" or "unsatisfactory." Unsatisfactory controllability would exist if the test pilot finds the controllability to be so inadequate that a

dangerous condition might easily occur and is unacceptable as a showing of compliance with the regulations.

(4) *Maneuverability*. Maneuverability is the ability of the pilot, through a proper manipulation of the controls, to alter the direction of the flight path of the airplane. In order to accomplish this, the airplane should be controllable, since a change about one of the axes is necessary to change a direction of flight. Any change in the direction of flight involves an acceleration normal to the flight path. Maneuverability is so closely related to controllability as to be inseparable in any real motion of the airplane. It is also similarly largely qualitative in its nature and should be treated in the same manner as has been suggested for controllability above.

(5) *Spring Devices*. If a spring device is installed in the control system, § 23.687 requires that the airplane not have any unsafe flight characteristics without the use of the spring device, unless the reliability of the device can be established by tests simulating service conditions. The airplane does not have to meet the handling, stability, and control requirements with a failed spring device; however, the airplane has to demonstrate that it is easily controllable by the pilot to continue flight to a safe landing with the failed spring(s).

(6) *Powered Trim Without Manual Backup*. Most of the part 23 airplanes built since the 1990s use some type of powered trim and have eliminated the manual trim wheel that was traditionally available to the pilot. This configuration makes the failure of the trim system more critical than in the past because pilots cannot change the trim position after the failure. If the failure of the trim system occurs during a slower flight regime such as climb, the control forces to return and land should be reasonable. If, on the other hand, the failure occurs during high-speed cruise in a fast airplane, the control forces when slowing down to land may exceed the prolonged (and maybe even the temporary) force limits in § 23.143. Applicants should account for this possibility and consider mitigation strategies to include in the AFM on how to handle this failure condition.

b. Procedures.

(1) *Landing*. Using the AFM recommended approach/landing speeds and power settings, determine that airplane controllability is satisfactory with the wing flaps extended and retracted. These tests should be accomplished at the critical weight/c.g. combination within the allowable landing range. For turboprop airplanes, the engine fuel control should be adjusted to the minimum flight-idle fuel flow permitted on airplanes in service unless it is shown that the range of adjustment permitted on airplanes in service has no measurable effect on flight-idle sink rate.

(2) *Other Flight Conditions*. Controllability and maneuverability procedures for other flight conditions, such as takeoff and V_{MC}, are covered in their respective sections.

(3) *Lateral imbalance*. Lateral imbalance flight evaluations should be conducted on all airplanes configured such that lateral trim and controllability may be affected. The following configurations should be considered and evaluated as appropriate:

(i) Takeoff - All engine, one-engine-inoperative (multiengine airplanes), V_{MC}, and crosswind operations.

(ii) Enroute - All engine, one-engine-inoperative (multiengine airplanes), and autopilot coupled operations.

(iii) Approach and Landing - All engine, one-engine-inoperative (multiengine airplanes), V_{MC} (where applicable), crosswind, and autopilot coupled operations.

(a) As a result of flight tests, appropriate lateral imbalance limitations and procedures should be developed. Different values of fuel imbalance for the various flight configurations may be required. Imbalance limits, if any, should be included in the AFM.

c. Data Acquisition and Reduction. A qualitative determination by the test pilot will usually suffice unless the control force limits are considered marginal. In this case, force gauges are used to measure the forces on each affected control while flying through the required maneuvers.

2. § 23.145 Longitudinal Control.

a. Explanation.

(1) *Elevator Power*. This regulation requires a series of maneuvers to demonstrate the longitudinal controllability during pushovers from low speed, flap extension and retraction, and during speed and power variations. The prime determinations to be made by the test pilot are whether or not there is sufficient elevator power to allow pitching the nose downward from a minimum speed condition and to assure that the required maneuvers can be performed without the resulting temporary forces becoming excessive.

(2) *Speeds Below Trim Speeds*. The phrase, "speeds below the trim speed," as used in § 23.145(a), means speeds down to V_{S1}.

(3) *Wing Flaps*. If gated or detented flap positions are provided, refer to the requirements in § 23.697(c). (An acceptable gate or detent is one that allows the pilot to readily determine the flap position without seriously detracting from other piloting duties under any flight condition, day or night.)

(4) *Loss of Primary Control Systems*. Section 23.145(e) is intended to cover a condition where a pilot has sustained some failure in the primary longitudinal control system of the airplane (for some multiengine airplanes, also loss of the directional control system) and is required to land using the power and trim system without the primary control. It is not intended that this test be demonstrated to an actual landing; however, a demonstration may be performed using manipulation of trim and power to a landing, if desired. Section 23.145(e) is the flight test to demonstrate compliance with the requirement that specifies a failure of the primary control system.

(5) *Analysis of System*. An analysis of the control system should be completed before conducting the loss of primary control system test. On some airplanes, the required single longitudinal control system failure could result in loss of both the downspring and the primary longitudinal control system. If this failure occurred on an airplane utilizing an extremely large

downspring, the loss of the downspring may result in a nose-up pitching moment at aft c.g. that could not be adequately countered by the basic pitch trim system.

b. Procedures. The wording of the regulation sufficiently describes the maneuvers required to show compliance. The selection of altitudes, weights, and c.g. positions to be flight tested by the FAA will depend on a study of the applicant's flight test report. Normally, the following combinations are checked during the certification tests:

(1) *Altitude*. Select a nominal altitude considering power available. Longitudinal control would not be expected to change much with typical part 23 altitude capabilities, so repeating tests near maximum altitude should only be needed when controllability is marginal and/or the airplane has high altitude capability like some of the part 23 jets.

(2) *Weight*. Maximum gross weight for all tests, except where otherwise described in paragraph (3) below.

(3) *C.G*. For conventional configurations, § 23.145(a), most aft c.g. and most aft c.g. approved for any weight; § 23.145 paragraphs (b) 1 through (b) 6, most forward and most aft c.g.; § 23.145(c), most forward c.g.; § 23.145(d), most forward c.g. and most forward c.g. approved for any weight; and § 23.145(e), both the forward and aft c.g. locations. Section 23.145(e) is sometimes more difficult to achieve at the aft c.g. than the forward limit, particularly if the airplane exhibits neutral to divergent phugoid tendencies.

(4) *Power or Configuration.* Pitching moments resulting from power or configuration changes should be evaluated under all conditions necessary to determine the most critical demonstration configuration.

c. Data Acquisition. No special instrumentation is required. The exception to this would be the l0-pound force in § 23.145(d), which should be measured with a force gauge. All longitudinal forces should be measured if the forces are considered marginal or excessive.

3. § 23.147 Directional and Lateral Control.

a. Explanation.

(1) *Yawed Flight*. Section 23.147(a) is intended as an investigation for dangerous characteristics during sideslip, which may result from blocked airflow over the vertical stabilizer and rudder. Rudder lock and possible loss of directional control are examples of the kinds of characteristics the test is aimed at uncovering. Section 23.177 also addresses rudder lock. Compliance may be demonstrated if the rudder stop is reached prior to achieving either l5 degrees of heading change or the l50-pound force limit, providing there are no dangerous characteristics. The control stop serves more effectively than the l50-pound force to limit the pilot's ability to induce a yaw beyond that demonstrated as acceptable.

(2) *Controllability following sudden engine failure.* Section 23.147(b) requires a demonstration of controllability following sudden engine failure during en route climb.

b. Procedures.

(1) *Yawed Flight*. The airplane configurations to be tested according to § 23.147(a) are:

(i) One engine inoperative and its propeller in the minimum drag position.

(ii) The remaining engines at not more than maximum continuous power.

(iii) The rearmost allowable c.g.

(iv) The landing gear: both retracted and extended

(v) The flaps retracted.

(vi) Most critical weight.

(vii) Airplane trimmed in the test condition, if possible.

(2) *Controllability Following Sudden Engine Failure*. In complying with the testing required by § 23.147(b), from an initial condition of straight flight with wings level, zero sideslip and in trim, simulate a sudden and complete failure of the critical engine. To allow for an appropriate delay, no action should be taken to recover the airplane for two seconds following the first indication of engine failure. The recovery action should not involve movement of the engine, propeller or trimming controls. At no time should the bank angle exceed 45 degrees or excessive yaw be developed. The evaluation of dangerous attitudes and characteristics should be based on each particular airplane characteristic and the flight test pilot's evaluation.

(i) The method used to simulate engine failure should be:

(a) For a reciprocating engine, closure of the mixture control; or

(b) For a turbine engine, termination of the fuel supply by the means which results in the fastest loss of engine power or thrust. Engine shut-off procedures would normally be sufficient.

c. Loss of Primary Control Systems. (Also, refer to AC 23-17.)

(1) *Explanation.* Section 23.147(c) is intended to cover a condition where a pilot has sustained some failure in the primary lateral control system of the airplane. If a single failure in the primary lateral control system could also cause the loss of additional control, then the loss of the additional controls must be considered. It must be shown that, with the loss of the primary lateral control, the airplane is safely controllable in all configurations and could be landed without exceeding the operational and structural limitations of the airplane. The rule calls out any engine configuration, speed, or altitude. This rule is interpreted to mean safely controllable such that the pilot can transition into a smaller, limited flight and configuration envelope, if necessary, for continued safe flight and landing. It is not intended that this test be demonstrated to an actual landing; however, a demonstration may be performed using manipulations of either lateral trim or sideslip, or both, generated by the rudder and differential power if available to a landing. Section 23.147(c) is the flight test to demonstrate compliance with the requirement that specifies a failure in the primary lateral control system. This failure implies a disconnection on the primary control system such that the ailerons are free to float and the lateral trim (if installed) is operational.

(2) *Analysis of System*. An analysis of the control system should be completed before conducting the loss of the primary lateral control test. On some airplanes, the required single lateral control system failure could result in loss of a rudder aileron interconnect and, perhaps, loss of directional control as well as the primary lateral control. The most critical linkage failure of the primary lateral control system must be considered.

(3) *Procedures*. The wording of the regulation sufficiently describes the maneuvers required to show compliance. The selection of altitudes, weights, c.g. position, lateral imbalance, and aircraft configurations to be flight tested by the FAA will depend on the study of the applicant's flight test report and whether the aircraft has a lateral trim system. Use of the lateral trim system to maneuver the aircraft and to hold wings level during an actual or simulated landing flare is authorized to comply with § 23.147(c). Those aircraft that do not have a separate and independent lateral trim system could use the rudder or differential power of a twin engine aircraft to generate a sideslip that would produce a rolling movement to control the bank angle. The use of rudder or asymmetric power to control bank angle implies that the aircraft exhibits lateral stability or dihedral effect. For those aircraft that use a rudder aileron interconnect to obtain lateral stability for which it is possible for a single failure in the primary lateral control system to disconnect the aileron rudder interconnect, compliance with § 23.147(c) must be performed without the interconnect. If compliance with § 23.147(c) can only be demonstrated with either flap, speed, power or procedure restrictions, or all of these, these restrictions should be noted in the AFM, in the emergency section.

(i) *Altitude*. An intermediate altitude and, if the airplane is approved for flight above 25,000 feet, an altitude near the maximum capability of the airplane needs to be tested. The high altitude test is to determine controllability with decreased Dutch roll damping.

(ii) *Weight*. Maximum gross weight for all tests, except where otherwise described in subparagraph (iii) below.

(iii) *C.G.* For conventional configuration, § 23.147(a) the most aft c.g. is critical if the rudder is used to roll the airplane. For unconventional configurations, the most critical c.g. must be used.

(iv) *Lateral Imbalance*. The maximum lateral imbalance for which certification is requested must be used when flight testing for compliance with § 23.147(c).

(v) *Configuration, Power and Speed*. Lateral controllability must be demonstrated with all practicable configurations and speeds. The maximum flaps used to demonstrate an actual or simulated landing need not be the maximum deflection possible.

(4) *Data Acquisition*. No special instrumentation is required.

4. § 23.149 Minimum Control Speed.

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

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

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

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

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

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

b. Explanation.

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

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

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

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

(5) *Deicer Boots, Antennas, and other External Equipment*. The installation of deicer boots, antennas, and other external gear could change the V_{MC} speed significantly. Re-evaluation of the V_{MC} speed should be considered when these installations are made. Refer to AC 23.l4l9-2 if a "flight into icing" approval is being sought.

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

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

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

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

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

c. Procedures.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

5. § 23.151 Acrobatic Maneuvers.

a. Explanation. This regulation requires each maneuver to be evaluated and safe entry speeds established. Section 23.1567(c), which is associated with this requirement, imposes a requirement for a placard that gives entry airspeeds and approved maneuvers. If inverted flight is prohibited, the placard should so state.

b. Procedures. The applicant should fly each maneuver for which approval is sought. The FAA test pilot should then evaluate those maneuvers considered most critical.

c. Data Acquisition. A recently calibrated airspeed system, airspeed indicator, accelerometer, and tachometer should be provided by the applicant for the test airplane. The following should be recorded:

(1) Load factor;

(2) Entry airspeeds;

(3) Maximum airspeeds; and

(4) Maximum r.p.m.

6. § 23.153 Control During Landings.

a. Explanation.

(1) *Purpose*. The purpose of this requirement is to ensure that airplanes do not encounter excessive control forces when approaching at a speed of five knots lower than normal landing approach speed. Also, a safe landing is required. Safe is considered to include having sufficient flare capability to overcome any excessive sink rate that may develop.

(2) *Landing Requirements.* Section 23.75 is a companion requirement and normally tests to determine compliance would be accomplished at the same time.

b. Procedures. The procedures applicable to § 23.75 would apply for § 23.153 except that, for turbopropeller airplanes, the flight-idle fuel flow should be adjusted to provide minimum thrust.

7. § 23.155 Elevator Control Force in Maneuvers.

a. Explanation.

(1) *Stick Force Per G.* The purpose of this requirement is to ensure that the positive stick force per g levels in a cruise configuration are of sufficient magnitude to prevent the pilot from inadvertently over-stressing the airplane during maneuvering flight. The minimum maneuvering stability levels are generally found at aft c.g. loadings. Both aft heavy and aft light loadings should be considered. During initial inflight investigations, caution should be exercised in the event that pitch-up tendencies or decreasing stick force per g conditions occur.

(2) *Buffet Boundaries*. Low speed buffet onset may occur during high altitude investigations. A qualitative evaluation should be conducted beyond the boundary of buffet onset to ensure a capability to maneuver out of the buffet regime.

b. Procedures. Compliance with the requirements of § 23.155 may be demonstrated by measuring the normal acceleration and associated elevator stick force in a turn while maintaining the initial level flight trim speed. A descent may be required in the turn to maintain the level flight trim speed. As a minimum, the following conditions shown in the table below should be investigated in the cruise configuration, that is, flaps up and gear up (if retractable):

Table 7 - Procedures

Condition	Power	Wings Level Trim Speed	Altitude
1	Refer to Note	Trimmed (but not to exceed V_{NE} or V_{MO}/M_{MO})	Altitude for highest dynamic pressure (q)
3	Refer to Note	V_O	Low
4	Refer to Note	V_O	Highest attainable approved altitude

Note: 75 percent maximum continuous power or maximum power (reciprocating engine) or maximum cruise power (turbine).

(1) Compliance may be demonstrated by measuring the normal acceleration achieved with the limiting stick force (50 pounds for wheel controls, 35 pounds for stick controls) or by establishing the stick force per g gradient and extrapolating to the appropriate limit. Linear stick force gradients may be extrapolated up to 0.5g maximum. Non-linear stick force gradients that indicate a possible gradient lightening at higher g levels should not be extrapolated more than 0.2g.

c. Data Acquisition and Reduction. The following should be recorded for each test condition:

(1) Weight/c.g.;

(2) Pressure altitude;

(3) Outside air temperature;

(4) Engine power parameters;

(5) Trim setting;

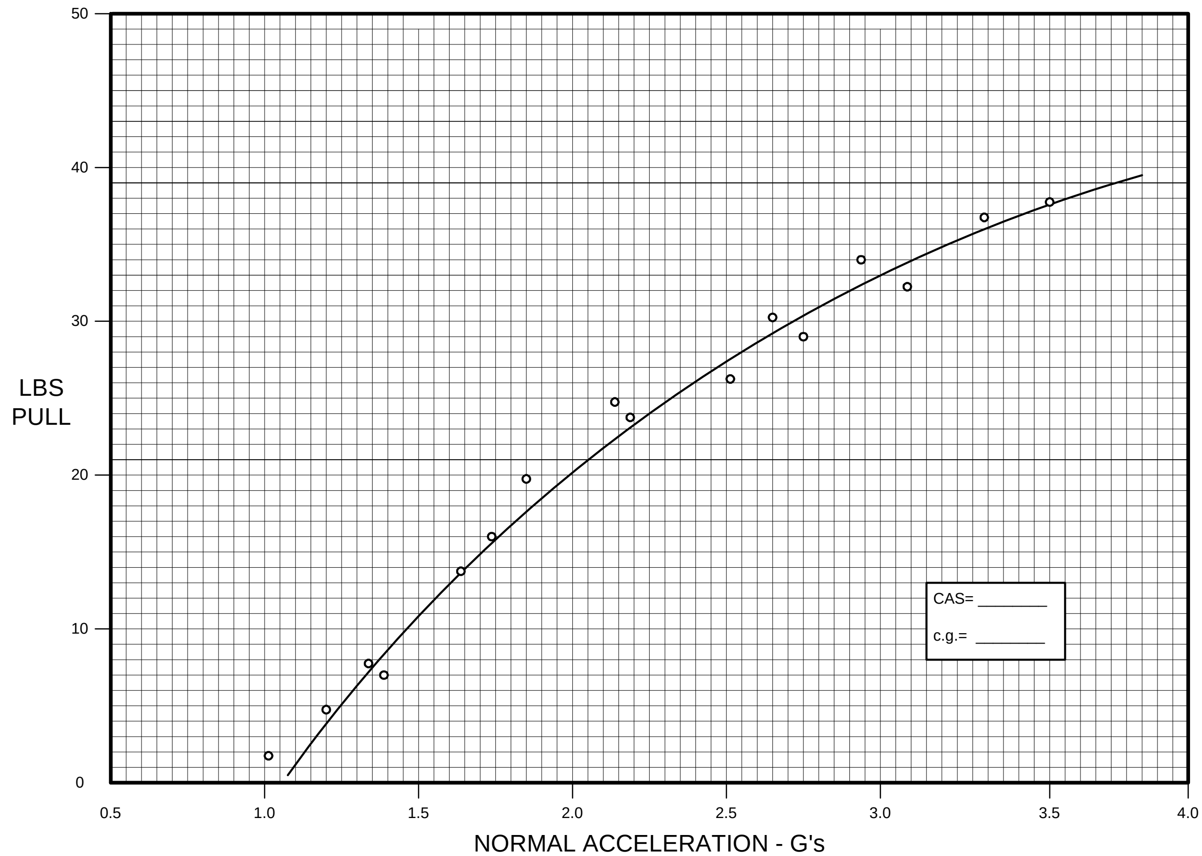
(6) Elevator force;

(7) Normal acceleration at c.g.; and

(8) Gear/flap position.

Note: The test data should be presented in stick force versus g plots. Figure 17 below shows a sample plot. Test results should be compared to the requirements of § 23.155(a).

Figure 17 - Stick Force Per G



d. Stick Force Per G, § 23.155(c). An increase in pull force should be required to produce an increase in normal acceleration throughout the range of required load factor and speed. Any reduction in control force gradient with change in load factor should not be so large or abrupt as to significantly impair the ability of the pilot to maintain control of normal acceleration and pitch rate. The elevator control force should increase progressively with increasing load factor.

(1) Flight tests to satisfy the above must be performed at sufficient points to establish compliance with § 23.155(c) throughout the normal flight envelope. During these tests, the load factor should be increased until either:

(i) The intensity of buffet provides a strong and effective deterrent to further increase of load factor;

(ii) Further increase of load factor requires an elevator control force in excess of 150 pounds for a wheel control or 125 pounds for a stick control or is impossible because of the limitations of the control system; or

(iii) The positive limit maneuvering load factor is achieved.

8. § 23.157 Rate of Roll.

a. Explanation. The purpose of this requirement is to ensure an adequately responsive airplane in the takeoff and approach configuration.

b. Procedures.

(1) *Bank Angle.* The airplane should be placed in a 30-degree bank and rolled through an angle of 60 degrees. For example, with the airplane in a steady 30-degree left bank, roll through a 30-degree right bank and measure the time. Sections 23.157(b) and (d) should be accomplished by rolling the airplane in both directions.

(2) *Controls*. Sections 23.157(a) and (c) permit using a favorable combination of controls. The rudder may be used as necessary to achieve a coordinated maneuver.

(3) *Weight*. The "W" in the formulas is the maximum takeoff weight.

Section 5. Trim

1. § 23.161 Trim.

a. Explanation. The trim requirements ensure that the airplane will not require exceptional skill, strength, or alertness on the pilot's part to maintain a steady flight condition. The tests require the airplane to be trimmed for hands-off flight for the conditions specified. It should be noted that for single-engine airplanes, lateral-directional trim is required at only one speed, thus ground adjustable tabs are acceptable. If appropriate, lateral baggage loading and fuel asymmetry should be considered in this evaluation. While ground adjustable tabs are acceptable, they are typically installed on simple single engine airplanes and aren't effective for addressing control forces with significant asymmetry loadings. Applicants should either provide a way to set the ground adjustable tab for specific loadings or install an air adjustable tab. For multiengine airplanes, directional trim is required for a range of speeds.

b. Procedures.

(1) *Actuator Settings*. Trim actuator travel limits should be set to the minimum allowable.

(2) *Altitude and Power*. Tests for trim should be conducted in smooth air. Those tests requiring use of maximum continuous power should be conducted at as low an altitude as practical to ensure attaining the required power.

(3) *Weight and C.G*. Longitudinal trim tests should be conducted at the most critical combinations of weight and c.g. Forward c.g. is usually critical at slow speeds and aft c.g. critical at high speeds.

Section 6. Stability

1. § 23.171 General.

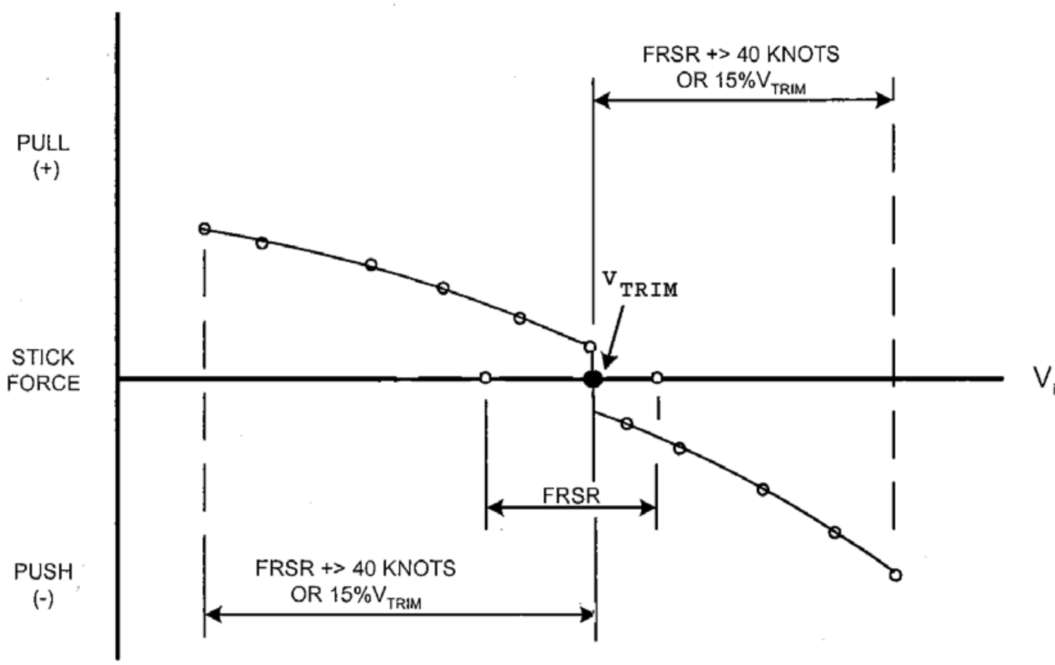
a. Explanation.

(1) *Required Stability.* The stability portion of part 23 is primarily concerned with static stability. No quantitative values are specified for the degree of stability required. This

allows simple test methods or qualitative determinations unless marginal conditions are found to exist. The regulations merely require that the airplane be stable and that it have sufficient change in control force, as it is displaced from the trimmed condition, to produce suitable control feel for safe operation.

(2) *Forces*. The magnitude of the measured forces should increase with departure from the trim speed up to the speed limits specified in § 23.175 or up to the 40 pound force limit specified in § 23.173. The stick force variation with speed changes should be stable. In other words, a pull force required to fly slower than trim and a push force required to fly faster than trim and the gradient should be clearly perceptible to the pilot at any speed between 1.3 V_{S1} and V_{NE} or V_{FC}/M_{FC}. Figure 18 below shows an example of cruise configuration:

Figure 18 - Static Longitudinal Stability Data

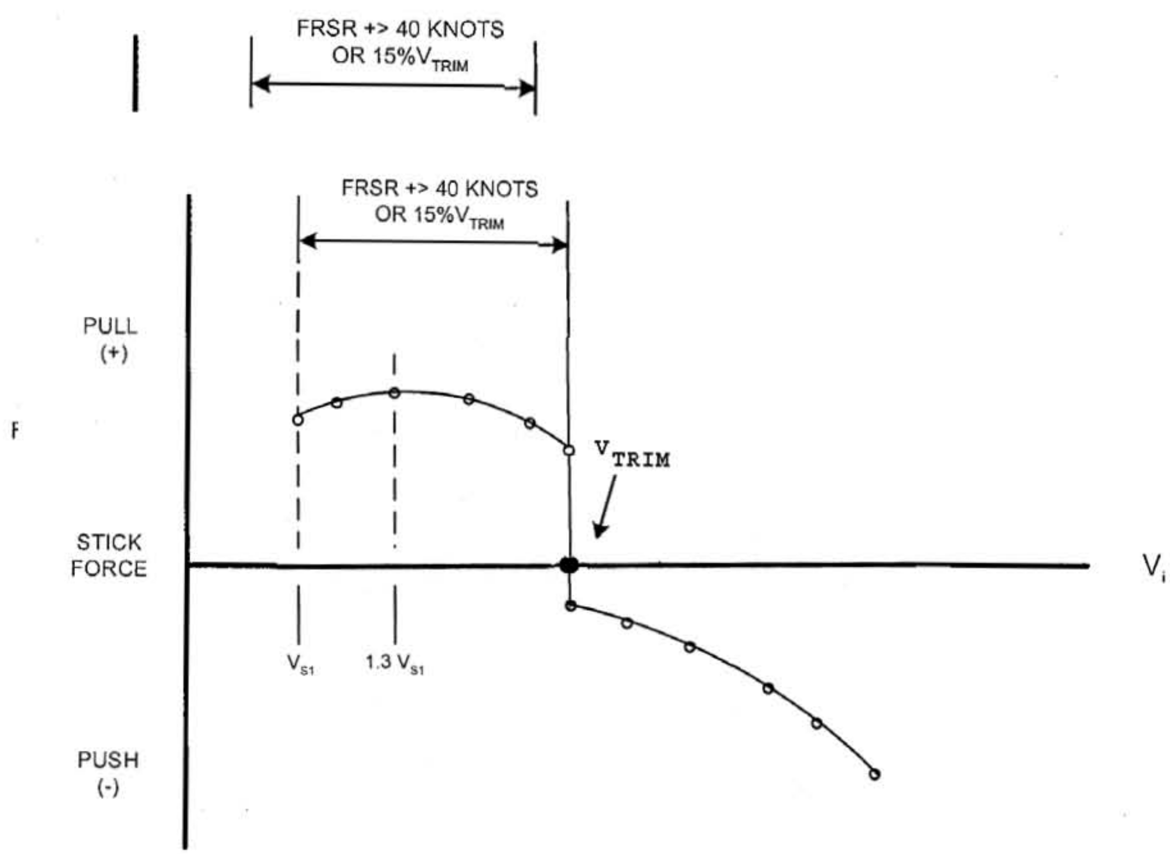


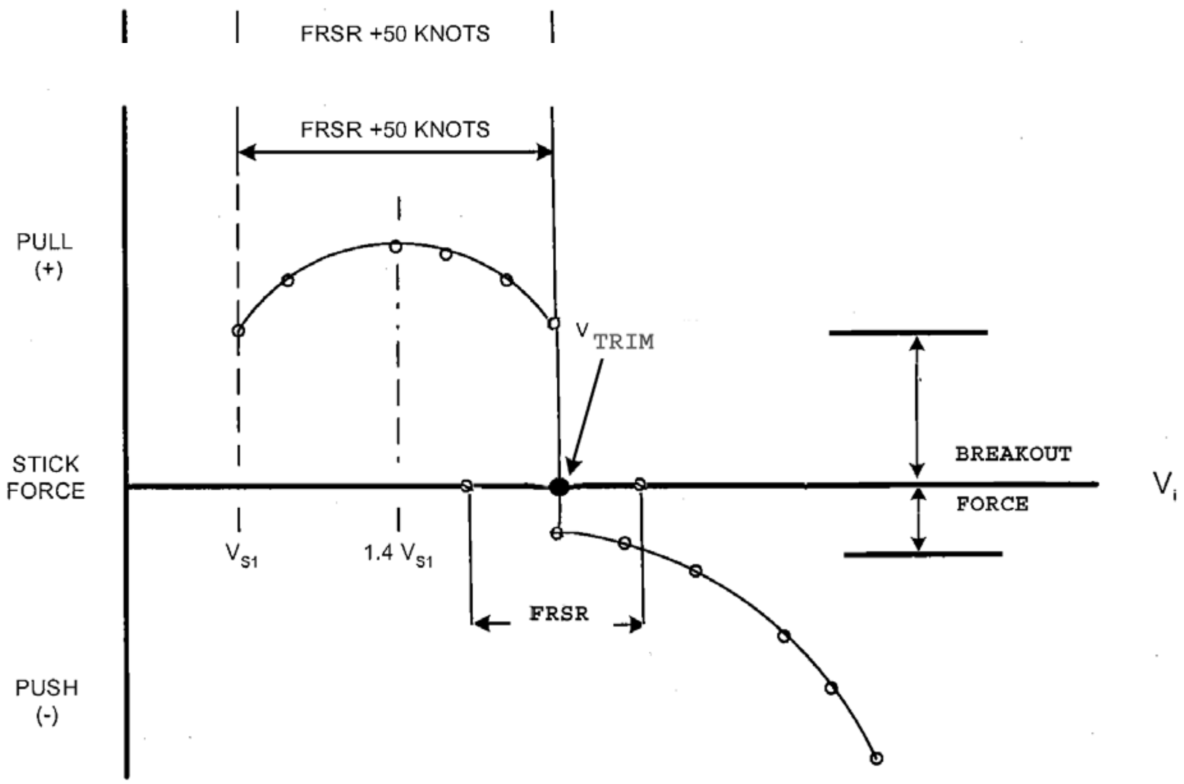
(i) Speed Range = Greater of + 40 knots (kts) or 15 percent V_{TRIM} + free return speed range (FRSR)

(ii) At speeds below 1.3 V_{S1} for normal, utility, and acrobatic airplanes, and at speeds below 1.4 V_{S1} for commuter airplanes, the slope need not be stable, refer to figures 19 and 20. The pull forces can decrease in magnitude with speed decrease down to, but not including, the stall speed V_{S1}; however, the pull force shall in no case fall below zero before the stall is reached.

(iii) Instrumented force measurements are required if there is any uncertainty in the qualitative assessment of the force gradients.

Figure 19 - Low Speed Instabilities; Normal, Utility, and Acrobatic Airplanes





b. Procedures. None required for this section.

2. § 23.173 Static Longitudinal Stability.

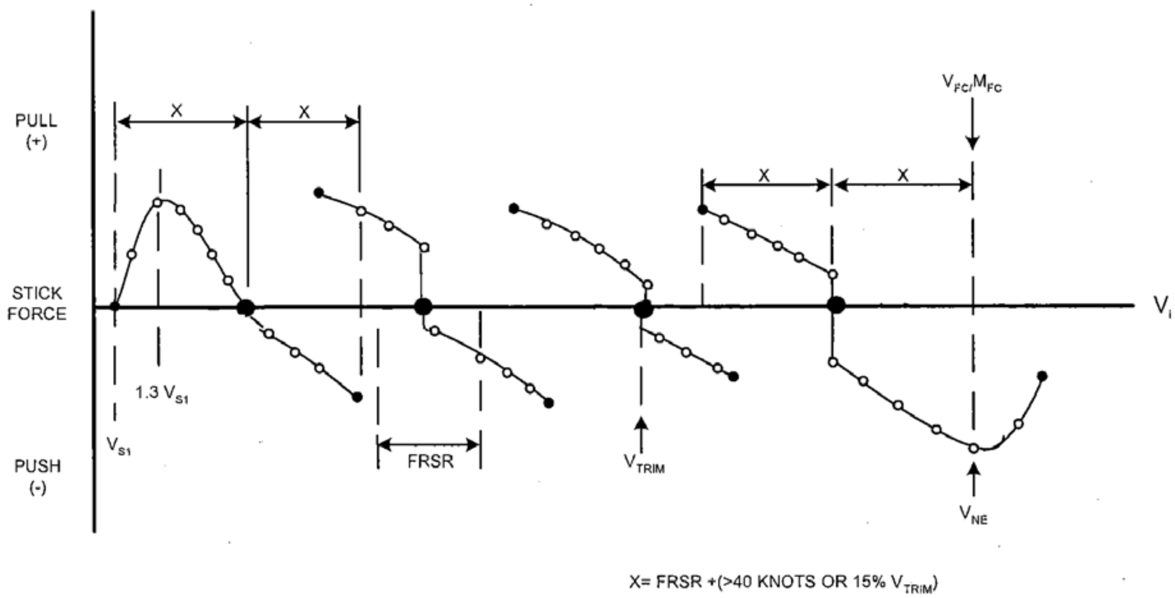
a. Explanation.

(1) *Demonstration Conditions*. The general requirements of § 23.173 are determined from a demonstration of static stability under the conditions specified in § 23.175.

(2) *Control Frictions*. Section 23.173(b) effectively limits the amount of control friction that will be acceptable since excessive friction would have a masking effect on stability. If autopilot or stability augmentation systems are of such a design that they tend to increase the friction level of the longitudinal control system, critical static longitudinal stability tests should be conducted with the system installed. Control cable tensions should be set to the maximum.

Note: A procedure that could be used is shown in figure 21 below:

Figure 21 – Static Longitudinal Stability Data over Complete Speed Range



(3) *Stable Slope*. Section 23.173(c) is extremely general. It requires the test pilot's best judgment as to whether the stable slope of the stick force curve versus speed is sufficiently steep so that perceptibility is satisfactory for the safe operation of the airplane.

(4) *Maximum Allowable Speed*. Should be taken to mean V_{FE}, V_{LE}, V_{NE}, and V_{FC}/M_{FC}, as appropriate.

b. Procedures. Refer to the guidance for § 23.175.

3. § 23.175 Demonstration of Static Longitudinal Stability.

a. Explanation. Section 23.175 requires that, for cruise configuration, static longitudinal stability tests be conducted at representative cruising speeds at high and low altitude up to V_{NE} or V_{FC}/M_{FC}, as appropriate, except that the trim speed need not exceed V_H. Section 23.173(a) states that static longitudinal stability must be shown at any speed that can be obtained; therefore, the longitudinal stability demonstration must cover the entire range from V_{S1} to V_{NE} or V_{FC}/M_{FC}. Figure 21 shows typical coverage of the speed range in cruise with overlapping data. Mid-range trim points should include speed for best endurance, range, and high-speed cruise.

(1) *V_{S1}*. Trim at V_{S1} + (>40 kts or 15 percent) + an estimate of the free return speed range (FRSR), perform static longitudinal stability tests from the trim speed within the speed range ensuring that the aircraft does not stall.

(2) *V_H*. Determine V_H at lowest altitude at MCP, perform longitudinal static stability tests within the prescribed speed range but do not exceed V_{NE}.

(3) *Additional trim points.* Select additional trim points, for example, speed for best range and endurance, and so forth, until the speed range covered by data, refer to figure 22.

(4) *Highest operating altitude*. Go to highest operating altitude, depending on pressurization, oxygen requirements, and so forth, trim at V_H, and repeat the test to a maximum speed of V_{FC}/M_{FC} or V_{NE}, whichever comes first. Note that a stable slope above V_{NE}, or V_{FC}/M_{FC}, or outside the (>40 kts or 15 percent) is desired, but not required.

b. Procedures.

(1) *Section 23.l75(a) Climb* .

(i) *Stabilized Method*. The airplane should be trimmed in smooth air for the conditions required by the regulation. Tests should be conducted at the critical combinations of weight and c.g. Normally, light weight and aft c.g. are critical.

(a) After observing trim speed, apply a pull force and stabilize at a slower speed. Continue this process in increments of 10 to 20 knots, depending on the speed spread being investigated, until reaching minimum speed for steady unstalled flight. At some stabilized point, the pull force should be gradually relaxed to allow the airplane to slowly return toward trim speed and zero stick force. Depending on the amount of friction in the control system, the eventual speed at which the airplane stabilizes will be somewhat less than the original trim speed. As required by § 23.173, the new speed, called free-return speed, must be within 10 percent (7.5 percent for commuter category airplanes in cruise) of the trim speed.

(b) Starting again at the trim speed, push forces should be applied and gradually relaxed in the same manner as previously described at speeds up to 115 percent of the trim speed, and the same determination should be made.

(c) The flight test data band should be ± 2,000 feet from the trim altitude to minimize changes in power/thrust with altitude at a fixed throttle setting that could affect static longitudinal stability. High performance airplanes in the climb configuration sometimes require a number of iterations to stay within the data band. Or if the airplane has a very high thrust to weight ratio, it may need 3,000 feet as used for part 25 airplanes (refer to AC 25-7).

(2) Section 23.175(b), Cruise

(i) *Acceleration-Deceleration Method*. The stabilized flight test technique described in paragraph (1)(i) above is suitable for low performance airplanes or airplane configurations with low climb performance. The acceleration-deceleration method is particularly suitable for airplanes with high cruise speed. The airplane is trimmed at the desired airspeed and the power/thrust setting noted. Power/thrust is then increased to accelerate the airplane to the extreme speed of the desired data band. The power/thrust is then reset to the original trim power setting and the airplane allowed to decelerate at a constant altitude back to the original trim speed. Longitudinal static stability data is obtained during the deceleration to trim speed with the power and the elevator trim position the same as the original trim data point. The data below trim speed is obtained in a similar manner by reducing power to decelerate the airplane to the lowest speed in the data band, reset the power to trim conditions, and record the data during the level acceleration back to trim speed. If, because of thrust/drag relationships, the airplane has difficulty returning to the trim data point, small altitude changes within ± 2,000 feet can also be used to coax an airplane acceleration-deceleration back to trim speed, but level flight is preferred if possible. The data to be measured approximately every ten knots are speed and elevator stick force.

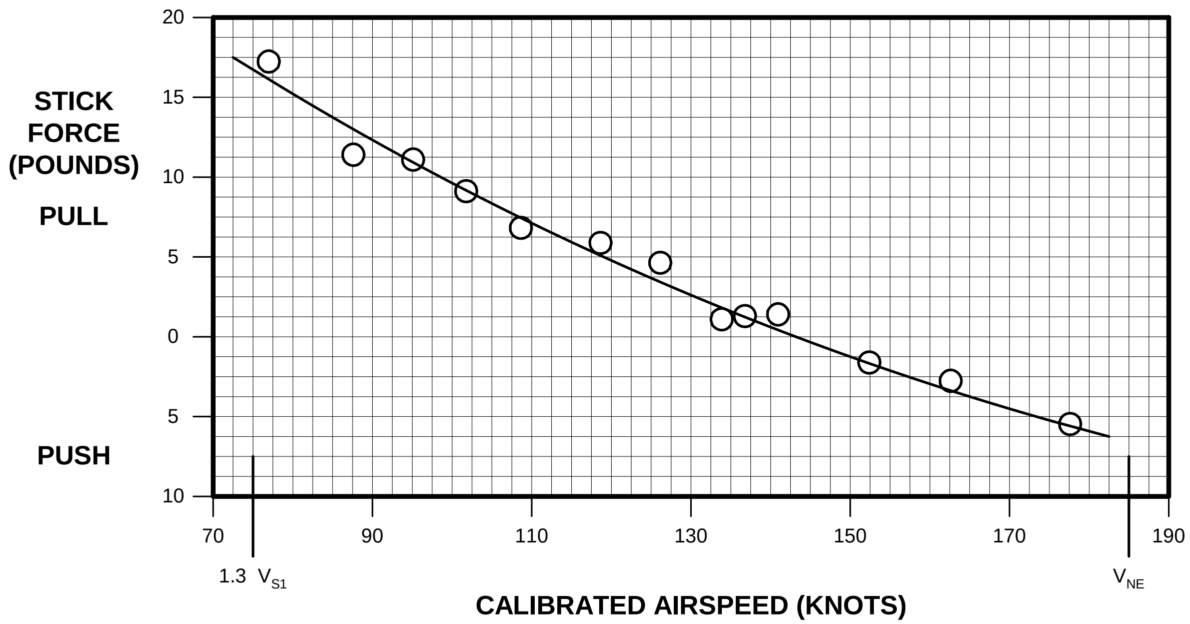
(3) *Other Stability Test Procedures.* The balance of the static longitudinal stability requirements are flown using either the stabilized method or the acceleration-deceleration method, but using the configurations, trim points, and speed ranges prescribed in § 23.175.

c. Data Acquisition and Reduction. Force readings can be made with a hand-held force gauge, fish scale, or by electronic means, and plotted against calibrated airspeed to determine compliance with the regulation. Refer to figure 22 for an example of the data plot. Collect test data within a reasonable altitude band of the trim point altitude, such as ±2,000 feet. Stick force measurements must be made unless:

(1) *Changes in speed*. Changes in speed are clearly reflected by changes in stick forces; and

(2) Maximum forces. The maximum forces obtained under §§ 23.173 and 23.175 are not excessive.

Figure 22 - Static Longitudinal Stability Plot (Cruise Condition)



4. § 23.177 Static Direction and Lateral Stability.

a. Explanation.

(1) *Purpose*. The purpose of this section is to require positive directional and lateral stability and to verify the absence of rudder lock tendencies.

(2) *Directional Stability.* In § 23.177(a), the determination of "appropriate" wings level sideslip (previously referred to as skid) angles will depend on sound judgment in considering such things as airplane size, maneuverability, control harmony, and forces to determine the magnitude of wings level sideslip angles that the airplane will probably experience in service. Tests are continued beyond these "appropriate" angles up to the point where full rudder control is used or a force limit of 150 pounds, as specified in § 23.143, is reached. The rudder force may lighten, but may not reverse. The rudder force tests are conducted at speeds between 1.2 V_{S1} and V_A. The directional stability tests are conducted at speeds from 1.2 V_{S1} to V_{NE} or the maximum allowable speed for the configuration, whichever is limiting.

(3) *Lateral Stability (Dihedral Effect).* The static lateral stability tests (reference § 23.177(b)) take a similar approach since the basic requirement must be met up to maximum sideslip angles "appropriate to the type of airplane." Up to this angle, the airplane must demonstrate a tendency to raise the low wing when the ailerons are freed. The static lateral stability may not be negative at 1.2 V_{S1} in the takeoff configuration and 1.3 V_{S1} in other configurations.

(4) *Forces*. The requirement of § 23.177(d) is to be tested at a speed of 1.2 V_{S1} and larger than "appropriate" sideslip angles. At angles up to those that require full rudder or aileron

control, or until the rudder or aileron force limits specified in the table in § 23.143 are reached, the aileron and rudder force may lighten but may not reverse.

(5) *Maximum Allowable Speed*. Should be taken to mean V_{FE}, V_{LE}, V_{NE}, and V_{FC}/M_{FC}, as appropriate.

(6) *Autopilot or Stability Augmentation Systems (SAS).* If autopilot or SAS are of such a design that they tend to increase the friction levels of the lateral and directional controls systems, then critical lateral and directional tests should be conducted with those systems installed, but not operating.

b. Procedures.

(1) *Altitude*. The tests should be conducted at the highest practical altitude considering engine power and aerodynamic damping.

(2) *Loading*. The airplane should be loaded to a nominal condition. Large lateral imbalance may mask lateral stability.

(3) *Directional*. To check static directional stability with the airplane in the desired configuration and stabilized on the trim speed, the airplane is slowly yawed in both directions keeping the wings level with ailerons. When the rudder is released, the airplane should tend to return to straight flight. Some deadband around neutral is acceptable. Refer to paragraph 23.161. for guidance on ground adjustable tabs.

(4) *Lateral*. To check lateral stability with a particular configuration and trim speed, conduct sideslips at the trim speed by maintaining the airplane's heading with rudder and banking with ailerons. Refer to paragraph 23.161 for guidance on ground adjustable tabs. Section 23.177(b) requires the slip angle to be appropriate to the type of airplane and the bank angle to be at least l0 degrees. Some airplanes cannot maintain a heading in a slip with a l0 degree bank angle. In those cases, the slip should be performed with no less than a l0 degree bank and full opposite rudder and the heading allowed to vary. When the ailerons are released, the low wing should return to level. Some deadband around neutral is acceptable. The pilot should not assist the ailerons during this evaluation. The pilot should hold the rudder as the wings level. For cases where there is not enough rudder to hold a steady heading, with bank angle, the pilot should use full rudder until the bank angle lowers to that where a steady heading can be maintained, then the rudder should be modulated as required to maintain the steady heading as the wings level.

c. Data Acquisition. Data recorded should be sufficient for showing compliance.

5. § 23.179 Stability. Reserved.

6. § 23.181 Dynamic Stability.

a. Explanation. Longitudinal Dynamic Stability.

(1) *Short and Long Period Modes*. Most normally configured airplanes will exhibit two distinct longitudinal modes of motion. The short period mode is the first response experienced after disturbing the airplane from its trim condition with the elevator control. It involves a succession of pitch acceleration, pitch rate, and pitch attitude changes that occur so rapidly the airspeed does not change significantly. Angle-of-attack will change in response to the pitching motions and produce accompanying changes in normal acceleration. Vertical gusts

and configuration changes, such as deploying flaps or speed brakes, may also excite the short period mode. The influence of control system springs and bob weights can be significant. If the disturbance from the trim condition is sustained long enough for the airspeed to change significantly, and if the pitch attitude excursions are not constrained by the pilot, the long period (or phugoid) oscillation will be excited with large but relatively slow changes in pitch attitude, airspeed, and altitude.

(2) *Damping*. Both the short period and long period modes are normally oscillatory in nature. However, the short period motion tends to be so heavily damped that no significant overshoot or residual oscillations are perceptible to the pilot, a condition described qualitatively as "deadbeat." If this is not the case, it should be determined that the motions do not interfere with performance of any required maneuver or task. The long period, or phugoid oscillation, is characteristically lightly damped, sometimes even unstable. Mild levels of instability are acceptable as long as they do not significantly interfere with normal piloting tasks such as trimming to a desired speed, holding altitude, or glide slope tracking. Useful guidelines include: the oscillation should be near neutrally stable if the period is less than 15 seconds or, for motions with longer period, the time to double amplitude should be greater than 55 seconds.

b. Procedures. Longitudinal, Short Period.

(1) *General*. The test for short period longitudinal dynamic stability is accomplished by a movement of pulse of the longitudinal control at a rate and degree to obtain a short period pitch response from the airplane. Initial inputs should be small and conservatively slow until more is learned about the airplane’s response. Gradually, the inputs can be made large enough to evaluate more readily the airplane’s oscillatory response and number of overshoots of the steady state condition.

(2) *The Doublet Input*. The “doublet input” excites the short period motion while suppressing the phugoid. It is generally considered to be the optimum means of exciting the short period motion of any airplane. The doublet input causes a deviation in pitch attitude in one direction (nose down) then cancels it with a deviation in the other direction (nose up). The total deviation in pitch attitude from trim at the end of a doublet is zero. Thus, the phugoid mode is suppressed. However, the short period motion will be evident since the doublet generates deviation in pitch rate, normal acceleration, and angle-of-attack at a constant airspeed. Short period characteristics may be determined from the manner in which these parameters return to the original trimmed conditions. The doublet is performed as follows:

(i) *Flight Condition*. Stabilize and trim carefully in the desired configuration at the desired flight condition.

(ii) *Control Inputs*. With a smooth but fairly rapid motion, apply airplane nose-down longitudinal control to decrease pitch attitude a few degrees then reverse the input to nose-up longitudinal control to bring the pitch attitude back to trim. As pitch attitude reaches trim, return the longitudinal cockpit control to trim and release it (controls-free short period) or restrain it in the trim position (controls-fixed short period). Both methods should be utilized. At the end of the doublet input, pitch attitude should be at the trim position (or oscillating about the trim position) and airspeed should be approximately trim airspeed.

(iii) *Short Period Data*. Obtaining quantitative information on short period characteristics from cockpit instruments is difficult and will be almost impossible if the motion is heavily damped. Short period oscillations are often of very low amplitude. If the pilot cannot see enough of the motion to measure and time a half-cycle amplitude ratio, the short period motion should be qualitatively described as essentially deadbeat.

(iv) *Input Frequency*. The frequency with which the doublet input is applied depends on the frequency and response characteristics of the airplane. The test pilot should adjust the doublet input to the particular airplane. The maximum response amplitude will be generated when the time interval for the complete doublet input is approximately the same as the period of the undamped short period oscillation.

(v) *Sequence of Control Inputs.* The doublet input may be made by first applying aft stick then reversing to forward stick. However, this results in less than 1g normal acceleration at the completion of the doublet and is more uncomfortable for the pilot.

(3) *The Pulse Input*. The pulse input also excites the short period nicely; however, it also tends to excite the phugoid mode. This confuses data analysis since the response of the airplane through the phugoid may be taken as a part of the short period response. This is particularly true for low frequency, slow-responding airplanes. Therefore, the pulse can usually only be utilized for high frequency, quick-responding airplanes in which the short period motion subsides before the phugoid response can develop. The pulse can always be used for a quick, qualitative look at the form of the short period motion. It is performed as follows:

(i) *Flight Condition*. Stabilize and trim in the desired configuration at the desired flight condition.

(ii) *Control Inputs.* With a smooth but fairly rapid motion, apply airplane nose-up longitudinal control to generate pitch rate, normal acceleration, and angle-of-attack changes then return the longitudinal control stick to the trim position. The short period motion may then be observed while restraining the control stick at the trim position (controls-fixed short period) or with the control stick free (controls-free short period).

(iii) *Sequence of Control Inputs*. Pulses may also be performed by first applying airplane nose-down longitudinal control.

(4) *Conditions and Configurations*. Short period dynamic longitudinal stability should be checked under all the conditions and configurations where static longitudinal stability is checked. Therefore, the test pilot may find it convenient to test for both on the same flights. It is not intended nor required that every point along a stick force curve be checked for dynamic stability; however, a sufficient number of points should be checked in each configuration to ensure compliance at all operational speeds.

c. Procedures. Longitudinal Long Period (phugoid) Dynamic Stability.

(1) *General*. The test for the phugoid mode is accomplished as follows:

(i) Cause the airplane to depart a significant amount from trim speed (about +10 percent should be sufficient) with an elevator input; and

(ii) Allow the ensuing oscillations in speed, rate of climb and descent, altitude, and pitch attitude to proceed without attempting to constrain any of the variables as long as airspeed, load factor, or other limitations are not exceeded.

(2) *The Pulse Input.* An appropriate control input for the phugoid test is a relatively slow elevator pulse to cause the airplane to increase or decrease speed from the trim point. Once the speed deviation is attained, the control is moved back to the original position and released.

(3) *Conditions and Configurations*. Long period dynamic stability should be checked under all of the conditions and configurations for which longitudinal static stability is

checked. As in the short period case, it is not intended that every point along a stick force curve be checked for phugoid damping; however, enough conditions should be checked to determine acceptable characteristics at all operational speeds.

(4) *Data*. The phugoid motion proceeds slowly enough that it is reasonable to record minimum and maximum airspeed excursions as a function of time and enable construction of an envelope from which time to half-double amplitude may be determined.

d. Explanation. Lateral/Directional Dynamic Stability. Characteristic lateral-directional motions normally involve three modes:

(1) *Roll mode.* A highly-damped convergence, called the roll mode, through which the pilot controls roll rate and, hence, bank angle;

(2) *Spiral.* A slow-acting mode, called the spiral, that may be stable but is often neutrally stable or even mildly divergent in roll and yaw; and

(3) *Dutch roll.* An oscillatory mode, called the Dutch roll, that involves combined rolling and yawing motions and that may be excited by either rudder or aileron inputs or by gust encounters.

(a) In addition, short period yawing oscillations due to rudder floating may sometimes be observed. The roll mode will almost always be satisfactory as judged by the ability to precisely control bank angle and counter gust upsets unless the response is slowed by high roll inertia or inadequate roll control power. Section 23.181(b) requires that the Dutch roll mode be investigated and determined to damp to 1/10 amplitude within seven cycles below 18,000 feet and 13 cycles from 18,000 feet to the certified maximum altitude. Also, any short period yawing oscillation associated with rudder motions must be heavily damped.

e. Procedures. Lateral/Directional. Two of the methods that may be used are described below:

(1) *Rudder Pulsing*. The rudder pulsing technique excites the Dutch roll motion nicely while suppressing the spiral mode if performed correctly. In addition, this technique can be used to develop a large amplitude oscillation that aids in data gathering and analysis, particularly if the Dutch roll is heavily damped. It is performed as follows:

(i) *Flight Condition*. Stabilize and trim carefully in the desired configuration at the desired flight condition.

(ii) *Control Inputs*. Smoothly apply alternating left and right rudder inputs in order to excite and reinforce the Dutch roll motion. Restrain the lateral cockpit control at the trim condition or merely release it. Continue the cyclic rudder pulsing until the desired magnitude of oscillatory motion is attained, then smoothly return the rudder pedals to the trim position and release them (controls free) or restrain them (controls fixed) in the trim position.

(iii) *Input Frequency*. The frequency with which the cyclic rudder inputs are applied depends on the frequency and response characteristics of the airplane. The test pilot should adjust the frequency of rudder pulsing to the particular airplane. The maximum Dutch roll response will be generated when the rudder pulsing is in phase with the airplane motion and the frequency of the rudder pulses is approximately the same as the natural (undamped) frequency of the Dutch roll.

(iv) *Spiral Motion.* The test pilot should attempt to terminate the rudder pulsing so that the airplane oscillates about a wings-level condition. This should effectively suppress the spiral motion.

(v) *Data*. Obtaining quantitative information on Dutch roll characteristics from cockpit instruments and visual observations requires patience, particularly if the motion is heavily damped. If instrumentation is available to record sideslip angle versus time, the dynamic characteristics of the maneuver can readily be determined. The turn needle of the needle-ball instrument can also be used to observe 1/10 amplitude damping and the damping period.

(2) *Steady Sideslip*. The steady sideslip release can also be used to excite the Dutch roll; however, the difficulty in quickly returning the controls to trim and the influence of the spiral mode often precludes the gathering of good quantitative results. Full rudder or a large amplitude sideslip may cause high loads on the airplane. The rudder pulsing technique usually produces better Dutch roll data. The steady sideslip release technique is performed as follows:

(i) *Flight Condition*. Stabilize and trim carefully in the desired configuration at the desired flight condition.

(ii) *Control Input*. Establish a steady heading sideslip of a sufficient magnitude to obtain sufficient Dutch roll motion for analysis. Utilize maximum allowable sideslip, using rudder as required. Stabilize the sideslip carefully. Quickly, but smoothly, return all cockpit controls to trim and release them (controls-free Dutch roll) or restrain them at the trim position (controls-fixed Dutch roll). Both methods should be utilized.

f. Stability Augmentation Systems (SAS). If the airplane is equipped with SAS, the airplane's characteristics should be evaluated throughout the approved operating envelope following failures that affect the damping of the applicable mode. Following a SAS failure, if unsatisfactory damping is confined to an avoidable flight area or configuration and is controllable to return the airplane to a satisfactory operational condition for continued safe flight, the lack of appreciable positive damping may be acceptable. Control of the airplane, including recovery, should be satisfactory using applicable control inputs. Following a critical failure, the degree of damping required should depend on the effect the oscillation will have on pilot tasks, considering environmental conditions. The capability to handle this condition should be demonstrated and evaluated. If a satisfactory reduced operational envelope is developed, appropriate procedures, performance, and limitations should be placed in the AFM. If a critical failure results in an unsafe condition, a redundant SAS may be required. The FAA has granted relief from the Dutch roll criteria for high performance jets that operate at high altitudes. These exemptions essentially allow for reduced damping until the pilots can decend to an altitude where the jet can aerodynamically meet the damping requirements in part 23. Examples of the exemptions are available on the FAA’s website.

g. Data Acquisition and Reduction. Data acquisition for this test should support a conclusion that any short period oscillation is heavily damped and any Dutch roll is damped to 1/10 amplitude in seven cycles below 18,000 feet and 13 cycles from 18,000 feet to the certified maximum altitude.

h. Maximum Allowable Speed. Should be taken to mean V_{FE}, V_{LE}, V_{NE}, and V_{FC}/M_{FC}, as appropriate.

Section 7. Stalls

1. § 23.201 Wings Level Stall.

a. Explanation.

(1) *Stall*. Section 23.201(b) defines when the airplane can be considered stalled for airplane certification purposes. When one of three conditions occurs, whichever occurs first, the airplane is stalled. The conditions are as follows:

(i) Uncontrollable downward pitching motion;

(ii) Downward pitching motion that results from the activation of a device (for example, stick pusher); or

(iii) The control reaches the stop.

Note: 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. Figure 1 shows a graphic representation of stall speed time histories for various configurations.

(2) *Related Sections*. The stalled condition is a flight condition that comes within the scope of §§ 23.49, 23.141, 23.143(b), 23.171, and 23.173(a). Section 23.143(b) requires that it be possible to effect a "smooth transition" from a flying condition up to the stalled flight condition and return without requiring an exceptional degree of skill, alertness, or strength. Any need for anticipated or rapid control inputs exceeding that associated with average piloting skill is considered unacceptable.

(3) *Recovery*. The flight tests include a determination that the airplane can be stalled, and flight control recovered, with normal use of the controls. Section 23.201(a) requires that it must be possible to produce and correct roll by unreversed use of the roll control and to produce and correct yaw by unreversed use of the directional control. The power used to regain level flight may not be applied until flying control is regained. This is considered to mean not before a speed of 1.2 V_{S1} is attained in the recovery dive.

(4) *Power*.

(i) *Power off*. The propeller condition for the "power-off" tests prescribed by § 23.201(e)(4) should be the same as the "throttles closed" condition prescribed for the stalling speed tests of § 23.49, that is, propellers in the takeoff position, engine idling with throttles closed. The alternative of using sufficient power to produce zero thrust does not apply to stall characteristics demonstrations.

(ii) *Power on*. For the power-on tests, an extreme nose up attitude is normally considered to be a pitch attitude of more than 30 degrees.

(5) *Configurations*. Stall characteristics should be evaluated as follows:

(i) At maximum to minimum weights at aft c.g., aft light loadings may be the most critical in airplanes with high thrust-to-weight ratios;

(ii) With the elevator up stop set to the maximum allowable deflection;

(iii) With maximum allowable lateral imbalance; and

(iv) At or near maximum approved altitude for airplanes approved to fly up to and above 25,000 feet. Clean, and any other reasonable configurations (such as spoiler), are the only stalls necessary at high altitude.

Note: Airplanes with de-rated engines should be evaluated up to the critical altitude of the engine and at maximum altitude for which the airplane is to be certified. An airplane may be approved if it has stick pusher operation in one configuration, such as power on, and has acceptable stall characteristics for the remaining configurations.

b. Procedures.

(1) *Emergency Egress*. It is the responsibility of the applicant to provide adequate provision for crew restraint, emergency egress, and use of parachutes (reference § 21.35(d)).

(2) *Buildup*. Generally, the stalls at more rearward, c.g. positions are more critical than at the forward c.g. position. For this reason, the stall characteristics at forward c.g. should be investigated first. Altitude should be low enough to ensure capability of setting 75 percent power, but high enough to accomplish a safe recovery. The 75 percent power requirement means 75 percent of the rated power adjusted to the temperature and altitude test conditions. Reciprocating engine tests conducted on a hot day, for example, would require higher manifold pressures to be set so that when chart brake horsepower is adjusted for temperature the result is 75 percent power.

(3) *Pilot Determinations*. During the entry and recovery, the test pilot should determine the following:

(i) That the stick force curve remains positive up to the stall (that is, a pull force is required) (reference § 23.171) when the trim speed is higher than the stall speed.

(ii) That it is possible to produce and correct roll and yaw by unreversed use of the rolling and directional control.

(iii) The amount of roll or yaw encountered during the recovery.

(4) *Speed Reduction Rate*. Section 23.201(b) requires the rate of speed reduction for entry not exceed one knot per second.

c. Data Acquisition and Reduction.

(1) *Instruments*. The applicant should provide a recently calibrated sensitive altimeter, airspeed indicator, accelerometer, outside air temperature gauge, and appropriate propulsion instruments; such as a torque meter or manifold pressure gauge and tachometer, a means to depict roll, pitch, and yaw angles; and force gauges when necessary.

(2) *Data Recording*. Automatic data recording is desirable, but not required, for recording time histories of instrumented parameters and such events as stall warning, altitude loss, and stall break. The analysis should show the relationship of pitch, roll, and yaw with respect to various control surface deflections. (Refer to figure 1, stall speed determination.)

d. Stick Pusher.

(1) *Background*. Stick pushers have been installed in some airplanes that would not meet the requirements of § 23.201. This was accomplished under the provisions of § 21.21b(1). In some airplanes, operation of the stick pusher was not critical to safe flight and, in others, stick pusher performance was essential to safe flight. In the latter case, the stick pusher typically functions as a stall barrier to prevent an airplane from entering flight regimes where a nonrecoverable stall could occur.

(2) *Stall Prevention*. There are two basic situations where a stick pusher would be necessary to show compliance with regulations. These are the following:

(i) *Airplane Recoverable*. The stall characteristics are investigated and, during these tests, the airplane does not meet regulatory requirements but an inadvertent aerodynamic stall would not be catastrophic or require exceptional piloting skill to recover. For example, during certain conditions of c.g., weight, or power, the airplane exceeds the l5 degree roll limit because of excessive angle-of-attack or other conditions. The pusher is installed and designed to function at some angle-of-attack where the 15 degrees of roll will not be exceeded. If this pusher system fails to function, the airplane is still recoverable from the stalled flight condition. For this system, the occurrence of a failure should be evaluated for an unsafe condition.

(ii) *Airplane Not Recoverable*. When the airplane is not capable of recovering from stalls or the applicant chooses not to investigate the consequences of stalling demonstrations with the pusher system rendered inoperative, then if the stick pusher fails to perform its intended function, an unsafe condition would exist.

(3) *System Tolerances*. Stick pusher system(s) tolerances should be evaluated and accounted for during certification flight tests. The applicant normally specifies the system tolerances in terms of plus or minus so many knots. The system(s) should be set to the minus (lowest stall speed) side of the tolerance when investigating stall characteristics and minimum longitudinal trim capability. The system(s) should be set to the plus (highest stall speed) side of the tolerance for stall speed determination and for determining performance stall speed multiples. Alternately, a nominal stick pusher stall speed may be used when it is determined that stick pusher tolerances result in no more than three knots or five percent variation in stall speed, whichever is greater.

(4) *Airspeed Margins*. The airspeed margin between unsatisfactory stall characteristics and the minimum stick pusher actuation speed, for identical flight conditions, should be evaluated. The following information is provided as a guide. For airplanes with unsatisfactory, hazardous or unrecoverable aerodynamic stall characteristics, the minimum speed margin between aerodynamic stall and minimum stick pusher systems actuation speed should not be less than five knots. For other airplanes with known and less hazardous aerodynamic stall characteristics, the speed margin may be reduced to not less than two knots.

(5) *Preflight Check*. If a reliability credit is to be given for a preflight check, the following should be evaluated:

(i) The check includes the functioning of the complete system, including the incidence sensors, so all faults would be detected.

(ii) The check is easily conducted, and requires little pilot time or effort.

(iii) A note in the limitations section of the AFM requires the check to be accomplished prior to flight.

(iv) The AFM identifies the criticality of the system and the need to accomplish the preflight check.

(6) *Inadvertent Operation*. Inadvertent stick pusher operation should be extremely improbable or investigated and shown not to be hazardous and to be recoverable.

2. § 23.203 Turning Flight and Accelerated Turning Stalls.

a. Explanation.

(1) Wings level stalls. Explanations for wings level stalls also apply to turning flight and accelerated turning stalls.

(2) *Turning flight and accelerated turning stalls.* The only differences between the investigation required for turning flight and accelerated turning stalls are in the speed reduction rate and the accepted roll off bank angles.

b. Procedures.

(1) Procedures for wings level stalls applies to turning flight and accelerated turning stalls.

(2) *Test pilot determinations*. During the maneuver, the test pilot should determine the following:

(i) That the stick force remains positive up to the stall;

(ii) That the altitude lost is not, in the test pilot's opinion, excessive;

(iii) There is no undue pitch up;

(iv) That there are no uncontrollable spinning tendencies; that is, while the airplane may have a tendency to spin, a spin entry is readily preventable;

(v) That the test pilot can complete the recovery with normal use of the controls and average piloting skill;

(vi) Roll does not exceed the value specified in the requirements; and

(vii) For accelerated turning stalls, maximum speed or limit load factors were not exceeded.

(3) *Section 23.203(a).* Section 23.203(a) requires the rate of speed reduction for a turning flight stall not exceed one knot per second; for an accelerated turning stall, three to five knots per second with steadily increasing normal acceleration.

c Data Acquisition. Same as for wings level stalls.

3. § 23.205. Reserved.

4. § 23.207 Stall Warning.

a. Explanation.

(1) *Purpose*. The purpose of this requirement is to ensure an effective warning in sufficient time to allow a pilot to recover from an approach to a stall without reaching the stall.

(2) *Types of Warning.* The effective warning may be from either aerodynamic disturbances or from a reliable artificial stall-warning device such as a horn or a stick shaker. The aerodynamic warning is usually manifested by a buffet, which vibrates or shakes the airplane. The type of warning should be the same for all configurations.

(3) *Artificial Stall Warning.* Stall warning devices may be used in cases where there is inadequate aerodynamic warning. The warning signal from the devices should be clear and distinctive and not require the pilot's attention to be directed inside the airplane. A stall warning light by itself is not acceptable. If a stick shaker is installed, the warning should be unmistakable even if flying hands off.

(4) Margin. The stall warning margin, as defined in the rule, is applicable with speed reduced at a rate of one knot per second for §§ 23.201 and 23.203(a)(1).

b. Procedures. The stall warning tests should be conducted in conjunction with the stall tests required by §§ 23.201 and 23.203.

Section 8. Spinning

1. § 23.221 Spinning.

a. Explanation.

(1) *Spin*. A spin is a sustained autorotation at angles-of-attack above stall. The rotary motions of the spin may have oscillations in pitch, roll, and yaw superimposed upon them. The fully developed spin is attained when the trajectory has become vertical and the spin characteristics are approximately repeatable from turn to turn. Some airplanes can autorotate for several turns, repeating the body motions at some interval, and never stabilize. Most airplanes will not attain a fully developed spin in one turn.

(2) *Category Spins.* Section 23.221 addresses three situations:

(i) Normal category spins.

(ii) Utility category spins.

(iii) Acrobatic category spins.

(3) *Utility Category Airplanes*. Utility category is used for airplanes intended for limited acrobatic operations in accordance with § 23.3. Spins (if approved for the particular type of airplane) are considered to be a limited acrobatic operation. This type of airplane may be approved in accordance with § 23.221(a), normal category, or with § 23.221(c), acrobatic category.

(4) *Stick Pushers*. Single engine airplanes equipped with a stick pusher will not be required to demonstrate compliance with § 23.221; however, the applicant will need to document the equivalency using an equivalent level of safety finding.

(5) *Margin*. The stall warning margin, as defined in the rule, is applicable when speed is reduced at a rate of one knot per second for §§ 23.201 and 23.203(a)(1).

b. Guidance and Procedures Applicable to Both Normal and Acrobatic Category Spins.

(1) *Weight and C.G. Envelope*. Refer to paragraph 23.23 of this AC for guidance on weight and c.g. envelope exploration.

(2) *Moments of Inertia*. Moments of inertia should also be considered when evaluating the c.g. envelope. Most general aviation airplanes have low inertias combined with high aerodynamic damping and relatively similar moments of inertia along the wing and fuselage axis. However, designs of modifications, such as wingtip fuel tanks, can change the spin recovery time and possibly the recovery method. Applicants are encouraged to consider these effects and approach flight testing at extreme mass distributions with caution.

(3) *Control Deflections*. Control surface deflections, i.e., rigging, should be set to a nominal value based on the production specifications. If the test results suggest some peculiarities that would indicate compliance issues, then the critical side of the allowable tolerances should be tested. For example, a possible spin flight test program could be to perform the spin matrix with the controls set at the nominal deflection values. Analysis of the data may show the critical conditions for entry and recovery. If a critical condition is found, defined, and agreed upon by the FAA, these critical tests are repeated with the control deflections set to the most critical tolerances.

(4) *Emergency Egress*. It is the responsibility of the applicant to provide adequate provision for crew restraint, emergency egress, and use of parachutes (reference § 21.35(d)).

(5) *Spin Recovery Parachutes.*

(i) Spin recovery parachutes should be installed on all airplanes requiring spin testing for certification unless experience with the airplane shows, and the applicant and the FAA agree that it is not necessary.

(ii) The spin recovery system installation should be carefully evaluated to determine its structural integrity, reliability, susceptibility to inadvertent or unwanted deployment or jettison, and adequate or redundant jettison capability. NASA recommendations should be referred to when evaluating the design of the chute deployment and jettison systems. The chute type, diameter, porosity, riser length, and lanyard length should be determined in accordance with NASA recommended practices to maximize the probability the chute will be effective in spin recovery. Chute sizes, and particularly riser and lanyard lengths, depend strongly on such aircraft variables as wing design, fuselage shape, tail arm, and mass properties. The sizes and lengths shown in the referenced NASA reports are for particular aircraft that were tested in the NASA Langley Spin Tunnel and will not necessarily be the correct size to recover other aircraft, even if the aircraft layout is similar. The following NASA documents are available from the National Technical Information Service (NTIS); 5285 Port Royal Road; Springfield, Virginia 22161; or at the following email address: http://www.ntis.gov/ Appropriate NASA recommendations can be found in the following publications:

(a) NASA Technical Paper 1076, "Spin-Tunnel Investigation of the Spinning Characteristics of Typical Single-Engine General Aviation Airplane Designs," dated November 1977.

(b) NASA Technical Note D-6866, "Summary of Design Considerations for Airplane Spin-Recovery Parachute Systems."

(c) NASA Conference Paper, CP-2127, l4th Aerospace Mechanisms Symposium, May 1980, entitled, "A Spin-Recovery System for Light General Aviation Airplanes."

(iii) Final certification of the spin characteristics should be conducted with the external spin chute removed unless it is determined that spin chute installation has no significant effect or a conservative effect on spin characteristics.

(6) *Build-Up*. When any doubt exists regarding the recovery characteristics of the test airplane, a build-up technique should be employed consisting of spin entries and recoveries at various stages as the maneuver develops. Excessive aerodynamic control wheel back pressure indicates a possibility of unsatisfactory spin characteristics. Any control force lightening or reversal is an indication of possible deep stall entry. Refer to paragraph c(7) for definition of excessive back pressure. A yaw rate instrument is valuable in detecting progress toward a fully developed spin condition or an uncontrollable maneuver. Unusual application of power or controls has sometimes been found to induce uncontrollable spins. Leading with elevator in recovery and cutting power as the airplane rolls into a spin have been known to induce uncontrollable spins.

(7) *Entry*. Spins should be entered in the same manner as the stalls in §§ 23.201 and 23.203 with trim at 1.5 V_{S1} or as close as practical. As the airplane stalls, with ailerons neutral, apply full-up elevator and full rudder in the direction of spin desired.

(8) *Recovery*. Recoveries should consist of throttle reduced to idle, ailerons neutralized, full opposite rudder, followed by forward elevator control as required to get the wing out of stall and recover to level flight. For acrobatic category spins, the manufacturer may establish additional recovery procedures, provided they show compliance for those procedures with this section.

(9) *Altitude*. The effect of altitude should be investigated.

(10) *Initial Investigation*. In all cases, the initial spin investigation should be accomplished at as high an altitude above the ground as reasonably possible and a predetermined, pre-briefed "hard" altitude established to be used as the emergency egress altitude. In other words, if the airplane cannot be recovered by that altitude, all occupants should exit the airplane without hesitation. The altitude selected should take into account the opening characteristics of the parachutes, the difficulty of egress, the estimated number of turns to get out and the altitude loss per turn, the distance required to clear the airplane before deploying the parachutes, and so forth.

(11) *Power*. The use of power during spin entry for both normal and abnormal spins is recommended in order to determine the effects of power on spin entry characteristics and possible spin recovery procedures. The power on setting should be that used for the power on demonstrations in paragraphs 23.201 and 23.203. For power-on normal category spins, the throttle can be reduced to idle after one turn.

c. Information and Procedures Applicable to Normal Category Spins.

(1) *Objective*. The basic objective of normal category spin testing is to assure that the airplane will not become uncontrollable within one turn (or three seconds, whichever takes longer) if a spin should be encountered inadvertently and that recovery can be effected without exceeding the airplane design limitations. Type certification testing requires recovery capability from a one-turn spin while operating limitations prohibit intentional spins. This one-turn "margin of safety" is designed to provide adequate controllability when recovery from a stall is delayed. Section 23.221(a) does not require investigation of the controllability in a true spinning condition for a normal category airplane. Essentially, the test is a check of the controllability in a delayed recovery from a stall.

(2) *Recovery from Spins with Normal Control Usage During Entry and Recovery.* Normal category airplanes must recover from a spin in no more than one turn after the initiation of the first control action for recovery. For example, if you are spinning left with ailerons neutral, recover by reducing power to idle, if not already at idle, apply full right rudder followed by forward elevator. Start the count (heading, ground reference, and so forth) for recovery with the application of the first action, which may be the reduction of power. Refer to paragraph c(5) for use of flaps.

(3) *Recovery from Spins Following Abnormal Control Usage.* Abnormal control usage should be evaluated during the spin to ensure that uncontrollable spins do not occur. The intent of these tests is to induce all of the types of control usage, whether they are right or wrong, that might be used during the operation of the airplane. The parameters that need to be investigated depend on the design of the airplane as well as on the results of the normal spin tests. These checks include, as a minimum, the following: the effect of ailerons with and against the spin, the effect of elevator applied before the rudder at recovery, the effect of slow elevator release, the effect of entry attitude. Ailerons with and against the spin should be applied at entry and during spins. Elevator and rudder against the spin should be applied during the spin. Spinning should continue for up to three seconds, or for one full turn, while the effects of abnormal aerodynamic control inputs are observed. Apply normal recovery controls as outlined in paragraph c(2). Up to two turns for recovery is considered acceptable.

(4) *Spin Matrix*. The effects of gear, flaps, power, accelerated entry and control abuse should be investigated. A suggested matrix for spin investigation is given in figure 100-1. It is the responsibility of the applicant to explore all critical areas. It may be possible to eliminate the need to conduct some of the additional conditions once the airplane responses are known.

(5) *Flaps*. Section 23.221(a) specifies that, for the flaps extended condition, the flaps may be retracted during the recovery. Flap retraction should not be initiated until after airplane rotation has ceased.

(6) *Aerodynamic Back Pressure.* Excessive aerodynamic back pressure is cause for non-compliance. Excessive aerodynamic back pressure is a judgment item and is defined as excessive force required to pitch the airplane down in recovery. Back pressure should not be more than normal elevator control forces and should not interfere with prompt and normal recovery.

d. Information and Procedures Applicable to Acrobatic Category Spins.

(1) *Objective*. The basic objective of acrobatic category spin testing is to ensure that the airplane will not become uncontrollable when a spin is intentionally entered and the following:

(i) The controls are used abnormally (as well as normally) either during the entry or during the spin, or both;

(ii) The airplane will recover in not more than 1 1/2 turns after completing application of normal or manufacturer-prescribed recovery controls; and

(iii) No airplane limitations are exceeded, including positive maneuvering load factor and limit speeds.

(2) *Pilot Training*. It is assumed that the pilot of the acrobatic category airplane that spins for six turns is doing so intentionally. If spinning is intentional, the pilot should have had proper instruction and proficiency to effect a proper recovery. The pilot should be expected to follow the published procedure to recover from this planned maneuver.

(3) *Abnormal Control Usage*. The information on "abnormal" use of controls also applies to acrobatic category spins. Abnormal control usage should be evaluated at several points throughout the spin to ensure that uncontrollable spins do not occur. These checks include, as a minimum, the following: the effect of ailerons with and against the spin, the effect of elevator applied before the rudder at recovery, the effect of slow elevator release, the effect of entry attitude, the effect of power on at the entry, and the effect of power left on during the spin. Spinning should continue for up to six full turns while the effects of abnormal aerodynamic control inputs are observed. The effect of leaving power on in the spin need only be examined by itself up to one full turn. Following abused control usage, reversion to normal pro-spin controls for up to two turns is acceptable, prior to the normal recovery control inputs, which must result in recovery in not more than two turns. In addition, going directly from the control abuse condition to the normal recovery control condition should not render the spin unrecoverable. For example, after evaluating the effect of relaxing the back stick input during the spin, it would be reasonable to expect the pilot to apply normal recovery use of rudder and elevator without first returning to full back stick.

(4) *Flaps.* If an acrobatic category airplane is placarded against intentional flaps down spins, then only normal category procedures need be used for the flaps down configurations.

(5) *Spin Matrix.* The effects of gear, flaps, power, accelerated entry, and normal and abnormal control use should be investigated. A suggested matrix for spin investigation is given in figure 23. It is the responsibility of the applicant to explore all critical areas. It is necessary to expand the matrix to cover six-turn spins. The normal procedure is to continue the same process and add one additional turn each time. It may be possible to eliminate the need to conduct some of the additional conditions once the airplane responses are known.

(6) *Spiral Characteristics.* The acrobatic spin requirement stipulates that, for the flap retracted six-turn spin, the spin may be discontinued after three seconds if spiral characteristics appear. This does not mean that the spin test program is discontinued. Each test point should stand alone and that spin be discontinued only after a spiral has developed. Limit speed should not be exceeded in the recovery. The airplane may be certificated as an acrobatic airplane whether or not it can spin a minimum of six turns.

(7) *Recovery Placard.* Section 23.1583(e)(4) requires that acrobatic airplanes have a placard listing the use of controls required to recover from spinning maneuvers. Utility category airplanes approved for spins should also have such a placard. Recovery control inputs should be conventional. If special sequences are employed, then they should not be so unique to create a recovery problem.

(8) *Complex Instrumentation*. When complex instrumentation is installed, such as wing tip booms or a heavy telemetry system, the instrumentation may affect the recovery characteristics. Critical spin tests should be repeated with the instrumentation removed.

e. Data Acquisition. The test airplane should be equipped with a calibrated airspeed indicator, accelerometer, and altimeter. Precise control of weight and balance and control deflections is essential.

f. Optional Equipment. In those cases where an airplane is to be certified with and without optional equipment such as deicing boots, asymmetric radar pods, outer wing fuel tanks, or winglets, sufficient tests should be conducted to ensure compliance in both configurations.

g. Spin Resistance. Reserved.

h. STCs.

(1) *Limited spin matrix*. The need for a limited spin matrix on an STC program is a subjective decision based on the service history of the specific airplane being modified. We cannot offer a comprehensive list of when to re-test the spin matrix because there are too many variables to account for. There are airplanes that have been significantly modified with little change in spin recovery. There are also airplanes that have subtle modifications made to them and yet the spin recovery changes dramatically. If you believe that the airplane needs to be re-evaluated for spin recovery, then a limited matrix using the middle and edges of the envelope is all that is needed to verify that the airplane recovers.

(2) *Stall/spin*. Key features that seem to relate directly to the “stall/spin” or departure accidents are:

(i) *Stall characteristics*. Does the airplane only buffet at full aft control or does it roll off dramatically with no aerodynamic warning? Does the airplane require aggressive footwork to keep the wings level or could you put your feet on the floor during the stall with little roll-off? The airplane that is resistant to stalling and is easy to keep the wings level does not need a spin recovery re-evaluation like an airplane that has poor stall handling qualities and a poor “stall/spin” accident history.

(ii) *Stick force gradient*. Airplanes with steep stick force gradients are involved in fewer “stall/spin” accidents than those airplanes with light force gradients.

(iii) *Stall warning*. A stall warning can reduce the number of “stall/spin” accidents depending on the effectiveness of the system. There are numerous stall warning systems ranging from the ineffective lights to the highly effective stick shakers with warning horn.

(3) *Rule of thumb*. Absent any technically researched criteria, the following “rule-of-thumb” procedures and criteria for power increases have been used since 1972 with reasonable success. Those criteria are:

(i) Airplanes modified by increasing the installed horsepower (maximum takeoff power) by more than 10 percent or 25 horsepower, whichever is less, over the original type certificated airplane installed horsepower rating, will require spin testing.

(a) Airplanes modified by increasing the installed horsepower may accept a derated power schedule in lieu of spin testing. The 10 percent or 25 horsepower, whichever is less, maximum hp difference criteria would apply from sea level to the airplane service ceiling. This will require a placard of manifold pressure versus pressure altitude (at rated r.p.m.) corresponding to the maximum allowable horsepower differential between the derated engine and the original type certificated engine.

(ii) Turbocharged and turboprop engine installations will be evaluated as follows:

(A) Determine the maximum power available on the original engine at 10,000 feet pressure altitude.

(B) Determine the value of 75 percent MCP/thrust on the new engine.

(C) If the difference between (a) and (b) exceeds either 10 percent of the original installed horsepower (maximum takeoff power) or 25 horsepower, spin tests will be conducted.

(4) *Limited spin matrix.* Consider a limited spin matrix if there is either a weight increase greater than ten percent or an inertial increase greater than ten percent, or both. Inertial changes to check are those that may affect the rotational characteristics of the airplane during spin recovery. When considering a 10 percent change, use the product of the weight and moment arm changes. Examples to consider are the addition of tip tanks, moving the engine forward, and locating the battery in the tailcone.

(5) *Subjective reasoning*. Again, there is some subjectivity that needs to be used when deciding on the need to re-evaluate the spin recovery ability of an airplane. The airplane's service history and the airplane's original spin recovery performance should be part of the decision. An airplane that typically recovers in a ¼ turn does not need the same re-evaluation matrix that an airplane recovering in 7/8 of a turn does. The airplane that recovers in 7/8 of a turn is close to the limit already and may have trouble with normal wear and tear. There is not a clear, easy approach to standardizing the spin requirements for STC's. The FAA encourages the use of issue papers to document the rational for not requiring spinning. This may help standardize future projects.

Figure 23 - Spin Evaluation Configuration Matrix

SPIN EVALUATION CONFIGURATION

Flight Condition Spins from Wing Level Attitude	Spin Number	Flaps Up	Flaps Appch. (As Approp.)	Flaps Landing	Gear Up	Gear Down	Cowl Flaps Closed	Cowl Flaps As Required	Power Off	Power On	Forward C.G.	Aft C.G.	Lateral C.G.
Test with Normal Spin Controls	1	X			X		X		X		X	X	X
Left Spin 1 thru 6	2		X			X	X		X		X	X	X
	3			X		X	X		X		X	X	X
	4	X			X			X		X	X	X	X
	5		X			X		X		X	X	X	X
	6			X		X		X		X	X	X	X
Repeat 1 through 6 from a right spin. Repeat 1 through 6 fromleft and right turning flight.													
Test with Abnormal Spin Controls	7	X			X		X		X		X	X	X
Left Spin Aileron Against 7 thru 12	8		X			X	X		X		X	X	X
	9			X		X	X		X		X	X	X
	10	X			X			X		X	X	X	X
	11		X			X		X		X	X	X	X
(Repeat 7 through 12 from a right spin)	12			X		X		X		X	X	X	X
	13	X			X		X		X		X	X	X
Left Spin Aileron with 13 thru 18	14		X			X	X		X		X	X	X
	15			X		X	X		X		X	X	X
	16	X			X			X		X	X	X	X
	17		X			X		X		X	X	X	X
	18			X		X		X		X	X	X	X
Repeat 13 through 18 from a right spin. Repeat 7 through 18 from left and right turning flight.													

Section 9. Ground and Water Handling Characteristics

1. § 23.231 Longitudinal Stability and Control.

a. Explanation.

(1) *Landplanes*. For landplanes, §§ 23.231(a) and 23.233 are companion requirements to § 23.75.

(2) *Floatplanes*. For floatplanes, §§ 23.231(b) and 23.233 are companion requirements to § 23.75.

(3) *Amphibians*. The requirements for both landplanes and floatplanes apply to amphibians.

b. Procedures.

(1) *Landplanes*. Landplanes should be operated from all types of runways applicable to the type of airplane. Taxi, takeoff, and landing operations should be evaluated for acceptable characteristics. This should include idle power landings as well as landings and takeoffs with procedures used in §§ 23.75 and 23.51.

(2) *Floatplanes*. Floatplanes should be operated under as many different water conditions as practical up to the maximum wave height appropriate to the type of airplane. Taxi (both displacement and step), takeoff, and landing operations should be evaluated for acceptable characteristics. This includes idle power landings as well as landings and takeoffs with procedures used under §§ 23.75 and 23.51.

(3) *Amphibians*. Amphibians should be evaluated in accordance with both items (1) and (2) above.

c. Procedures - Multiengine Airplanes. Evaluate all of the considerations contained in paragraph b(2) plus the effects of one engine loss during water operations.

d. Airplane Flight Manual (AFM). The AFM should include appropriate limitations plus demonstrated wind and sea state conditions.

2. § 23.233 Directional Stability and Control.

a. Explanation.

(1) *Crosswind*. This regulation establishes the minimum value of crosswind that must be demonstrated. Since the minimum required value may be far less than the actual capability of the airplane, higher values may be tested at the option of the applicant. The highest 90-degree crosswind component tested satisfactorily should be put in the AFM as performance information. If a demonstrated crosswind is found limiting, it has to be introduced in Section 2 of the AFM.

(2) *Ground Loops*. Section 23.233(a) does not preclude an airplane from having a tendency to ground loop in crosswinds, providing the pilot can control the tendency using engine power, brakes, and aerodynamic controls. The operating procedures should be placed in the AFM in accordance with § 23.1585(a).

(3) *Controllability*. Section 23.233(b) is not related to the crosswind requirement of § 23.233(a). The demonstration of compliance with this requirement is accomplished into the wind. The test pilot is searching for any unusual controllability problems during landing and must use judgment as to what constitutes "satisfactorily controllable" since, at some point in the landing rollout, the aerodynamic controls may become ineffective.

(4) *Taxi Controllability*. Section 23.233(c) requires the airplane to have adequate directional controllability for taxi operations on land for landplanes, on water for floatplanes, and on land and water for amphibians.

b. Procedures.

(1) *Crosswind.*

(a) The airplane should be operated throughout its approved loading envelope at gradually increasing values of crosswind component until a crosswind equivalent to 0.2 V_{SO} is reached. All approved takeoff and landing configurations should be evaluated. Higher crosswind values may be evaluated at the discretion of the test pilot for AFM inclusion.

(b) For floatplanes, the use of water rudders or the use of airplane attitude on the water to control weathervaning should be described in the AFM.

(2) *Controllability.*

(a) A landplane should demonstrate satisfactory controllability during power-off (idle power) landings through landing rollout. This may be conducted into the existing wind and should be evaluated at all key loading envelope points.

(b) Although power-off landings are not expressly required for floatplanes under § 23.233(b), it is recommended they be evaluated.

(3) *Taxi Controllability.*

(a) A landplane should have sufficient directional control available through the use of nose/tail wheel steering, differential braking (if provided), differential power (multiengine airplanes), and aerodynamic control inputs to allow taxiing at its "maximum demonstrated crosswind" value.

(b) A floatplane should have sufficient directional control available through the use of water rudders, airplane attitude (displacement or plow), taxi technique (displacement or step), differential power (multiengine floatplanes) and aerodynamic control inputs to allow taxiing at its "maximum demonstrated crosswind" value. This is not intended to suggest that all of the above must be evaluated at 0.2 V_{SO}, but accepted techniques using one or more of the above must allow controllable taxiing.

(c) Amphibians should exhibit suitable directional controllability on both land and water in accordance with the preceding two paragraphs. In addition, amphibians should have suitable directional controllability to taxi from the water to a land facility and vice-versa unless prohibited by the operating limitations.

c. Data Acquisition and Reduction. The determination of compliance is primarily a qualitative one. However, wind readings (velocity and direction) should be taken and compared to the wind component chart (Appendix 7) to determine that the minimum 90-degree crosswind component has been tested.

3. § 23.235 Operation on Unpaved Surfaces.

a. Explanation. This requirement states that the airplane landing gear shock absorbing mechanism must function as intended throughout the expected operating envelope of the airplane.

b. Procedures. During the development and certification flight testing, the airplane should be operated on a variety of runways including those considered to be the worst (in terms of roughness) appropriate to the type of airplane. There should be no evidence of damage to the airplane during these operations.

4. § 23.237 Operation on Water. Allowable water surface conditions should be established during the certification flight testing, depending on the type of aircraft, to ensure safe operation and attainment of the published takeoff and landing performance.

5. § 23.239 Spray Characteristics.

a. Explanation. This rule is intended to ensure that any spray produced during water operation neither excessively interferes with the pilot's visibility nor damages, beyond "normal wear-and-tear," the airplane itself.

b. Procedures.

(1) *Taxi, takeoff, and landing*. Taxi, takeoff, and landing operations should be conducted throughout the approved loading envelope. Spray patterns should be specifically noted with respect to visibility and their contact areas on the airplane. These areas should be monitored to assure compliance with the rule.

(2) *Reversing propellers*. Airplanes with reversing propellers should be demonstrated to comply at the highest reverse power expected to be applicable to the airplane operation.

Section 10. Miscellaneous Flight Requirements

1. § 23.251 Vibration and Buffering.

a. Explanation.

(1) *Flutter*. The test required under this section should not be confused with flutter tests, which are required under § 23.629. Test are typically considered elevated risk and should be carefully planned and conducted.

(2) *Test Speeds*. Prior to the test, the pilot should coordinate with the airframe engineer to determine that the flutter requirements of § 23.629 have been satisfied and to determine the most critical weight and c.g. for the test. The flight test engineer and pilot should obtain from the airframe engineer the dive equivalent airspeed and Mach number to which the test should be conducted. In the absence of a well-calibrated Mach meter, knowing the Mach number and equivalent airspeed, a schedule of pressure altitude and indicated airspeed should be developed for the test.

(3) *Airspeed Determination*. Another major consideration is CAS determination during the test. In this regard, a calibrated, sensitive airspeed indicator should be installed to provide accurate readability. Careful study of the airplane's airspeed position error/correction curve is required with respect to the characteristics of the slope at the high-speed end and how the airspeed calibration was conducted. This is necessary to determine the adequacy of the airspeed position error curve for extrapolating to V_D/M_D. Refer to appendix 7, figure 5, for compressibility corrections. An expanded Mach number calibrated-airspeed graph may be found in the Air Force "Flight Test Engineering Handbook" (refer to appendix 2, paragraph f(2) of this AC).

(4) *Springs*. If the airplane incorporates spring devices in any of the control systems, the test should be conducted with the spring devices connected and disconnected. Alternately, if satisfactory spring reliability is shown in accordance with § 23.687, tests with springs disconnected are not required.

(5) *Mach Limits*. For those airplanes that are observing Mach limits, the tests should be repeated at M_D speed. Careful selection of the test altitude for both M_D and V_D tests will help cut down on the number of repeat runs necessary to determine compliance. Attempting to combine the tests at the knee of the airspeed/Mach curve should be approached cautiously since it can result in overshooting the desired speed.

b. Procedures.

(1) *Configuration*. In the clean configuration at the gross weight, most critical c.g. (probably most aft) and the altitude selected for the start of the test, the airplane should be trimmed in level flight at maximum continuous power. Speed is gained in a dive in gradual increments until V_D/M_D, or V_{DF}/M_{DF} for turbojets, is attained. The airplane should be trimmed, if possible, throughout the maneuver. Remain at the maximum speed only long enough to determine the absence of excessive buffet, vibration, or controllability problems.

(2) *Flaps extended.* With flaps extended and the airplane trimmed in level flight at a speed below V_{FE}, stabilize at V_{FE} in a shallow dive and make the same determinations as listed in (1) above.

2. § 23.253 High Speed Characteristics.

a. Explanation.

(1) *Related Sections.* The design dive speeds are established under the provisions of § 23.335, with the airspeed limits established under the provisions of § 23.1505. There is distinction made in both regulatory sections for airplanes that accelerate quickly when upset. The high-speed characteristics, in any case, should be evaluated by flight demonstration. Section 23.1303(e) gives the requirements for a speed-warning device.

(2) *Dynamic Pressure and Mach*. In general, the same maneuvers should be accomplished in both the dynamic pressure (q) and Mach (M) critical ranges. All maneuvers in either range should be accomplished at thrust and trim points appropriate for the specific range being evaluated. Some maneuvers in the Mach range may be more critical for some airplanes due to drag rise characteristics.

(3) *Flight Crew Duties*. The airplane's handling characteristics in the high-speed range should be investigated in terms of anticipated action on the part of the flight crew during normal and emergency conditions. Consideration should be given to their duties, which not only

involve piloting the airplane, but also the operational and navigational duties having to do with traffic control and record keeping necessary to the progress of safe flight.

(4) *Upset Axes.* The upset criteria of § 23.335(b)(4)(i) is predicated on an upset in pitch while operational evaluation of upsets expected to occur in service should cover pitch, roll, yaw, and critical combinations of multi-axis upsets.

(5) *Factors*. The following factors are involved in the flight test investigation of high-speed characteristics:

(i) Effectiveness of longitudinal control at V_{MO}/M_{MO} and up to the demonstrated V_D/M_D speed;

(ii) Effect of any reasonably probable mis-trim on upset and recovery;

(iii) Dynamic and static stability;

(iv) The speed increase that may result from likely mass movement that occurs when trimmed at any cruise speed to V_{MO}/M_{MO};

(v) Trim changes resulting from compressibility effects. Evaluation should cover Mach tuck, control reversal, or other phenomena associated with high speed;

(vi) Characteristics exhibited during recovery from inadvertent speed increase;

(vii) Upsets due to turbulence (vertical, horizontal, and combination gusts);

(viii) Effective and unmistakable aural speed warning at V_{MO} plus six knots, or M_{MO} plus 0.0lM;

(ix) Speed control during application of devices (power, speed brakes, high-speed spoilers, and so forth); and

(x) Characteristics and controllability during and after failure or malfunction of any stability augmentation system.

(6) *Type of Warning*. Operational experience has revealed that an important and effective deterrent to inadvertent overspeeding is an aural warning device, which is distinctively different from aural warning used for other purposes. Aerodynamic buffeting is influenced by, and is similar to, the effects of turbulence at high speed and is not normally considered to be suitable as an overspeed warning.

(7) *Speed Margins*. Once it is established whether the airplane limits will be V_{NE} or V_{MO}, appropriate speed margins and markings may be evaluated. The factors outlined in § 23.335 have been considered in establishing minimum speed margins during past type certification programs for the appropriate speeds. The factors to be considered are the following:

(i) Increment allowance for gusts (0.02M);

(ii) Increment allowance for penetration of jet stream or cold front (0.0l5M);

(iii) Increment allowance for production differences of airspeed systems (0.005M), unless larger tolerances or errors are found to exist;

(iv) Increment allowance for production tolerances of overspeed warning errors (0.0lM), unless larger tolerances or errors are found to exist;

(v) Increment allowance ΔM, due to speed overshoot from M_{MO}, established by upset during flight tests in accordance with § 23.253, should be added to the values for production differences and equipment tolerances. The minimum acceptable combined value should not be less than that required by § 23.335(b)(4) between M_{MO} and M_D. The value of M_{MO} should not be greater than the lowest value obtained from each of the following equations and from § 23.1505:

$$M_{MO} = M_D - \Delta M - .005M - .01M$$

or $M_{MO} = M_D$ - the Mach increment required by § 23.335(b)(4)

(vi) Altitudes where dynamic pressure (q) is limiting, the allowances of items (i) and (ii) are applicable, and the Mach increment is converted to the units used for the limits;

(vii) At altitudes where q is limiting, the increment allowance for production differences of airspeed systems and production tolerances of overspeed warning errors are three and six knots, respectively, unless larger differences or errors are found to exist; and

(viii) Increment allowance ΔV, due to speed overshoot from V_{MO} established by upset during flight tests in accordance with § 23.253, should be added to the values for production differences and equipment tolerances. The value of V_{MO} should not be greater than the lowest obtained from the following:

$V_{MO} = V_D - \Delta V$ - 3 knots (prod. diff.) - 6 knots (equip. tol.)

or for V_{NO} airplanes:

$V_{NO} = V_D - \Delta V$ - 3 knots (prod. diff.) - 6 knots (equip. tol.)

b. Procedures. Using the V_{MO}/V_{NO}, M_{MO}, or the associated design or demonstrated dive speeds determined in accordance with §§ 23.251, 23.335, and 23.1505, the airplane should be shown to comply with the high speed characteristics of § 23.253 and that adequate speed margins exist. The airplane characteristics should be investigated at any speed up to and including V_{NO}, V_{MO}/M_{MO} or V_D/M_D, as required by § 23.253. The recovery procedures used should be those selected by the applicant, except that the normal acceleration during recovery should not exceed l.5g (total).

(1) *C.G. Shift*. The airplane should be upset by the c.g shift corresponding to the forward movement of a representative number of passengers depending upon the airplane interior configuration. The airplane should be allowed to accelerate for three seconds after the calibrated V_{MO}/M_{MO} (not overspeed warning) occurs before recovery is initiated. Note the maximum airspeed. Do not exceed V_D /M_D.

(2) *Inadvertent Control Movement*. Simulate an evasive control application when trimmed at V_{MO}/M_{MO} by applying sufficient forward force to the elevator control to produce 0.5g (total) for a period of five seconds, after which recovery should be effected at not more than l.5g (total). Care should be taken not to exceed V_D /M_D during the entry maneuver.

(3) *Gust Upset*.

(i) *Lateral Upset*. With the airplane trimmed at any likely cruise speed up to V_{MO}/M_{MO} in wings level flight, perform a lateral upset to the same angle as that for autopilot approval, or to a maximum bank angle appropriate to the airplane, whichever is critical. Operationally, it has been determined that the maximum bank angle appropriate for the airplane should not be less than 45 degrees, need not be greater than 60 degrees, and should depend upon airplane stability and inertia characteristics. The lower and upper limits should be used for airplanes with low and high maneuverability, respectively. Following this, with the controls free, the evaluation should be conducted for a minimum of three seconds after the calibrated value of V_{MO}/M_{MO} (not overspeed warning) or ten seconds, whichever occurs first.

(ii) *Longitudinal Upset*. Perform a longitudinal upset as follows:

(A) Trim at V_{MO}/M_{MO} using power required for level flight but with not more than maximum continuous power. If the airplane will not reach V_{MO}/M_{MO} at maximum continuous power, push over to V_{MO}/M_{MO} and trim.

(B) If descending to achieve V_{MO}/M_{MO}, return to level flight without changing trim.

(C) Perform a longitudinal upset from normal cruise by displacing the attitude of the airplane in the range between 6-12 degrees, which has been determined from service experience to be an optimum range. The value of displacement should be appropriate to the airplane type and should depend upon airplane stability and inertia characteristics. The lower and upper limits should be used for airplanes with low and high maneuverability, respectively.

(D) The airplane should be permitted to accelerate until three seconds after the calibrated value of V_{MO}/M_{MO} (not overspeed warning).

(iii) *Two-Axis Upset*. Perform a two-axis upset consisting of a longitudinal upset combined with a lateral upset. Perform a longitudinal upset by displacing the attitude of the airplane as in the previous paragraph, and simultaneously perform lateral upset by rolling the airplane to the 15-25 degree bank angle range, which was determined to be operationally representative. The values of displacement should be appropriate to the airplane type and should depend upon airplane stability and inertia characteristics. The lower and upper limits should be used for airplanes with low and high maneuverability, respectively. The established attitude should be maintained until the overspeed warning occurs. The airplane should be permitted to accelerate until three seconds after the calibrated value of V_{MO}/M_{MO} (not overspeed warning).

(4) *Leveling Off From Climb*. Perform transition from climb to level flight without reducing power below the maximum value permitted for climb until the overspeed warning has occurred. Recovery should be accomplished by applying not more than l.5g (total).

(5) *Descent From Mach to Airspeed Limit Altitude*. A descent should be initiated at M_{MO} and performed at the airspeed schedule defined in M_{MO} until the overspeed warning occurs. The airplane should be permitted to descend into the airspeed limit altitude where recovery should be accomplished after overspeed warning occurs by applying not more than l.5g (total). The maneuver should be completed without exceeding V_D.

Chapter 3. Subpart D--Design and Construction

Section 1. General

1. § 23.629 Flutter.
This subject is covered in AC 23.629-1B.

Section 2. Control Systems

1. § 23.671 General.
Reserved.

2. § 23.672 Stability Augmentation and Automatic and Power Operated Systems.
Reserved.

3. § 23.677 Trim Systems.

a. Qualitative Evaluation. Trim should be qualitatively evaluated during all phases of the flight test program. Cockpit control trim devices should be evaluated for smoothness, sense of motion, and ease of operation, accessibility, and visibility of the trim tab indicators (both day and night). Ease in establishing and maintaining a trim condition should be evaluated.

b. Electric Trim Background. Electrically-actuated, manually-controlled trim systems have been certificated in several ways, depending on systems design. The simpler systems are tested for failure in flight. More sophisticated systems, which generally incorporate dual-wire, split-actuating switches, may require a dual failure to produce a runaway. Analysis of these systems discloses that one switch could fail closed and remain undetected until a failure occurred in the other switch or circuit to produce a runaway. This is still considered acceptable if the applicant provided a preflight test procedure that will detect such a dormant failure. Service experience dictates that evaluation of fail-safe trim systems by analysis alone is not acceptable and flight testing is required.

c. Explanation.

(1) *Fault Analysis*. A fault analysis should be evaluated for each trim system.

(2) *Single Failure and Back-up System*. For a system in which the fault analysis indicates a single failure will cause runaway, flight tests should be conducted. For a system with back-up features, or a redundant system where multiple failures would be required for runaway, the certification team should determine the extent of the flight tests necessary after consideration of the fault analysis and determination of the probability and effect of runaway. In all cases, flight test evaluations should be conducted to determine functional system/airplane compatibility in accordance with § 23.1301.

(3) *Failure*. For the purpose of a fault analysis, a failure is the first fault obviously detectable by the pilot and should follow probable combinations of undetectable failures assumed as latent failures existing at the occurrence of the detectable failure. When an initial failure also causes other failures, the initial failure and the subsequent failures are considered to constitute a single failure for purposes of fault analysis. Only independent failures may be introduced into the fault analysis to show multiple failure integrity.

(4) *Failure Warning.* The first indication a pilot has of a trim runaway is a deviation from the intended flight path, abnormal control movements, or a warning from a reliable failure warning system. The following time delays after pilot recognition are considered appropriate:

(i) Takeoff, approach, landing - one second.

(ii) Climb, cruise, descent - three seconds.

(5) *Second Set of Controls*. If a set of controls and instruments are provided for a second crew member, multi-function systems disconnect or quick-disconnect/interrupt switches, as appropriate, should be provided for both crew members regardless of minimum crew.

d. Definitions.

(1) *Disconnect Switch*. A switch, which has the primary purpose of stopping all movement of the electric trim system, that is located within immediate reach and readily accessible to the pilot. A circuit breaker is not considered to be a disconnect switch.

(2) *Quick-Disconnect/Interrupt Switch*. A switch or device, which is located on the control wheel on the side opposite the throttles, or on the stick control, that momentarily interrupts all movement of the electric trim system and can be operated without moving the hand from its normal position on the control. The primary purpose of the switch is to stop all movement of the electric trim system.

e. Procedures.

(1) *Quick-Disconnect or Interrupt Switch*. With a quick-disconnect or interrupt switch located on the pilot's control wheel or stick, disconnect may be initiated after the delay times given in 23.677c(4).

(2) *Disconnect Switch*. With a disconnect switch located somewhere on the panel other than the pilot's control wheel or stick, the time delays given in § 23.677c(4) should be applied prior to corrective action by use of primary controls. In addition to these time delays, an appropriate reaction time to locate the switch and disconnect the systems should be added. When there are other switches in the immediate area of the disconnect switch, a time increment the same as for the quick disconnect should be added to account for identifying the switch. This effectively doubles the time delay for a cockpit located disconnect switch.

(3) *Loads*. The loads experienced as a result of the malfunction should normally not exceed an envelope of 0 to +2g. The positive limit may be increased if analysis has shown that neither the malfunction nor subsequent corrective action would result in a load beyond limit load. In this case, careful consideration should be given to the delay time applied, since it may be more difficult for the pilot to reach the disconnect switch.

(4) *High Speed Malfunctions*. When high speed malfunctions are introduced at V_{NE} or V_{MO}/M_{MO}, whichever is appropriate, the speed excursion, using the primary controls and any speed reduction controls/devices, should not exceed the demonstrated upset speed established under § 23.253 for airplanes with a V_{MO}/M_{MO} speed limitation and a speed midway between V_{NE} and V_D for those airplanes certified with a V_{NE} limitation.

(5) *Speed Limitations.* The use of a reduction of $V_{NE}/V_{MO}/M_{MO}$ in complying with paragraph e(4) of this section is not considered acceptable, unless these new speeds represent limitations for the overall operation of the airplane.

(6) *Forces*. The forces encountered in the tests should conform to the requirements of § 23.143 for temporary and prolonged application. Also, refer to paragraph 23.143 of this AC.

(i) To allow expansion of the 0 to 2g envelope, the FAA suggests a test procedure that incorporates both control restrained and unrestrained malfunctions. The following test matrix considers the probability of trim runaways, high airframe limit loads, control stick/wheel configuration and absence of an autopilot system. Because rudder trim can be adjusted without the pilot directly in the control loop (that is, feet on the floor), restrained runaways for rudder trim are not considered acceptable. (Refer to table 8 below.)

Table 8 - Trim Systems Requirements

Axis	Time	Load(g) (unrestrained)	Maximum Attitude Change (unrestrained)	Maximum Force (restrained and unrestrained)	Maximum Rate of Force Change (restrained)
Pitch	recognition +3 seconds	structural limits NTE 3.5g	+/-45 degrees	60 pounds	20 pounds/sec
Roll	recognition +3 seconds	structural limits	+/-90 degrees	30 pounds	10 pounds/sec
Yaw	recognition +3 seconds	structural limits	+/-30 degrees	150 pounds (unrestrained only)	N/A

Note 1: "Restrained" means the pilot is in the control loop (hands on) and "unrestrained" means the pilot is not in the control loop (hands off).

Note 2: Trim systems with a monitor/limiter will be tested at a magnitude just below that required for monitor/limiter trip.

Note 3: NTE is Not to Exceed.

4. § 23.679 Control System Locks.
This subject is covered in AC 23-17.

5. § 23.689 Cable Systems. Section 23.689(f) allows for tab control cables that are not part of the primary control system to be less then 1/8 inch in diameter as long as the airplane is safely controllable with the tabs in the most adverse positions. Flight testing only requires that the tabs be in the most adverse positions associated with the airplane's operating envelope. This would typically be at the lowest and fastest trimmable operating speeds with the airplane loaded at forward cg. Safely controllable is subjective and has to be determined by an FAA test pilot. If there is disagreement between an applicant and the FAA, a multiple pilot evaluation may be used to make the final compliance determination. Typically, the forces in § 23.143 for "prolonged" use are not used because they are intended for normal operation and are unreasonably low for a failure condition. If the forces are so high that the pilot cannot adequately control the airplane, as determined by an FAA flight test evaluation, then the applicant should consider mitigation strategies and include them in the AFM.

6. § 23.691 Artificial Stall Barrier System.
Reserved.

7. § 23.697 Wing Flap Controls.
Reserved.

8. § 23.699 Wing Flap Position Indicator. Reserved.

9. § 23.701 Flap Interconnection. This subject is covered in AC 23-17.

Section 3. Landing Gear

1. § 23.729 Landing Gear Extension and Retraction System. This subject is covered in AC 23-17.

2. § 23.735 Brakes. Reserved.

Section 4. Personnel and Cargo Accommodations

1. § 23.771 Pilot Compartment.
Reserved.

2. § 23.773 Pilot Compartment View.

a. Pilot Position and View. For all evaluations, the pilot(s) should be seated at the intended design eye level as determined by an installed guide, if established. If an intended design eye level is not provided, the normal seating position should be used. The field of view that should remain clear should include the area specified in § 23.775(e).

b. External View. The external vision should be evaluated in all lighting and environmental conditions (day and night) with the airplane in all attitudes normally encountered. Attention to windshield distortion or refraction should especially be given to the view toward the approach and runway lights and the runway markings. Since glare and reflection often differ with the sun's inclination, consideration should be given to evaluating the cockpit at midday and in early morning or late afternoon. If the windshield is heated, evaluations should be conducted with heat on and off. Distortion and refraction should be so low as to prevent any unsafe condition, unusual eye strain or fatigue. "Safe operation," as used in § 23.773(a)(1), includes the ability to conduct straight ahead and circling approaches under all approved operating conditions, including operations in high humidity and icing conditions (if appropriate).

(1) Section 23.773(a)(2) requires that windshields be free from glare and reflections that could interfere with the pilot's vision. Multiple imaging can be a problem with acrylic windshields 0.250 inches or thicker. Apparently, this is not a condition caused by any manufacturing operation, but it is caused by the highly polished reflective surface of the new acrylic sheet when viewed at an angle. Tests for reflections can be performed at night using runway and taxiway lights or by using the guidance in SAE AMS-G-25871.

c. Night Approval. If night approval is requested, all lighting, both internal and external, should be evaluated in likely combinations and under expected flight conditions. Instrument lighting should be evaluated at night under a variety of ambient conditions, including night IFR. Windshield/side window reflections that distract from traffic avoidance, landing approach and landing are not acceptable. Landing lights, strobes, beacons, and recognition lights should be evaluated to ensure no adverse reflections or direct impingement into the cockpit.

d. Defog/Defrost/Deice. The adequacy of the defog/defrost/deice systems should be evaluated under the following conditions:

(1) *Extended cold soak at maximum altitudes and minimum temperatures.* The airplane should be exposed to a cold environment appropriate to minimum expected temperatures. The airplane should be also evaluated after remaining outside on a cold night.

(2) *Field of view*. The airplane should be exposed to cold temperatures (cold soaked) and then descended into a warmer, moister air mass to assess ability to maintain a clear field of view. To properly evaluate internal fogging, the test airplane should be flown at night at high altitude for at least two hours (or until the windshield temperature stabilizes). Then, using proposed AFM procedures, the airplane should be rapidly descended to an approach and landing in a high humidity area (recommend dewpoint of least 70 °F (21 °C)). If manual clearing by the pilot(s) is required, it should be "easily" accomplished by an average pilot. The applicant should provide any special equipment required to accomplish the manual clearing. Repeated immediate clearing after manually wiping the windshield would not seem to fit the "easily cleared" requirements. The "easily cleared" aspects should also be evaluated considering that the fogged windshield could frost under certain conditions. If manual clearing is required, pilot workload should be carefully evaluated if IFR approval is sought.

(3) *Evaluation conditions*. Evaluations should be conducted in moderate rain, day and night (if approval is sought), takeoffs, landings, and taxi.

e. Two Pilot Airplanes. It is recommended that two pilot airplanes have pilot visibility in accordance with SAE Aerospace Standard AS 580B, "Pilot Visibility from the Flight Deck Design Objectives for Commercial Transport Aircraft."

f. Cockpit Camera. An evaluation and documentation of the cockpit using a binocular camera is highly desirable.

3. § 23.775 Windshields and Windows. For commuter category airplanes, assuming loss of vision through any one panel in front of the pilot(s), either side panels or co-pilot panels, or both, may be used to show that continued safe flight and landing is possible using these panels only while remaining seated at a pilot(s) station. For aircraft to be certified for IFR, the applicant should show that a safe landing can be demonstrated with IFR certified minimum visibility conditions.

4. § 23.777 Cockpit Controls. Reserved.

5. § 23.785 Seats, Berths, Litters, Safety Belts and Shoulder Harnesses.

a. Explanation. This subpart requires an approved seat for each occupant.

b. Procedures. Confirm that, when approved production seats are in place, the seats can be easily adjusted and will remain in a locked position.

6. § 23.803 Emergency Evacuation. This subject is covered in AC 20-118A.

7. § 23.807 Emergency Exits. This subject is covered in AC 23-17.

8. § 23.831 Ventilation.

a. Explanation. This subpart requires the carbon monoxide concentration not to exceed one part in 20,000 parts of air, which is 0.005 of one percent or 50 parts-per-million. A sample matrix for CO concentration is given in table 9.

b. Procedures. Test for Carbon Monoxide:

(1) Airplane may be at any convenient weight and c.g. position.

(2) Using a "CO" indicator reading instrument, record the values for the following table:

Table 9 – Sample of Co-Concentration Matrix

	Climb M.C. Power or Full Throttle Speed V_{REF} Mixture Full Rich		Cruise 75 percent M.C. Power Mixture		Glide Engine(s) throttled Speed V_{REF} Flaps up	
	Windows and/or Vents					
	Partly open	Closed	Partly open	Closed	Partly open	Closed
a. Maximum Reading (Cockpit): (1) Along Windows and /or Vents						
(2) Along Floor						
(3) Front of Instrument Panel						
(4) Front of Pilots Face						
b. Maximum Reading (cabin): (1) Front						
(2) Center						
(3) Rear						
	AUXILIARY POWER UNIT Installed? No Yes		HEATERS Installed? No Yes		OTHERS	
c. With Tester Directly in Front of Unit While Unit is Operating						

Section 5. Pressurization

1. **§ 23.841 Pressurization Cabins.** This subject is covered in AC 23-17.

2. **§ 23.843 Pressurization Tests.** Reserved.

Chapter 4. Subpart E--Powerplant

Section 1. General

1. § 23.901 Installation.

2. § 23.903 Engines.

a. Explanation.

(1) *Automatic Propeller Feathering Systems*. All parts of the feathering device that are integral with the propeller or attached to it in a manner that may affect propeller airworthiness should be considered. The determination of airworthiness should be made on the following basis:

(i) The automatic propeller feathering system should not adversely affect normal propeller operation and should function properly under all temperatures, altitudes, airspeeds, vibrations, accelerations, and other conditions to be expected in formal ground and flight operation.

(ii) The automatic device should be demonstrated to be free from malfunctioning, which may cause feathering under any conditions other than those under which it is intended to operate. For example, it should not cause feathering during the following:

(A) Momentary loss of power; and

(B) Approaches with reduced throttle settings.

(iii) The automatic propeller feathering system should be capable of operating in its intended manner whenever the throttle control is in the normal position to provide takeoff power. No special operations at the time of engine failure should be necessary on the part of the crew in order to make the automatic feathering system operative.

(iv) The automatic propeller feathering installation should be such that not more than one propeller will be feathered automatically even if more than one engine fails simultaneously.

(v) The automatic propeller feathering installation should be such that normal operation may be regained after the propeller has begun to feather automatically.

(vi) The automatic propeller feathering installation should incorporate a switch or equivalent means to make the system inoperative. (Also refer to §§ 23.67 and 23.1501.)

(vii) If performance credit is given for the automatic propeller feathering system, there should be means provided to satisfactorily preflight check the system.

(viii) Some turbopropeller airplanes are equipped with some type of engine ignition system intended for use during flight in heavy precipitation conditions and for takeoff/landing on wet or slush-covered runways. The engine ignition system may be either automatic or continuous. The purpose of this system is to prevent or minimize the possibility of an engine flameout due to water ingestion. Compatibility with auto-feather systems should be ensured.

(2) *Negative Torque Sensing Systems.* Reserved.

b. Procedures.

(1) *Automatic and Manual Propeller Feathering System Operational Tests.*

(i) Tests should be conducted to determine the time required for the propeller to change from windmilling (with the propeller controls set for takeoff) to the feathered position at the takeoff speed determined in § 23.51.

(ii) The propeller feathering system should be tested at one engine inoperative climb airspeed. The configuration should be the following:

(A) Critical engine inoperative;

(B) Wing flaps retracted;

(C) Landing gear retracted; and

(D) Cowl flaps closed.

Note: If the feathered propeller has a residual rotation, this has to be considered for aircraft performance.

(iii) The propeller should be tested in the actual configuration for an emergency descent. A sufficient speed range should be covered to assure that any propeller rotation is not hazardous. In addition, the propeller should not inadvertently unfeather during these tests.

(iv) In order to demonstrate that the feathering system operates satisfactorily, propeller feather should be demonstrated throughout both the airspeed and the altitude envelope since engine failure may occur at any time. Propeller unfeathering, manually or automatically, need only be demonstrated up to the maximum one-engine-inoperative service ceiling or maximum airstart altitude, whichever is higher. Satisfactory propeller unfeathering should also be demonstrated after a 30-minute cold soak.

(2) *Continued Rotation of Turbine Engines.*

(i) Means should be provided to completely stop the rotation of turbine engines if continued rotation would cause a hazard to the airplane. Devices such as feathering propellers, brakes, doors, or other means may be used to stop turbine engine rotation.

(ii) If engine induction air duct doors or other types of brakes are provided to control engine rotation, no single fault or failure of the system controlling engine rotation should cause the inadvertent travel of the doors toward the closed position. Also, it should not cause the inadvertent energizing of braking means unless compensating features are provided to ensure that engine failure or a critical operating condition will not occur. Such provisions should be of a high order of reliability, and the probability should be remote that doors or brakes will not function normally on demand.

(3) *Engine Operation with Automatic Propeller Control System Installed*.

(i) When an automatic control system for simultaneous r.p.m. control of all propellers is installed, it should be shown that no single failure or malfunction in this system or in the engine controlling this system will cause the following:

(A) The allowable engine overspeed for this condition to be exceeded at any time; and

(B) A loss of thrust that will cause the airplane to fail to meet the requirements of §§ 23.51 through 23.77 if such system is certificated for use during takeoff and climb. This should be shown for all weights and altitudes for which certification is desired. A period of five seconds should be allowed from the time the malfunction occurs to the initial motion of the cockpit control for corrective action taken by the crew.

(ii) Compliance with this policy may be shown by analysis, flight demonstration, or a combination thereof.

c. Restart Envelope.

(1) *Explanation*. The applicant should propose a practicable airstart envelope wherein satisfactory inflight engine restarts may be accomplished as required by the regulation. Airstarts should be accomplished satisfactorily at critical combinations of airspeed and altitude. During these tests, normally, time history data showing airspeed, altitude, r.p.m., exhaust temperature, and so forth, are obtained for inclusion in the type inspection report.

(i) The airstart envelope should be included in the limitations section of the AFM, and the procedures used to restart the engine(s) should be contained in the emergency or abnormal procedures section of the AFM.

(ii) Results of restart tests completed by the engine manufacturer on the same type of engine in an altitude test facility or flying test bed, if available, are included in the type inspection report. The experience accumulated in other aircraft with the same engine and engine installation, may be taken into account if justified.

(2) *Procedures*. To establish the required envelope of altitude and airspeed, sufficient flight tests should be made as follows:

(i) From sea-level to the maximum declared restarting altitude in all appropriate configurations likely to affect restarting, including the emergency descent configuration;

(ii) From the minimum to the maximum declared airspeed at all altitudes up to the maximum declared engine restarting altitude. The airspeed range of the declared restart envelope normally should cover at least 30 knots, but should be adapted to the type of airplane.

(A) The tests should include the effect on engine restarting performance of delay periods between engine shutdown and restarting as follows:

(iii) Up to two minutes; and

(iv) At least until the engine oil temperature is stabilized at its approximate cold soak value.

3. § 23.905 Propellers. Refer to paragraph 23.903 of this AC for guidance.

4. § 23.909 Turbo Superchargers. Refer to AC 23-16A for guidance.

5. § 23.925 Propeller Clearance. Reserved.

6. § 23.929 Engine Installation Ice Protection.

a. Explanation. This regulation requires that propellers and other components of the complete engine installation, such as oil cooling inlets, generator cooling inlets, and so forth, function satisfactorily and operate properly without an appreciable and unacceptable loss of power when the applicant requests approval for flight in icing conditions. An unacceptable loss of power may depend on the kind of aircraft and the power available. For details refer to the latest version of AC 23.1419-2. Refer to § 23.1093 for induction system ice protection requirements.

b. Procedures. Each propeller and other components of the complete installation that is to be approved for flight in icing conditions should be evaluated under the icing conditions specified in part 25, Appendix C. If the propellers are equipped with fluid-type deicers, the flow test should be conducted starting with a full tank of fluid and operated at maximum flow for a time period found operationally suitable. The operation should be checked at all engine speeds and powers.

7. § 23.933 Reversing Systems.

a. Explanation. Self-explanatory.

b. Procedures. Reversing system installations may be approved provided the following is acceptable:

(1) *Pilot skill.* Exceptional pilot skill should not be required in taxiing or any condition in which reverse thrust is to be used.

(2) *Operating procedures.* Necessary operating procedures, operating limitations, and placards are established.

(3) *Control characteristics*. The airplane control characteristics are satisfactory with regard to control forces encountered, and buffeting should not cause structural damage.

(4) *Directional control*. The directional control is adequate using normal piloting skill.

(5) *Sudden engine failure*. A determination is made that no dangerous condition is encountered in the event of sudden failure of one engine in any likely operating condition.

(6) *Reasonable safeguards*. The operating procedures and airplane configuration are such as to provide reasonable safeguards against serious structural damage to parts of the airplane due to the reverse airflow.

(7) *Pilot's vision*. It is determined that the pilot's vision is not dangerously obscured under normal operating conditions on dusty or wet runways and where light snow is on the runway.

(8) *Pilots vision for seaplanes*. It is determined that the pilot's vision is not dangerously obscured by spray due to reverse airflow under normal water operating conditions with seaplanes.

(9) *Reverse idle setting*. The procedure and mechanisms for reversing should provide a reverse idle setting such that without requiring exceptional piloting skill at least the following conditions are met:

(i) Sufficient power is maintained to keep the engine running at an adequate speed to prevent engine stalling during and after the propeller reversing operation.

(ii) The propeller does not overspeed during and after the propeller reversing operation.

(10) *Engine cooling*. The engine cooling characteristics should be satisfactory in any likely operating condition.

(11) *Ground idle position*. If using ground idle for disking drag credit on landing distance, the ground idle position of the power levers should be identified with a gate or a detent with satisfactory tactile feel (reference paragraph 23.75a(6)(iv) of this AC).

(12) *Thrust reverser position*. If compliance with § 23.933(a)(1)(ii) is intended to be shown by flight tests, any possible position of any one thrust reverser has to be assumed.

8. § 23.939 Powerplant Operating Characteristics.

a. Explanation. Self-explanatory.

b. Procedures.

(1) *Stall, Surge, Flameout Tests*. For turbine engines, tests should be conducted to determine that stall, surge, and flameout will not occur, to a hazardous degree, on any engine during acceleration and deceleration throughout the normal flight envelope of the airplane. This would include tests throughout the approved altitude range and throughout the airspeed range from V_S to V_{MO}/M_{MO} using sideslip angles appropriate to the individual airplane. For normal category multiengine airplanes, an appropriate sideslip angle is generally considered to be approximately one ball width on a standard slip-skid indicator. The low airspeed tests should be accomplished at light weight and with gear and flaps extended to further reduce the stall speed. Tests need not be accomplished with gear and flaps extended at airspeeds above which extension is prohibited in the AFM. At the conditions mentioned above, the effects of engine bleed air off and on and engine ice protection systems off and on should be investigated.

(2) *Throttle Techniques for Turbine Engines.* With the engine stabilized at maximum continuous power, rapidly retard the throttle to the flight idle position. Before the engine reaches idle power or r.p.m., rapidly advance the throttle to maximum continuous power. Repeat this process, except begin with the engine stabilized at flight idle power. Rapid throttle movement is generally defined as one which results in the throttle moving from maximum continuous power to flight idle, or vice versa, in not more than 0.5 seconds.

(3) *Throttle Techniques for Reciprocating Engines.* The techniques are similar to turbine engines except throttle movements should be slower and smoother to avoid damaging the engine. Most reciprocating engines are still manually controlled and rapid throttle movements

can damage the engine. This is not an issue for reciprocating engines equipped with FADEC because the system should make the throttle speed irrelevant.

9. § 23.943 Negative Acceleration.

a. Explanation. Tests should be conducted to show that no hazardous malfunction occurs under negative accelerations within the flight envelope. A hazardous malfunction in this case usually is considered to be one which causes a loss or sustained malfunction of the engine, or improper operation of the engine accessories or systems.

b. Procedures.

(1) *Tests.* Critical points of negative acceleration may be determined through tests. Consideration should be given to the possibility of critical level of fuel and oil.

(2) *Normal, Utility and Acrobatic Category Airplanes.* With engines operating at maximum continuous power, the airplane is flown at a critical negative acceleration within the prescribed flight envelope. Normally, a duration of the negative acceleration in separate tests of -0.2g for five seconds, -0.3g for four seconds, -0.4g for three seconds, and -0.5g for two seconds should reveal any existing hazardous malfunctioning of the engine. Alternately, -0.5g for five seconds may be used.

(3) *Acrobatic Category Airplanes.* In addition, for acrobatic category airplanes, for which certification is requested for inverted flight or for negative g maneuvers, the airplane should be subjected to the maximum value and time of negative acceleration for which approval is requested.

(4) *Commuter Category Airplanes.* For commuter category airplanes, one continuous period of at least five seconds at -0·5g, and separately a period containing at least two excursions to 0·5g in rapid succession, in which the total time at less than zero g is at least five seconds has to be shown without any existing hazardous malfunctioning of the engine.

(5) *Accelerations*. In addition, it may be necessary to consider other points within the flight envelope at other levels of fuel with shorter applications of accelerations. In all cases, the accelerations are measured as near as practicable to the c.g. of the airplane.

Section 2. Fuel System

1. § 23.959 Unusable Fuel Supply. Refer to AC 23-16 for guidance.

2. § 23.961 Fuel System Hot Weather Operation. Refer to AC 23-16 for guidance.

Section 3. Fuel System Components

1. § 23.1001 Fuel Jettisoning System.

a. Explanation. The basic purpose of these tests is to determine that the required amount of fuel may be safely jettisoned under reasonably anticipated operating conditions within the prescribed time limit without danger from fire, explosion, or adverse effects on the flying qualities. The applicant should have made sufficient jettisoning tests to prove the safety of the jettisoning system.

b. Procedures.

(1) *Fire Hazard.*

(i) Fuel in liquid or vapor form should not impinge upon any external surface of the airplane during or after jettisoning. Colored fuel, or surfaces so treated that liquid or vaporous fuel changes the appearance of the airplane surface, may be used for detection purposes. Other equivalent methods for detection may be acceptable.

(ii) Fuel in liquid or vapor form should not enter any portion of the airplane during or after jettisoning. The fuel may be detected by its scent, combustible mixture detector, or by visual inspection. In pressurized airplanes, the presence of liquid or vaporous fuel should be checked with the airplane unpressurized.

(iii) There should be no evidence of fuel valve leakage after it is closed.

(iv) If there is any evidence that wing flap (slats/slots) positions other than those used for the test may adversely affect the flow pattern, the airplane should be placarded "Fuel should not be jettisoned except when flaps (slats/slots) are set at ___ degrees."

(v) The applicant should select, for demonstration, the tanks or tank combinations that are critical for demonstrating the flow rate during jettisoning.

(vi) Fuel jettisoning flow pattern should be demonstrated from all normally used tank or tank combinations on both sides of the airplane whether or not both sides are symmetrical.

(vii) Fuel jettisoning rate may be demonstrated from only one side of symmetrical tank or tank combinations that are critical for flow rate.

(viii) Fuel jettisoning rate and flow pattern should be demonstrated when jettisoning from full tanks using fuel.

(2) *Control*.

(i) Changes in the airplane control forces during the fuel jettisoning tests should be noted.

(ii) The capability to shut off the fuel jettisoning system should be demonstrated in flight.

(3) *Residual Fuel.* The residual fuel should be measured by draining the tanks from which fuel has been jettisoned in flight, measuring the total drained fuel, and subtracting from the total the unusable fuel quantity for each tank to determine if there is sufficient reserve fuel after jettisoning to meet the requirements of this section. This may be a ground test.

Section 4. Oil System

1. § 23.1027 Propeller Feathering System. Refer to paragraph 23.903 of this AC for guidance.

Section 5. Cooling

1. § 23.1041 General. Refer to paragraphs 23.1043, 23.1045, and 23.1047 of this AC for guidance.

2. § 23.1043 Cooling Tests.

a. Explanation. Paragraphs 23.1045 and 23.1047 of this AC provide details on reciprocating engine and turbine engine cooling tests. Additional procedures for certification of winterization equipment are given below.

b. Weight and C.G. Forward c.g. at maximum gross weight is usually the most critical condition. For reciprocating engine-powered airplanes of more than 6,000 pounds maximum weight and for turbine engine-powered airplanes, the takeoff weight need not exceed that at which compliance with § 23.63(c)(1) has been shown. If engine cooling is critical at high altitude, it may not be possible to achieve the critical point with the maximum weight, in which case a lower weight may represent the most critical weight condition.

c. Winterization Equipment Procedures. The following procedures should be applied when certificating winterization equipment:

(1) *Other Than a 38 °C (100 °F).* Cooling test results for winterization installations may be corrected to any temperature desired by the applicant rather than the conventional 38 °C (100 °F) hot day. For example, an applicant may choose to demonstrate cooling to comply with requirements for a 10 °C (50 °F) or 15.5 °C (60 °F) day with winterization equipment installed. This temperature becomes a limitation to be shown in the AFM. In such a case, the sea level temperature for correction purposes should be considered to be the value elected by the applicant with a rate of temperature drop of 2 °C (3.6 °F) per thousand feet above sea level.

(2) *Tests*. Cooling tests and temperature correction methods should be the same as for conventional cooling tests.

(3) *Limit Temperature.* The AFM should clearly indicate that winterization equipment should be removed whenever the temperature reaches the limit for which adequate cooling has been demonstrated. The cockpit should be placarded accordingly.

(4) *Equipment Marking*. If practical, winterization equipment, such as baffles for oil radiators or for engine cooling air openings, should be marked clearly to indicate the limiting temperature at which this equipment should be removed.

(5) *Installation Instructions.* Since winterization equipment is often supplied in kit form and accompanied by instructions for its installation, manufacturers should provide suitable information regarding temperature limitations in the installation instructions.

3. § 23.1045 Cooling Test Procedures for Turbine Engine-Powered Airplanes.

a. Explanation.

(1) *Purpose*. Cooling tests are conducted to determine the ability of the powerplant cooling provisions to maintain the temperatures of powerplant components and engine fluids within the temperature limits for which they have been certificated. These limits will normally be specified on the TC data sheet.

(2) *Components With Time/Temperature Limits.* The conventional method of approving engine components is to establish a temperature limit that will ensure satisfactory operation during the overhaul life of the engine. However, a component that exceeds the temperature limit can be approved at the elevated temperature for a specific period of time. To ensure that a component having a time/temperature limit will operate within the established limitation, a means should be provided to record the time and temperature of an excessive temperature and warn the pilot accordingly. The method of recording elapsed time and temperature should be automatic or activated by the pilot with a simple operation. Operating limitations requiring the pilot to detect a critical airplane operating condition and record the elapsed time in the airplane logs would not be acceptable due to the other pilot duties during the critical airplane operating condition.

(3) *Altitude*. Cooling tests should be conducted under critical ground and flight operating conditions to the maximum altitude for which approval is requested.

b. Test Procedures Applicable to Both Single-Engine and Multiengine Airplanes.

(1) *Performance and Configuration*. Refer to § 23.45, which has performance requirements related to engine cooling.

(2) *Moisture*. The tests should be conducted in air free of visible moisture.

(3) *Weight and C.G*. Forward c.g. at maximum gross weight is usually the most critical condition.

(4) *Oil Quantity*. The critical condition should be tested.

(5) *Thermostat*. Airplanes that incorporate a thermostat in the engine oil system may have the thermostat retained, removed, or blocked in such a manner as to pass all engine oil through the oil cooler. If the thermostat is retained, the oil temperature readings obtained on a cooler day corrected to hot-day conditions may, therefore, be greater than those obtained under actual hot-day conditions. Caution should be exercised when operating an airplane with the thermostat removed or blocked during cold weather to prevent failure of the lubricating system components.

(6) *Instrumentation*. Accurate and calibrated temperature-measuring devices should be used, along with acceptable thermocouples or temperature-pickup devices. The proper pickup should be located at critical engine positions.

(7) *Generator*. The alternator/generator should be electrically loaded to the rated capacity for the engine/accessory cooling tests.

(8) *Temperature Limitations*. For cooling tests, a maximum anticipated temperature (hot-day conditions) of at least 38 °C (100 °F) at sea level must be used. Temperatures at higher altitudes assume a change at 2 °C (3.6 °F) per 1,000 feet of altitude, up to -56.5 °C (-69.7 °F). The maximum ambient temperature selected and demonstrated satisfactorily becomes an airplane operating limitation per the requirements of § 23.1521(e).

(9) *Temperature Stabilization*. For the cooling tests, a temperature is considered stabilized when its observed rate of change is less than 2 °F per minute.

(10) *Altitude*. The cooling tests should be started at the lowest practical altitude, usually below 3,000 feet MSL, to provide a test data point reasonably close to sea level.

(11) *Temperature Correction for Ground Operation.* Recorded ground temperatures should be corrected to the maximum ambient temperature selected, without consideration of the altitude temperature lapse rate. For example, if an auxiliary power unit is being tested for ground cooling margins, the cooling margin should be determined from the recorded ground temperature without regard to the test site altitude.

c. Test Procedures for Single-Engine, Turbine-Powered Airplanes.

(1) *Normal engine start*. A normal engine start should be made and all systems checked out. The engine should be run at ground idle and temperatures and other pertinent data should be recorded.

(2) *Taxi.* Taxi airplane for approximately one mile to simulate normal taxi operations. Record cooling data at one-minute intervals.

(3) *Seaplanes*. For hull-type seaplanes operating on water, taxi tests should be conducted such that spray characteristics do not bias the cooling characteristics. Engine cooling during water taxiing should be checked by taxiing downwind at a speed approximately five knots above the step speed for a minimum of ten minutes continuously. Record cooling data at one-minute intervals.

(4) *Pre-takeoff*. Establish a pre-takeoff holding condition on the taxiway (crosswind) for 20 minutes minimum or until temperatures stabilize. Record cooling data at five-minute intervals.

(5) *Runway*. On the runway, set takeoff power and record cooling data.

(6) *Takeoff*. Takeoff as prescribed in § 23.53 and climb to pattern altitude. Record cooling data upon reaching pattern altitude or at one-minute intervals if it takes more than one-minute to reach pattern altitude.

(7) *Flaps and climb*. Retract flaps and continue climb with maximum continuous power at the speed selected to meet the requirements of § 23.65(b). Climb to the maximum approved altitude, recording cooling data at one-minute intervals.

(8) *Cruise*. Cruise at maximum continuous power (or V_{MO}/M_{MO}, if limiting) at maximum operating altitude until temperatures stabilize. Record cooling data at one-minute intervals. For many components, this will be the critical temperature operating condition.

(9) *Descent*. Conduct a normal descent at V_{MO}/M_{MO} to holding altitude and hold until temperatures stabilize. Record cooling data at one-minute intervals.

(10) *Approach.* Conduct a normal approach to landing. Record cooling data at one-minute intervals.

(11) *Balked landing*. From not less than 200 feet above the ground, perform a balked landing go-around in accordance with § 23.77. Record cooling data at one-minute intervals during a traffic pattern circuit.

(12) *Climb to pattern*. Climb to pattern altitude, perform a normal approach and landing in accordance with the applicable portion of § 23.75. Record cooling data at one-minute intervals.

(13) *Taxi back to ramp*. Shut down engine. Allow engine to heat-soak. Record temperature data at one-minute intervals until five minutes after temperatures peak.

d. Test Procedures for Multiengine, Turbine-Powered Airplanes. A multiengine airplane should conduct the same profile as the single-engine airplane, in an all-engine configuration. On completion of the all-engine profile, conduct the applicable one-engine-inoperative cooling climb test recording data at one-minute intervals. Shut down critical engine and, with its propeller (if applicable) in the minimum drag position, the remaining engine(s) at not more than maximum continuous power or thrust, landing gear retracted, and wing flaps in the most favorable position. Climb at the speed used to show compliance with § 23.67. Continue until five minutes after temperatures peak.

e. Data Acquisition. The following data should be recorded at the time intervals specified in the particular test program. The data may be manually recorded unless the quantity and frequency necessitate automatic or semi-automatic means:

(1) *Outside air temperature (OAT);*

(2) *Altitude;*

(3) *Airspeed (knots);*

(4) *Gas generator r.p.m.;*

(5) *Engine torque;*

(6) *Time;*

(7) *Propeller r.p.m.;*

(8) *Engine oil temperature;*

(9) *Pertinent engine temperature; and*

(10) *Pertinent nacelle and component temperatures*.

f. Data Reduction.

(1) *Limitations*. A maximum anticipated temperature (hot-day conditions) of at least 38 °C (100 °F) at sea level must be used. The assumed temperature lapse rate is 2 °C (3.6 °F) per 1,000 feet altitude up to the altitude at which a temperature of -56.5 °C (-69.7 °F is reached, above which altitude the temperature is constant at -56.5 °C (-69.7 °F). On turbine-powered airplanes, the maximum ambient temperature selected becomes an airplane operating limitation in accordance with the requirements of § 23.1521(e). On turbine-powered airplanes, the applicant should correct the engine temperatures to as high a value as possible in order to not be limited.

(2) *Correction Factors*. Unless a more rational method applies, a correction factor of 1.0 is applied to the temperature data as follows and as shown in the sample calculation below: corrected temperature = true temperature + 1.0
[100 - 0.0036 (Hp) - true OAT].

Figure 24 – Sample Calculation

Sample Calculation:

True Temperature	-- 300 °F
True OAT	-- 15 °F
Hp	-- 5,000 feet

The corrected temperature = 300 + 1.0 [100 - 0.0036 (5,000) - 15] = 367 °F.

The corrected temperature is then compared with the maximum permissible temperature to determine compliance with the cooling requirements.

4. § 23.1047 Cooling Test Procedures for Reciprocating Engine-Powered Airplanes.

a. Procedures.

(1) *Additional Procedures*. The procedures of paragraph 23.1045b(1) through 23.1045b(6) of this AC also apply to reciprocating engines.

(2) *Altitude*. Engine cooling tests for reciprocating engine airplanes are normally initiated below 2,000 feet pressure altitude. Service experience indicates that engine cooling tests started above 5,000 feet may not assure adequate cooling margins when the airplane is operated at sea level. If an applicant elects not to take the airplane to a low altitude test site, additional cooling margins have been found acceptable. If engine cooling tests cannot be commenced below 2,000 feet pressure altitude, the temperature margin should be increased. It should be increased by 17 °C (30 °F) at 7,000 feet for cylinder heads and 33 °C (60 °F) for both engine oil and cylinder barrels with a straight line variation from sea level to 7,000 feet, unless the applicant demonstrates that some other correction margin is more applicable.

(3) *Hull-Type Seaplanes*. Cooling tests on hull-type seaplanes should include, after temperatures stabilize, a downwind taxi for ten minutes at five knots above the step speed, recording cooling data at one-minute intervals.

(4) *Test Termination*. If at any time during the test temperatures exceed the manufacturer's specified limits, the test is to be terminated.

(5) *Climb Transition*. At the beginning of the cooling climb, caution should be used in depleting the kinetic energy of the airplane while establishing the climb speed. The climb should not be started by "zooming" into the climb. The power may be momentarily reduced provided that the stabilized temperatures are not allowed to drop excessively. This means that a minimum of time should be used in slowing the airplane from the high cruise speed to the selected cooling climb speed. This may be accomplished by maneuver loading the airplane or any other means that provides minimum slow-down time.

(6) *Component Cooling*. Accessories or components on the engine or in the engine compartment that have temperature limits should be tested and should be at the maximum anticipated operating conditions during the cooling tests; for example, generators should be at maximum anticipated loads.

(7) *Superchargers*. Superchargers and turbo-superchargers should be used as described in the AFM. Engine cooling should be evaluated in the cruise condition at the maximum operating altitude, since this may be a more critical point than in climb. Also,

turbocharged engines sometimes give a false peak and the climb should be continued long enough to be sure that the temperatures do not begin to increase again.

(8) *Single-Engine Airplanes*. The cooling tests for single-engine airplanes should be conducted as follows:

(i) At the lowest practical altitude, establish a level flight condition at not less than 75 percent maximum continuous power until temperatures stabilize. Record cooling data.

(ii) Increase engine power to takeoff rating and climb at a speed corresponding to the applicable performance data given in the AFM/POH, which are criteria relative to cooling. Maintain takeoff power for one minute. Record cooling data.

(iii) At the end of one minute, reduce engine power to maximum continuous and continue climb for at least five minutes after temperatures peak or the maximum operating altitude is reached. Record cooling data at one-minute intervals. If a leaning schedule is furnished to the pilot, it should be used.

(9) *Multiengine Airplanes*. For multiengine-powered airplanes that meet the minimum one-engine-inoperative climb performance specified in § 23.67 with the airplane in the configuration used in establishing critical one-engine-inoperative climb performance, the cooling tests should be conducted as follows:

(i) At the lower altitude of 1,000 feet below engine critical altitude or 1,000 feet below the altitude at which the minimum one-engine-inoperative climb gradient is 1.5 percent, or at the lowest practical altitude (when applicable), stabilize temperatures of the test engine in level flight at not less than 75 percent maximum continuous power. Record cooling data.

(ii) After temperatures stabilize, initiate a climb at a speed not more than the highest speed at which compliance with the climb requirement of § 23.67 is shown. With the test engine at maximum continuous power (or full throttle), continue climb until five minutes after temperatures peak or the maximum operating altitude is reached. Record cooling data at one-minute intervals.

(10) *Performance Limited Multiengine Airplanes*. For multiengine airplanes that cannot meet the minimum, one-engine-inoperative performance specified in § 23.67 is shown below:

(i) Set zero thrust on the planned "inoperative" engine and determine an approximate rate of sink (or climb). A minimum safe test altitude should then be established.

(ii) Stabilize temperatures in level flight with engines operating at no less than 75 percent maximum continuous power and as near sea level as practicable or the minimum safe test altitude.

(iii) After temperatures stabilize, initiate a climb at a speed not more than the highest speed at which compliance with the climb requirements of § 23.67 is shown with one engine inoperative and remaining engine(s) at maximum continuous power. Continue for at least five minutes after temperatures peak. Record cooling data at one-minute intervals.

b. Data Acquisition. The following data should be recorded at the time intervals specified in the applicable test programs and may be manually recorded unless the quantity and frequency necessitate automatic or semi-automatic means:

(1) *Time;*

(2) *Hottest cylinder head temperature*;

(3) *Hottest cylinder barrel temperature (only if a limitation);*

(4) *Engine oil inlet temperature*;

(5) *Outside air temperature*;

(6) *Indicated airspeed (knots)*;

(7) *Pressure altitude*;

(8) *Engine r.p.m.*;

(9) *Propeller r.p.m.;*

(10) *Manifold pressure;*

(11) *Carburetor air temperature*;

(12) *Mixture setting*;

(13) *Throttle setting; and*

(14) *Temperatures of components or accessories that have established limits that may be affected by powerplant heat generation.*

c. To Correct Cylinder Barrel Temperature to Anticipated Hot-Day Conditions.

(1) *Cooling requirements*. To determine compliance with cooling requirements and find the corrected cylinder barrel temperature, follow the formulas shown in figure 25 below:

Figure 25 – Corrected Cylinder Barrel Temperature

Corrected cylinder barrel temperature = true observed cylinder barrel temperature + 0.7 [100 - 0.0036 (pressure altitude) - true OAT].

For example:

True observed maximum cylinder barrel temperature-- 244 °F.
Pressure Altitude --8330 feet
True OAT --+55 °F.

Corrected cylinder barrel temperature (°F) = 244 + 0.7 [100 - 0.0036 (8330) - 55] = 255°F.

(2) *Corrected temperatures*. The corrected temperatures are then compared with the maximum permissible temperatures to determine compliance with cooling requirements.

d. To Correct Cylinder Head or Other Temperatures to Anticipated Hot-Day Conditions.

(1) *Cooling requirements*. To determine compliance with cooling requirements, find the correct cylinder head temperature and follow the formula shown in figure 26 below:

Figure 26 – Correct Cylinder Head Temperature

Corrected temperature (°F) = true temperature + 1.0 [100 - 0.0036 (pressure altitude) - true outside air temperature].

Corrected temperature (°C) = true temperature + 1.0[38-0.002(pressure altitude, ft) – true outside air temperature, °C].

For example (using metric units):

True maximum cylinder head temperature--	208 °C.
Pressure Altitude --	8330 feet
True OAT --	+13 °C.

Corrected cylinder head temperature = 208 + 1.0 [38 - 0.002 (8330) -13] = 216 °C.

(2) *Corrected temperatures*. The corrected temperatures are then compared with the maximum permissible temperatures to determine compliance with cooling requirements.

e. Liquid Cooled Engines. Reserved.

Section 6. Induction System

1. § 23.1091 Air Induction. AC 20-124 covers the turbine engine water ingestion aspects of this requirement.

2. § 23.1093 Induction System Icing Protection.

a. Explanation.

(1) *Purpose*. Tests of engine induction system icing protection provisions are conducted to ensure that the engine is able to operate throughout its flight power range without any adverse effect on engine operation. Reciprocating engines utilize a preheater or a sheltered alternate air source to provide adequate heat rise to prevent or eliminate ice formation in the engine induction system. The adequacy of this heat rise is evaluated during the test. The amount of heat available is determined by measuring the intake heat rise by temperature measurements of the air before it enters the carburetor. Turbine engine inlet ducts must be protected to prevent the accumulation of ice as specified in § 23.1093(b)(1).

(2) *Reciprocating Sea Level Engine Configurations.*

(i) *Venturi Carburetor*. Section 23.1093(a)(1) requires a 50 °C (90 °F) heat rise at 75 percent maximum continuous power at –1 °C (30 °F) OAT.

(ii) *Single-Engine Airplanes With a Carburetor Tending to Prevent Icing (Pressure Carburetor).* Section 23.1093(a)(5) requires an alternate air source with a temperature equal to that of the air downstream of the cylinders.

(iii) *Multiengine Airplane With Carburetor Tending to Prevent Icing (Pressure Carburetor).* Section 23.1093(a)(5) requires a 50 °C (90 °F) heat rise at 75 percent maximum continuous power at –1 °C (30 °F) OAT.

(iv) *Fuel Injection With Ram Air Tubes*. A heat rise of 50 °C (90 °F) at 75 percent maximum continuous power is recommended.

(v) *Fuel Injection Without Projections Into the Induction Air Flow*. An alternate air source with a temperature not less than the cylinder downstream air is recommended.

(3) *Reciprocating Altitude Engine Configurations.*

(i) *Venturi Carburetor.* Section 23.1093(a)(2) requires a 67 °C (120 °F) heat rise at 75 percent maximum continuous power at –1 °C (30 °F) OAT.

(ii) *Carburetors Tending to Prevent Icing (Pressure Carburetor).* Section 23.1093(a)(3) requires a heat rise of 100 °F at 60 percent maximum continuous power at –1 °C (30 °F) OAT or 22 °C (40 °F) heat rise if an approved fluid de-icing system is used.

(iii) *Fuel Injection*. Same as for sea level fuel injected engines. See 23.1093(a)(3)

(4) *Turbine Engines*. Section 23.1093(b) requires turbine engines to be capable of operating without adverse effects on operation or serious loss of power or thrust under the icing conditions specified in part 25, Appendix C. The powerplant should be protected from ice at all times, whether or not the airplane is certificated for flight into known icing conditions.

b. Reciprocating Engine Test Considerations.

(1) *Visible Moisture.* The tests should be conducted in air free of visible moisture.

(2) *Instrumentation*. All instruments used during the test should be calibrated and all calibration curves made part of the Type Inspection Report. Calibrations should be made of complete systems as installed and shall cover the temperature range expected during the tests.

(3) *Heat Rise*. All carburetor air heat rise requirements should be met at an outside air temperature of –1 °C (30 °F). If the test cannot be conducted in an atmosphere with an ambient air temperature of –1 °C (30 °F), it will normally be flown at low, intermediate, and high altitudes. If a –1 °C (30 °F) day exists at an altitude where 75 percent of rated power is available, only one test is necessary.

(4) *Intake Air*. Care should be exercised to assure that the method of measuring the temperature of the air will give an indication of the average temperature of the airflow through the intake and not just a stratum of air. This may be accomplished by temperature measurements of the intake air at several points. Usually, the temperate probe is placed at the carburetor deck. Other temperature probe locations may be acceptable, provided that the temperatures measured can be correlated with the air temperature at the carburetor deck. Care should be taken not to measure the temperature of a stratum of air, but the average temperature of the air entering the carburetor. Temperature probes placed in the carburetor throat, or venturi, are not acceptable for the carburetor air heat rise test. Temperature probe locations should be specified in any test plan for determining induction system ice protection.

c. Test Procedures for Reciprocating Engine Airplanes.

(1) *Stabilize*. At low altitude, stabilize airplane with full throttle or, if the engine is supercharged, with maximum continuous power on the test engine. With carburetor air heat control in the "cold" position, record data. Manually operated turbochargers should be off. For integrally turbocharged engines, heat rise data should be taken at lowest altitude conditions, where the turbo is providing minimum output.

(2) *Apply heat*. Apply carburetor heat and, after condition stabilizes, record data.

(3) *Reduce airspeed*. Reduce airspeed to 90 percent of that attained under item (1). With carburetor air heat control in the "cold" position and condition stabilized, record data.

(4) *Apply heat*. Apply carburetor heat and, after condition stabilizes, record data.

(5) *Reduce airspeed*. Reduce airspeed to 80 percent of that attained under item (1). With carburetor air heat control in the "cold" position and condition stabilized, record data.

(6) *Apply heat*. Apply carburetor heat and, after condition stabilizes, record data.

(7) *Repeat*. At the intermediate altitude, repeat steps (1) through (6).

(8) *Repeat*. At high altitude, repeat steps (1) through (6). Data to be recorded:

(i) Altitude (feet);

(ii) Airspeed (IAS) (Knots);

(iii) Ambient air temperature °F;

(iv) Carburetor air temperature °F;

(v) Carburetor heat control position;

(vi) Engine r.p.m.;

(vii) Engine manifold pressure (in Hg); and

(viii) Throttle position.

d. Data Reduction. Figures 27 and 28 show sample carburetor air heat rise determinations.

e. Test Procedures for Turbine Engine-Powered Airplanes. Tests to determine the capability of the turbine engine to operate throughout its flight power range without adverse effect on engine operation or serious loss of power or thrust should be conducted to encompass the icing conditions specified in part 25, Appendix C. Each airplane should be evaluated for compliance. Thermodynamic exercises and dry air tests alone are not usually adequate, and actual icing encounters or wind tunnel testing are necessary.

NOTE: May be flown at only one altitude if O.A.T. of 30°F is Available	MINIMUM ALTITUDE						INTERMEDIATE ALTITUDE						MAXIMUM ALTITUDE (75%)					
	Full Throttle or MC Power*		90% IAS of Column #1		80% IAS of Column #1		Full Throttle of MC Power*		90% IAS of Column #1		80% IAS of Column #1		Full Throttle or MC Power*		90% IAS of Colummn #1		80% IAS of Column #1	
Carburetor Air Heat Control Position	C	H	C	H	C	H	C	H	C	H	C	H	C	H	C	H	C	H
Pressure Altitude (ft.)	1500						5000						8000					
O.A.T. (F)	83	83	83	83	83	83	72	72	72	72	72	72	60	60	60	60	60	60
C.A.T. (F)	84	215	84	205	84	200	73	201	73	189	73	184	61	190	61	185	61	176
Heat Rise		132		122		117		129		117		112		130		125		116
I.A.S. (M.P.H.)	105	99	95	92	84	82	96	88	87	78	77	70	90	80	82	75	72	67
R.P.M.	2850	2730	2690	2590	2430	2310	2800	2640	2555	2400	2410	2280	2770	2525	2665	2480	2525	2310
M.P. (In. Hg.)	26.4	25.7	24.0	23.5	22.0	21.3	23.5	22.8	19.6	19.3	19.0	18.5	21.2	20.4	19.9	19.4	18.0	17.2
Indicated B.H.P.	144	132	120	112	105	99	125	114	92	85	76	72	113	100	101	90	73	65
Std. Temperature for Pressure Altitude (F)	54						41						30					
Temperature Correction Factor (See note 1)	.972	.872	.972	.879	.972	.882	.970	.870	.970	.879	.970	.882	.970	.868	.970	.871	.970	.878
Actual B.H.P.	140	115	117	98.4	102	87.4	121	99.2	89	74.7	74	63.5	110	86.8	98	78.4	71	57.1
% Rated B.H.P. (See note 2)	100	82.2	83.5	70.2	72.8	62.4	86.4	71.0	63.5	53.4	52.8	45.3	78.5	62.1	70	56.0	50.6	40.8
Throttle Position	FT	FT	P	P	P	P	FT	FT	P	P	P	P	FT	FT	P	P	P	P

*Supercharged Engines Only

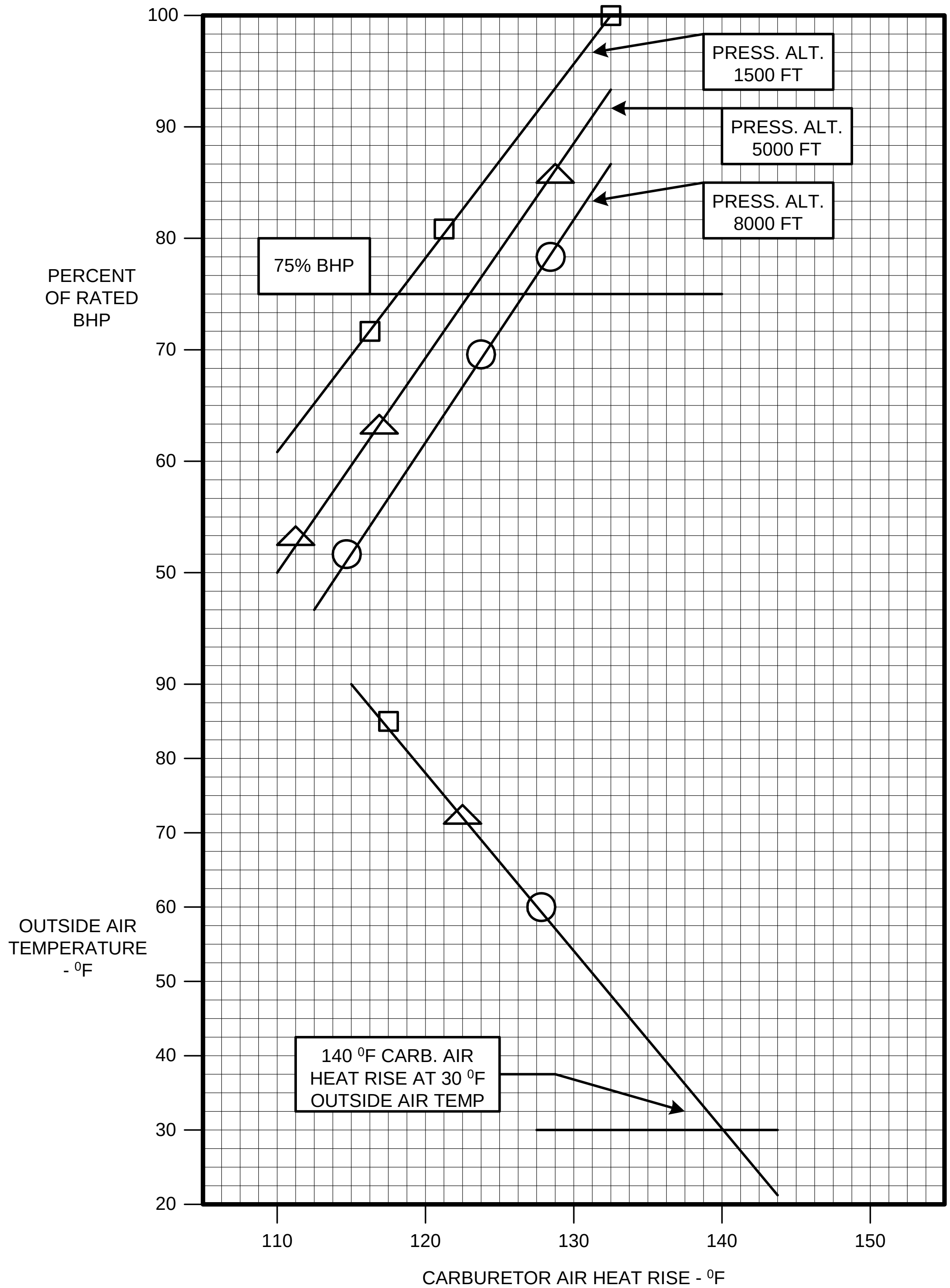
NOTE 1: Temperature Correction Factor = $\sqrt{\frac{\text{std temp } (^{o}F) + 460}{\text{CAT } (^{o}F) + 460}}$

NOTE 2: Rated BHP = 140

NOTE 3: Circled numbers indicate data plotted on figure 256-2.

Figure 27 - Carburetor Air Heat Rise Calculations

Figure 28 - Carburetor Air Heat Rise Plots



Section 7. Powerplant Controls and Accessories

1. § 23.1141 Powerplant Controls: General.

a. Explanation. Powerplant controls for each powerplant function will be grouped for each engine allowing simultaneous or independent operation as desired. Each control will be clearly marked as to function and control position. (Refer to § 23.777). Controls are required to maintain any position set by the pilot without tendency to creep due to vibration or control loads. Electronic engine control system installations must meet the requirements of § 23.1309.

b. Procedures. None.

2. § 23.1145 Ignition Switches. Reserved.

3. § 23.1153 Propeller Feathering Controls.

a. Explanation. If the propeller pitch or speed control lever also controls the propeller feathering control, some means are required to prevent inadvertent movement to the feathering position.

b. Procedures. None.

Section 8. Powerplant Fire Protection

1. § 23.1189 Shutoff Means.

a. Explanation. The location and operation of any required shutoff means is substantiated by analysis of design data, inspection, or test. The location and guarding of the control (switch), the location and clarity of any required indicators, and the ability to operate the controls with the shoulder harnesses locked (if applicable) should be evaluated.

b. Procedures. Control locations and guarding and indicator effectiveness should be part of the complete cockpit evaluation. Check the shutoff means function by performing an after-flight engine shutdown using the fuel shutoff.

Chapter 5. Subpart F--Equipment

Section 1. General

1. § 23.1301 Function and Installation.

a. Explanation. Section 23.1301 gives specific installation requirements. Particular attention should be given to those installations where an external piece of equipment could affect the flight characteristics. The flight test pilot should evaluate all installations of this nature to verify that the equipment functions properly when installed.

b. Avionics Test.

(1) *Very High Frequency VHF Communication Systems*. Refer to AC 20-67B. AC 20-67B references Radio Technical Commission for Aeronautics (RTCA) document DO-186. DO-186, paragraph 3.4.2.3 speaks to ground facility coverage area. FAA Order 6050.32, Appendix 2, shows the coverage limits for various facility parameters.

(2) *High Frequency (HF) Communication Systems*.

(i) *Ground Station Contacts*. Acceptable communication should be demonstrated by contacting a ground station on as wide a range of frequencies as HF propagation conditions allow. Distances may vary from 100 to several hundred nautical miles (n.m.). The system should perform satisfactorily in its design modes.

(ii) *Precipitation Static*. It should be demonstrated that precipitation static is not excessive when the airplane is flying at cruise speed (in areas of high electrical activity, including clouds and rain if possible). Use the minimum amount of installed dischargers for which approval is sought.

(iii) *Electromagnetic Compatibility (EMC)*. Electromagnetic compatibility tests should be conducted on the ground and in flight at 1.0 MHz intervals. Any electromagnetic interference (EMI) noted on the ground should be repeated in flight at the frequency at which the EMI occurred on the ground. Since squat switches may isolate some systems from operation on the ground (that is, air data system, pressurization, and so forth), EMI should be evaluated with all systems operating in flight to verify that no adverse effects are present in the engine, fuel control computer, brake antiskid, and so forth, systems.

(3) *Very High Frequency Omnirange (VOR) Systems*.

(i) *Antenna Radiation Patterns*. These flight tests may be reduced if adequate antenna radiation pattern studies have been made and these studies show the patterns to be without significant holes (with the airplane configuration used in flight; that is, flaps, landing gear, and so forth). Particular note should be made in recognition that certain propeller r.p.m. settings may cause modulation of the course deviation indication (prop-modulation). This information should be made a part of the AFM.

(A) *Reception*. The airborne VOR system should operate normally with warning flags out of view at all headings of the airplane (wings level) throughout the standard service volumes depicted in the Aeronautical Information Manual (AIM) up to the maximum altitude for which the airplane is certified.

(B) *Accuracy*. The accuracy determination should be made such that the indicated reciprocal agrees within two degrees. Tests should be conducted over at least two known points on the ground such that data are obtained in each quadrant. Data should correlate with the ground calibration, and in no case should the absolute error exceed ±6 degrees. There should be no excessive fluctuation in the course deviation indications.

(ii) *En Route Reception*. Fly from a VOR facility rated for high altitude along a radial at an altitude of 90 percent of the airplane's maximum certificated altitude to the standard service volume range. The VOR warning flag should not come into view, nor should there be deterioration of the station identification signal. The course width should be 20 degrees ±5 degrees (10 degrees either side at the selected radial). The tests should be flown along published route segments to preclude ground station anomalies. If practical, perform an en route segment on a Doppler VOR station to verify the compatibility of the airborne unit. Large errors have been found when incompatibility exists. Contact the nearest FAA Airway Facilities Sector Office to locate a Doppler VOR.

(iii) *Low-Angle Reception*. Perform a 360 degree right and 360 degree left turn at a bank angle of at least ten degrees at an altitude just above the lowest edge of the standard service volume and at the maximum service volume distance. Signal dropout should not occur as evidenced by the warning flag appearance. Dropouts that are relieved by a reduction of bank angle at the same relative heading to the station are satisfactory. The VOR identification should be satisfactory during the left and right turns. [note to myself, do a search]

(iv) *High-Angle Reception*. Repeat the turns described in (c) above, but a distance of 50-70 n.m. (20-30 n.m. for airplanes not to be operated above 18,000 feet) from the VOR facility and at an altitude of at least 90 percent of the maximum certificated altitude of the airplane.

(v) *En Route Station Passage*. Verify that the to-from indicator correctly changes as the airplane passes through the cone of confusion above a VOR facility.

(vi) *VOR Approach*. Conduct VOR approaches with gear and flaps down. With the facility 12-15 n.m. behind the airplane, use sufficient maneuvering in the approach to ensure the signal reception is maintained during beam tracking.

(vii) *Electromagnetic Compatibility (EMC)*. With all systems operating in flight, verify, by observation, that no adverse effects are present in the required flight systems. In VMC, incur fault condition to test activation of failure flag on the display.

(4) *Localizer Systems*.

(i) *Antenna Radiation Patterns*. Flight test requirements should be modified to allow for adequate antenna radiation pattern measurements as discussed in VOR systems, paragraph (3)(A).

(A) *Signal Strength*. The input to the receiver, presented by the antenna system, should be of sufficient strength to keep the malfunction indicator out of view when the airplane is in the approach configuration (landing gear extended - approach flaps) and within the normal limits of localizer coverage shown in the AIM. This signal should be received for 360 degrees of the airplane heading at all bank angles up to ten degrees left or right at all normal pitch attitudes and at an altitude of approximately 2,000 feet (refer to RTCA guidance).

(B) *Bank Angles*. Satisfactory results should also be obtained at bank angles up to 30 degrees when the airplane heading is within 60 degrees of the inbound localizer course. Satisfactory results should result with bank angles up to 15 degrees on headings from 60 degrees to 90 degrees of the localizer inbound course and up to 10 degrees bank angle on headings for 90 degrees to 180 degrees from the localizer inbound course.

(C) *Course Deviation Indicator (CDI).* The deviation indicator should properly direct the airplane back to course when the airplane is right or left of course.

(D) *Station Identification.* The station identification signal should be of adequate strength and sufficiently free from interference to provide positive station identification, and voice signals should be intelligible with all electric equipment operating and pulse equipment transmitting.

(ii) *Localizer Intercept*. In the approach configuration and at a distance of at least 18 n.m. from the localizer facility, fly toward the localizer front course, inbound, at an angle of at least 50 degrees. Perform this maneuver from both left and right of the localizer beam. No flags should appear during the time the deviation indicator moves from full deflection to on-course.

(iii) *Localizer Tracking*. While flying the localizer inbound and not more than five miles before reaching the outer marker, change the heading of the airplane to obtain full needle deflection. Then, fly the airplane to establish localizer on-course operation. The localizer deviation indicators should direct the airplane to the localizer on-course. Perform this maneuver with both a left and a right needle deflection. Continue tracking the localizer until over the transmitter. Acceptable front course and back course approaches should be conducted to 200 feet or published minimums. In VMC, incur fault condition to test activation of failure flag on the display.

(iv) *Electromagnetic Compatibility (EMC).* With all systems operating in flight, verify, by observation, that no adverse effects are present in the required flight system.

(5) *Glide Slope Systems*.

(i) *Signal Strength*. The signal input to the receiver should be of sufficient strength to keep the warning flags out of view at all distances to ten n.m. from the facility. This performance should be demonstrated at all airplane headings between 30 degrees right and left of the localizer course (refer to RTCA Document DO-1010). The deviation indicator should properly direct the airplane back to path when the airplane is above or below the path. Interference with the navigation operation, within ten n.m. of the facility, should not occur with all airplane equipment operating and all pulse equipment transmitting. There should be no interference with other equipment as a result of glide slope operation.

(ii) *Glide Slope Tracking*. While tracking the glide slope, maneuver the airplane through normal pitch and roll attitudes. The glide slope deviation indicator should show proper operation with no flags. Acceptable approaches to 200 feet or less above threshold should be conducted.

(iii) *Electromagnetic Compatibility (EMC).* With all systems operating in flight, verify, by observation, that no adverse effects are present in the required flight systems.

(6) *Marker Beacon System*.

(i) *Flight Test*.

(A) In low sensitivity, the marker beacon annunciator light should be illuminated for a distance of 2,000 to 3,000 feet when flying at an altitude of 1,000 feet AGL on the localizer centerline in all flap and gear configurations.

(B) An acceptable test to determine distances of 2,000 to 3,000 feet is to fly at a ground speed listed in the table below (table 10) and time the marker beacon light duration.

Table 10 – Light Duration

Altitude = 1,000 feet (AGL)

Ground Speed	**Light Time (Seconds)**	
Knots	2000 feet	3000 feet
90	13	20
110	11	16
130	9	14
150	8	12

(C) For ground speeds other than table values, the following formulas may be used:

$$\text{Upper limit (seconds)} = \frac{1775}{\text{Ground Speed in Knots}}$$

$$\text{Lower limit (seconds)} = \frac{1183}{\text{Ground Speed in Knots}}$$

(D) In high sensitivity, the marker beacon annunciator light and audio will remain on longer than when in low sensitivity.

(E) The audio signal should be of adequate strength and sufficiently free from interference to provide positive identification.

(F) As an alternate procedure, cross the outer marker at normal ILS approach altitudes and determine adequate marker aural and visual indication.

(ii) *Electromagnetic Compatibility (EMC)*. With all systems operating in flight, verify, by observation, that no adverse effects are present in the required flight system.

(7) *Automatic Direction Finding (ADF) Equipment*.

(i) *Range and Accuracy*. The ADF system installed in the airplane should provide operation with errors not exceeding five degrees, and the aural signal should be clearly audible up to the distance listed for any one of the following types of radio beacons:

(A) 75 n.m. from an HH facility.

(B) 50 n.m. from an H facility. Caution —service ranges of individual facilities may be less than 50 n.m.

(C) 25 n.m. from an MH facility.

(D) 15 n.m. from a compass locator.

(ii) *Needle Reversal*. The ADF indicator needle should make only one 180 degree reversal when the airplane flies over a radio beacon. This test should be made with and without the landing gear extended.

(iii) *Indicator Response*. When switching stations with relative bearings differing by 180 degrees ± 5 degrees, the indicator should indicate the new bearing within ± 5 degrees in not more than ten seconds.

(iv) *Antenna Mutual Interaction*. For dual installations, there should not be excessive coupling between the antennas.

(v) *Technique*.

(A) *Range and Accuracy*. Tune in a number of radio beacons spaced throughout the 190-535 kHz range and located at distances near the maximum range for the beacon. The identification signals should be understandable and the ADF should indicate the approximate direction to the stations. Beginning at a distance of at least 15 n.m. from a compass locator in the approach configuration (landing gear extended, approach flaps), fly inbound on the localizer front course and make a normal ILS approach. Evaluate the aural identification signal for strength and clarity and the ADF for proper performance with the receiver in the ADF mode. All electrical equipment on the airplane should be operating and all pulse equipment should be transmitting. Fly over a ground or appropriately established checkpoint with relative bearings to the facility of 0 degrees, 45 degrees, 90 degrees, 135 degrees, 180 degrees, 225 degrees, 270 degrees, and 315 degrees. The indicated bearings to the station should correlate within five degrees. The effects of the landing gear on bearing accuracy should be determined. (A calibration placard should be provided, if appropriate.)

(B) *Needle Reversal*. Fly the airplane over an H, MH, or compass locator facility at an altitude 1,000 to 2,000 feet above ground level. Partial reversals that lead or lag the main reversal are permissible.

(C) *Indicator Response*. With the ADF indicating station dead ahead, switch to a station having a relative bearing of 175 degrees. The indicator should indicate within ±5 degrees of the bearing in not more than ten seconds.

(D) *Antenna Mutual Interaction.*

(1) If the ADF installation being tested is dual, check for coupling between the antenna by using the following procedure.

(2) With #1 ADF receiver tuned to a station near the low end of the ADF band, tune the #2 receiver slowly throughout the frequency range of all bands and determine whether the #1 ADF indicator is adversely affected.

(3) Repeat (2) with the #1 ADF receiver turned to a station near the high end of the ADF band.

(vi) *Electromagnetic Compatibility (EMC).* With all systems operating in flight, verify, by observation, that no adverse effects are present in the required flight systems.

(8) *Distance Measuring Equipment (DME).*

(i) *Tracking Performances*. The DME system should continue to track without dropouts when the airplane is maneuvered throughout the airspace within the standard service volume of the VORTAC/DME station and at altitudes above the lower edge of the standard service volume to the maximum operating altitude. This tracking standard should be met with the airplane:

(A) In cruise configuration;

(B) At bank angle up to ten degrees;

(C) Climbing and descending at normal maximum climb and descent attitude;

(D) Orbiting a DME facility; and

(E) Providing a clearly readable identification of the DME facility.

(ii) *Electromagnetic Compatibility (EMC).* With all systems operating in flight, verify, by observation, that no adverse effects are present in the required flight systems.

(iii) *Climb and Maximum Distance*. Determine that there is no mutual interference between the DME system and other equipment aboard the airplane. Beginning at a distance of at least ten n.m. from a DME facility and at an altitude of 2,000 feet above the DME facility, fly the airplane on a heading so that the airplane will pass over the facility. At a distance of five to ten n.m. beyond the DME facility, operate the airplane at its normal maximum climb attitude up to 90 percent of the maximum operating altitude, maintaining the airplane on a station radial (within five degrees). The DME should continue to track with no unlocks to the range of the standard service volume.

(iv) *Long-Range Reception.*

(A) Perform two 360 degree turns, one to the right and one to the left, at a bank angle of at leastten degrees at the maximum service volume distance of the DME facility and at an altitude of at least 90 percent of the maximum operating altitude.

(B) Unlocks may occur and are acceptable if they do not interfere with the intended flight path of the airplane or are relieved by a reduction of bank angle at the same relative heading to the station.

(v) *High-Angle Reception*. Repeat the flight pattern and observations of (iii) above at a distance of 50-70 n.m. (20-30 n.m. for airplanes not to be operated above 18,000 feet) from the DME facility and at an altitude of at least 90 percent of the maximum operating altitude.

(vi) *Penetration*. From 90 percent of the maximum operating altitude, perform a letdown directly toward the ground station using normal maximum rate of descent procedures to a DME facility so as to reach an altitude of 5,000 feet above the DME facility 5-10 n.m. before reaching the DME facility. The DME should continue to track during the maneuver with no unlocks.

(vii) *Orbiting*. At an altitude of 2,000 feet above the terrain, at holding pattern speeds appropriate for the type of airplane and with the landing gear extended, fly at least 15 degree sectors of left and right 35 n.m. orbital patterns around the DME facility. The DME should continue to track with no more than one unlock, not to exceed one search cycle, in any five miles of orbited flight.

(viii) *Approach*. Make a normal approach at an actual or simulated field with a DME. The DME should track without an unlock (station passage expected).

(ix) *DME Hold*. With the DME tracking, activate the DME hold function. Change the channel selector to a localizer frequency. The DME should continue to track on the original station.

(9) *Transponder Equipment*.

(i) *Signal Strength*. The Air Traffic Control (ATC) transponder system should furnish a strong and stable return signal to the interrogating radar facility when the airplane is flown in straight and level flight. This includes the airspace within 160 n.m. of the radar station from radio line of sight to within 90 percent of the maximum altitude for which the airplane is certificated or to the maximum operating altitude. Airplanes to be operated at altitudes not exceeding 18,000 feet should meet the above requirements to only 80 n.m.

(ii) *Single Site Tracking*. Special arrangements should be made for single-site tracking. ATC coverage includes remote stations and, unless single-site is utilized, the data may be invalid.

(iii) *Dropout Times*. When the airplane is flown within the airspace described above, the dropout time should not exceed 20 seconds in the following maneuvers:

(A) In turns at bank angles up toten degrees;

(B) Climbing and descending at normal maximum climb and descent attitude; and

(C) Orbiting a radar facility.

(iv) *Climb and Distance Coverage.*

(A) Beginning at a distance of at least ten n.m. from and at an altitude of 2,000 feet above that of the radar facility and using a transponder code assigned by the ARTCC, fly on a heading that will pass the airplane over the facility. Operate the airplane at its normal maximum climb attitude up to within 90 percent of the maximum altitude for which the airplane is certificated, maintaining the airplane at a heading within five degrees from the radar facility. After reaching the maximum altitude for which the airplane is certificated, fly level at the maximum altitude to 160 (or 80) n.m. from the radar facility.

(B) Communicate with the ground radar personnel for evidence of transponder dropout. During the flight, check the "ident" mode of the ATC transponder to ensure that it is performing its intended function. Determine that the transponder system does not interfere with other systems aboard the airplane and that other equipment does not interfere with the operation of the transponder system. There should be no dropouts for two or more sweeps.

(v) *Long-Range Reception.* Perform two 360 degree turns, one to the right and one to the left, at bank angles of at least ten degrees with the flight pattern at least 160 (or 80) n.m. from the radar facility. During these turns, the radar display should be monitored and there should be no signal dropouts (two or more sweeps).

(vi) *High-Angle Reception.* Repeat the flight pattern and observations of (d) above at a distance of 50 to 70 n.m. from the radar facility and at an altitude of at least 90 percent of the maximum operating altitude. There should be no dropout (two or more sweeps). Switch the transponder to a code not selected by the ground controller. The airplane secondary return should disappear from the scope. The controller should then change his control box to a common system and a single slash should appear on the scope at the airplane's position.

(vii) *High-Altitude Cruise*. Fly the airplane within 90 percent of its maximum certificated altitude or its maximum operating altitude beginning at a point 160 (or 80) n.m. from the radar facility on a course that will pass over the radar facility. There should be no transponder dropout (two or more sweeps) or "ring-around."

(viii) *Holding and Orbiting Patterns*.

(A) At an altitude of 2,000 feet or minimum obstruction clearance altitude (whichever is greater) above the radar antenna and at holding pattern speeds, flaps and gear extended, fly one each standard rate 360 degree turn right and left at a distance of approximately ten n.m. from the ARSR facility. There should be no signal dropout (two or more sweeps).

(B) At an altitude of 2,000 feet or minimum obstruction clearance altitude (whichever is greater) above the radar antenna and at holding pattern speeds appropriate for the type of airplane, fly 45 degree sectors of left and right ten n.m. orbital patterns around a radar facility with gear and flaps extended. There should be no signal dropout (two or more sweeps).

(i) *Electromagnetic Compatibility (EMC).* With all systems operating in flight, verify, by observation, that no adverse effects are present in the required flight systems.

(10) *Weather Radar*.

(i) *Bearing Accuracy.* The indicated bearing of objects shown on the display should be within ±10 degrees of their actual relative bearing. Verify that as airplane turns to right or left of target, the indicated display moves in the opposite direction. Fly under conditions that allow visual identification of a target, such as an island, a river, or a lake, at a range of approximately 80 percent of the maximum range of the radar. When flying toward the target, select a course that will pass over a reference point from which the bearing to the target is known. When flying a course from the reference point to the target, determine the error in displayed bearing to the target on all range settings. Change heading in increments of ten degrees and determine the error in the displayed bearing to the target.

(ii) *Distance of Operation.* The radar should be capable of displaying distinct and identifiable targets throughout the angular range of the display and at approximately 80 percent of the maximum range.

(iii) *Beam Tilting*. The radar antenna should be installed so that its beam is adjustable to any position between ten degrees above and below the plane of rotation of the antenna. Tilt calibration should be verified.

(iv) *Contour Display (ISO Echo).*

(A) If heavy cloud formations or rainstorms are reported within a reasonable distance from the test base, select the contour display mode. The radar should differentiate between heavy and light precipitation.

(B) In the absence of the above weather conditions, determine the effectiveness of the contour display function by switching from normal to contour display while observing large objects of varying brightness on the indicator. The brightest object should become the darkest when switching from normal to contour mode.

(v) *Antenna Stabilization, When Installed*. While in level flight at 10,000 feet or higher, adjust the tilt approximately 2-3 degrees above the point where ground return was eliminated. Roll right and left approximately 15 degrees, then pitch down approximately ten degrees (or within design limits). No ground return should be present.

(vi) *Ground Mapping*. Fly over areas containing large, easily identifiable landmarks such as rivers, towns, islands, coastlines, and so forth. Compare the form of these objects on the indicator with their actual shape as visually observed from the cockpit.

(vii) *Mutual Interference*. Determine that no objectionable interference is present on the radar indicator from any electrical or radio/navigational equipment when operating and that the radar installation does not interfere with the operation of any of the airplane's radio/navigational systems.

(viii) *Electromagnetic Compatibility*. With all systems operating in flight, verify, by observation, that no adverse effects are present in the required flight systems.

(ix) *Light Conditions*. The display should be evaluated during all lighting conditions, including night and direct sunlight.

(11) *Area Navigation*.

(i) *AC 90-96*. This AC has the basic criteria for evaluating an area navigation system, including acceptable means of compliance to 14 CFR.

(ii) *Electromagnetic Compatibility (EMC).* With all systems operating in flight, verify, by observation, that no adverse effects are present in the required flight systems.

(12) *Inertial Navigation.*

(i) *Basic Criteria*. AC 25-4 has the basic criteria for the engineering evaluation of an INS and offers acceptable means of compliance with the applicable 14 CFR part. The engineering evaluation of an INS should also include an awareness of AC 121-13, which presents criteria to be met before an applicant can get operational approval. For flights up to ten hours, the radial error should not exceed two n.m. per hour of operation on a 95 percent statistical basis. For flights longer than ten hours, the error should not exceed ±20 n.m. cross-track or ±25 n.m. along-track error. A two n.m. radial error is represented by circle, having a radius of two n.m., centered on the selected destination point.

(i) *Electromagnetic Compatibility (EMC).* With all systems operating in flight, verify, by observation, that no adverse effects are present in the required flight systems.

(13) *Doppler Navigation*.

(i) *Doppler navigation system*. Installed performance should be evaluated in accordance with AC 121-13.

(ii) *Electromagnetic Compatibility (EMC).* With all systems operating in flight, verify, by observation, that no adverse effects are present in the required flight systems.

(14) *Audio Interphone Systems*.

(i) *Acceptable communications*. These should be demonstrated for all audio equipment including microphones, speakers, headsets, and interphone amplifiers. All modes of operation should be tested, including operation during emergency conditions (that is, emergency descent, and oxygen masks) with all engines running, all pulse equipment transmitting and all electrical equipment operating. If aural warning systems are installed, they should be evaluated, including distinguishing aural warnings when using headphones and with high air noise levels.

(ii) *Electromagnetic Compatibility (EMC).* With all systems operating during flight, verify, by observation, that no adverse effects are present in the required flight systems.

(15) *Electronic Flight Instrument Systems*. Refer to AC 23.1311-1.

(16) *LORAN C Navigation Systems*. Refer to AC 20-121A.

(17) *Microwave Landing Systems.* Reserved.

(18) *Global Positioning System Navigation.* Reserved.

2. § 23.1303 Flight and Navigation Instruments.

a. Free Air Temperature (FAT). Section 23.1303(a)(4) requires that reciprocating engine- powered airplanes of more than 6,000 pounds maximum weight and turbine-powered airplanes have a free air temperature indicator or an air temperature indicator that provides indications that are convertible to free air. The temperature pickup can be calibrated against a test pick-up of known characteristics, or by flying at various speeds at constant altitude, or by tower fly-by. This calibration is frequently done in conjunction with one or more of the airspeed calibration methods described in paragraph 23.1323 of this AC.

b Speed Warning Device. The production tolerances of the speed warning device required with § 23.1303(a)(5) must be set to minimize nuisance warnings. In considering this requirement, manufacturers should endeavor to reduce, lessen, or diminish such an occurrence to the least practical amount with current technology and materials. The least practical amount is that point at which the effort to further reduce a hazard significantly exceeds any benefit, in terms of safety, derived from that reduction. Additional efforts would not result in any significant improvements in reliability.

3. § 23.1305 Powerplant Instruments.

a. Explanation. Section 23.1305 is specific as to the powerplant instruments required for each type of installation. The requirement for specific instruments on specific airplanes should be determined by analysis of type design data prior to certification flight test.

b. Procedures. Verify proper functioning of each required instrument/indicator installed. If the creation of a required malfunction would require establishing a potentially hazardous condition in flight, proper functioning of these indicators may be verified by ground test.

c. Fuel Flowmeters. AC 23-17 covers the installation of fuel flowmeters in airplanes with continuous-flow fuel injection reciprocating engines.

4. § 23.1307 Miscellaneous Equipment. Reserved.

5. § 23.1309 Equipment, Systems, and Installations. This item is covered in AC 23.1309-1E.

Section 2. Instruments: Installation

1. § 23.1311 Electronic Display Instrument Systems. This item is covered in AC 23.1311-1.

2. § 23.1321 Arrangement and Visibility. Reserved.

3. § 23.1322 Warning, Caution, and Advisory Lights. Reserved.

4. § 23.1323 Airspeed Indicating System.

a. Explanation.

(1) *Airspeed Indicator.* An airspeed indicator is usually a pressure gauge that measures the difference between free stream total pressure and static pressure and is usually marked in knots. Pitot tubes for duplicate airspeed indicators are usually located on opposite sides of an aircraft fuselage but may be situated on the same side provided that they are separated by at least 14 inches (35.6 cm.) vertically.

(2) *Air Data Computer Systems*. Reserved.

(3) *Definitions*. Section 1.1 of part 1 of 14 CFR defines IAS, CAS, equivalent air speed (EAS), true air speed (TAS), and Mach number. These definitions include the terms position error, instrument error, and system error, which may need further explanation.

(i) *Position Error*. Position error is the total-pressure (pitot) and static-pressure errors of the pilot-static installation. By proper design, the total pressure error may be reduced to the point where it is insignificant for most flight conditions. NASA Reference Publication 1046 (refer to paragraph g gives various design considerations. The static pressure is more difficult to measure and the static position error may result in large airspeed and altitude errors.

(ii) *Instrument Error*. Instrument errors are errors inherent in the instrument for mechanical instruments. These errors are the result of manufacturing tolerances, hysteresis, temperature changes, friction, and inertia of moving parts. For electronic instruments, these errors are due to errors in the electronic element that converts pitot-static pressures into electronic signals. Instrument errors are determined for inflight conditions in steady state conditions. Ground run system calibrations may require the consideration of internal instrument dynamics, electronic lags, and display filtering that would cause indication errors during takeoff acceleration.

(iii) *System Error*. System error is the combination of position error and instrument error.

(4) *Temperatures*. Static air temperature (SAT) and total air temperature (TAT) are not defined in section 1.1 of 14 CFR but may be significant in accurate calibration of airspeed systems. For stabilized values of pressure altitude and calibrated airspeed, TAS is a function of static air temperature. Reference (2) in section f of appendix 2 discusses the heating effect of the airflow on the temperature sensor and shows how to determine the recovery factor of the sensor. Figure 7 of appendix 7 gives temperature ram rise, if the sensor recovery factor is known.

(5) *System Calibration*. The airspeed system is calibrated to determine compliance with the requirements of § 23.1323 and to establish an airspeed reference that is used in demonstrating compliance with other applicable regulations. The airspeed system may be calibrated using the speed course method, pacer airplane method, tower fly-by method, trailing cone method or either the trailing bomb or airspeed boom method or both. The method used will depend on the speed range of the airplane tested, the configuration, and the equipment available. System calibration of the airspeed system is usually determined at altitudes below 10,000 feet. For airplanes approved for flight above 31,000 feet, it is appropriate to verify validity of position errors at the higher operating altitudes. For airplanes where the static ports are located in close proximity to the propeller plane, it should be verified that sudden changes in power do not appreciably change the airspeed calibration. Additionally, for commuter category airplanes, § 23.1323(e) requires an airspeed calibration for use during the accelerate-takeoff ground run.

(6) *Instrument Calibration*. All instruments used during the test should be calibrated, and all calibration curves should be included in the type inspection report.

b. Speed Course Method. The speed course method consists of using a ground reference to determine variations between indicated airspeed and ground speed of the airplane. Refer to appendix 9 for test procedures and a sample data reduction.

c. Trailing Bomb or Airspeed Boom Method. Refer to appendix 9 for procedures, test conditions, and a sample data reduction.

d. Pace Airplane Method. Refer to appendix 9 for test procedures.

e. Tower Fly-by. Refer to appendix 9 for test procedures.

f. Ground Run Airspeed System Calibration. The airspeed system is calibrated to show compliance with commuter category requirements of § 23.1323(c) during the accelerate-takeoff ground run and is used to determine IAS values for various V_1 and V_R speeds. Refer to appendix 9 for definitions, test procedures, and sample data reductions.

g. Other Methods. Other methods of airspeed calibration are described in NASA Reference Publication 1046, "Measurement of Aircraft Speed and Altitude," by W. Gracey, May 1980. Refer to appendix 9 for GPS method.

5. § 23.1325 Static Pressure System.

a. Definitions. Section 23.1323 defines several of the terms associated with the pitot-static systems. Others may need further explanation.

(1) *Altimeter*. An altimeter is a pressure gauge that measures the difference between a sea level barometer pressure set on the instrument and static pressure, and indicates in units of feet.

(2) *Static Error (error in pressure altitude).* The error that results from the difference between the actual ambient pressure and the static pressure measured at the airplane static pressure source is called static error. Static error causes the altimeter to indicate an altitude that is different than actual altitude. It may also affect the errors in the airspeed indicating system.

b. Static System Calibration. The static system is calibrated to determine compliance with the requirements of § 23.1325. The static system may be calibrated by utilizing a trailing bomb, cone, or tower fly-by method. Alternately, for properly designed pitot systems, the pitot has minimal affect on the airspeed position error (dV_C), as determined for § 23.1323. For these systems, static error (dh) may be calculated by the following equation:

$$dh = 0.08865(dV_C)\left[1 + 0.2\left[\frac{V_C}{661.5}\right]^2\right]^{2.5}\left[\frac{V_C}{\sigma}\right], \text{ft.}$$

where V_c = calibrated airspeed, knots

σ = ambient air density ratio

dV_c = airspeed position error

c. Test Methods. The methods specified for calibration of the airspeed indicating systems, including test conditions and procedures, apply equally for determining static error and error in indicated pressure altitude, and are usually determined from the same tests and data.

d. Tower Fly-by. The tower fly-by method is one of the methods that results in a direct determination of static error in indicated pressure altitude without the need for calculating from airspeed position error.

e. Procedures and Test Conditions for Tower Fly-by.

(1) *Air Quality*. Smooth, stable air is needed for determining the error in pressure altitude.

(2) *Weight and C.G.* Same as for calibrations of the airspeed indicating system.

(3) *Speed Range*. The calibration should range from 1.3 V_{SO} to 1.8 V_{S1}. Higher speeds up to V_{MO} or V_{NE} are usually investigated so that errors can be included in the AFM for a full range of airspeeds.

(4) *Test Procedures*.

(i) Stabilize the airplane in level flight at a height that is level with the cab of a tower, or along a runway while maintaining a constant height of 50 to 100 feet by use of a radio altimeter. A ground observer should be stationed in the tower, or on the runway with an altimeter of known instrument error. Pressure altitude is recorded on the ground and in the airplane at the instant the airplane passes the ground observer.

(ii) Repeat step (i) at various airspeeds in increments sufficient to cover the required range and at each required flap setting.

(5) *Data Acquisition*. Data to be recorded at each test point:

(i) Airplane IAS;

(ii) Airplane indicated pressure altitude;

(iii) Ground observer indicated pressure altitude;

(iv) Radar altimeter indication (if flown along a runway);

(v) Wing flap position; and

(vi) Landing gear position.

(6) *Data Reduction.*

(i) *Method*.

(A) Correct indicated pressure altitude values for instrument error associated with each instrument.

(B) To obtain test pressure altitude, adjust the ground observed pressure altitude by the height read from the radar altimeter. No adjustment is required if the airplane was essentially the same level as the ground operator (tower cab). Static errors may be adjusted from test pressure altitude to sea level by the following:

$$dh_{(S.L.)} = \left[dh_{(TEST)}\right]\left[\sigma_{(TEST)}\right]$$

Where:

$dh_{(TEST)}$ = Difference in test pressure altitude and airplane pressure altitude with associated instrument errors removed.

σ (TEST) = ambient air density ratio.

(i) *Plotting*. Static error at sea level ($dh_{(S.L.)}$) should be plotted vs. test calibrated airspeeds.

(7) *Required Accuracy*. Section 23.1325(e) requires that the error in pressure altitude at sea level (with instrument error removed) must fall within a band of ±30 feet at 100 knots or less, with linear variation of ±30 feet per 100 knots at higher speeds. These limits apply for all flap settings and airspeeds from 1.3 V_{SO} up to 1.8 V_{S1}. For commuter category airplanes, the altimeter system calibration should be shown in the AFM.

6. § 23.1326 Pitot Heat Indication Systems. Reserved.

7. § 23.1327 Magnetic Direction Indicator. Reserved.

8. § 23.1329 Automatic Pilot System. This subject is covered in AC 23-17.

9. § 23.1331 Instruments Using a Power Supply. Reserved.

10. § 23.1335 Flight Director Systems. Reserved.

11. § 23.1337 Powerplant Instruments.

a. Explanation.

(1) *Fuel Quantity Indicator*. The indicator should be legible and easily read without excessive head movement. The calibration units and the scale graduations should be readily apparent. Units should be consistent with AFM procedures and performance data.

(2) *Auxiliary Tanks*. A fuel quantity indicator is not required for a small auxiliary tank that is used only to transfer fuel to another tank if the relative size of the tank, the rate of fuel flow, and operating instructions are adequate. The requirement for a separate quantity indicator should be determined by analysis of design data prior to flight test. The relative size of the tanks, intended use of the auxiliary tanks, complexity of the fuel system, and so forth, should be considered in determining the need for a fuel quantity indicator. If an indicator is not installed, flight manual procedures should ensure that once transfer of fuel is started, all fuel from the selected auxiliary tank can be transferred to the main tank without overflow or overpressure.

b. Procedures. Evaluate indicators for clarity and legibility. Review AFM for consistency of units and validity of procedures.

Section 3. Electrical Systems and Equipment

1. § 23.1351 General. Reserved.

2. § 23.1353 Storage Battery Design and Installation.
Reserved.

3. § 23.1357 Circuit Protective Devices. Reserved.

4. § 23.1361 Master Switch Switch Arrangement. This subpart requires a master switch arrangement to be installed. Confirm that the master switch arrangement is prominently located and marked. The master switch, in accordance with § 23.1355(e)(2), is considered to be an emergency control and should be colored red.

5. § 23.1367 Switches. Reserved.

Section 4. Lights

1. § 23.1381 Instrument Lights. Reserved.

2. § 23.1383 Landing Lights. Reserved.

Section 5. Safety Equipment

1. § 23.1411 General. Reserved.

2. § 23.1415 Ditching Equipment. Reserved.

3. § 23.1416 Pneumatic Deicer Boot System. Refer to AC 23-17.

4. § 23.1419 Ice Protection. Refer to AC 23-17 and AC 23.1419-2D.

Section 6. Miscellaneous Equipment

1. § 23.1431 Electronic Equipment. Section 23.1431(e) requires that the flight crewmembers will receive all aural warnings when any headset is being used. For those installations where not all warnings are provided through the radio/audio equipment, the manufacturers should demonstrate that all warnings will be heard and recognized when noise canceling headsets are used.

2. §23.1435 Hydraulic Systems. Reserved.

3. § 23.1441 Oxygen Equipment and Supply. Reserved.

4. § 23.1447 Equipment Standards for Oxygen Dispensing Units. Reserved.

5. § 23.1449 Means for Determining Use of Oxygen. Reserved.

6. § 23.1457 Cockpit Voice Recorders. Reserved.

7. § 23.1459 Flight Data Recorders. Reserved.

Chapter 6. Subpart G--Operating Limitations and Information

Section 1. General

1 § 23.1501 General.

a. Explanation.

(1) *Flight Crew Information*. This section establishes the obligation to inform the flight crew of the airplane's limitations and other information necessary for the safe operation of the airplane. The information is presented in the form of placards, markings, and an approved AFM. Appendix 4 can be used to assist in determining which methods of presentation are required.

(2) *Minimum Limitations*. Sections 23.1505 through 23.1527 prescribe the minimum limitations to be determined. Additional limitations may be required.

(3) *Information Presentation*. Sections 23.1541 through 23.1589 prescribe how the information should be made available to the flight crew.

b. Procedures. None.

2. § 23.1505 Airspeed Limitations.

a. Explanation. This section establishes the operational speed limitations for safe margins below design speeds. For reciprocating engine-powered airplanes, there is an option. They may either establish a never-exceed speed (V_{NE}) and a maximum structural cruising speed (V_{NO}) or they may be tested in accordance with § 23.335(b)(4), in which case the airplane is operated under a maximum operating speed concept (V_{MO}/M_{MO}). For turbine-powered airplanes, a V_{MO}/M_{MO} should be established. Tests associated with establishing these speeds are discussed under § 23.253, High speed characteristics.

b. Procedures. None.

3. § 23.1507 Maneuvering Speed. This regulation is self-explanatory.

4. § 23.1511 Flap Extended Speed. This regulation is self-explanatory.

5. § 23.1513 Minimum Control Speed. This regulation is self-explanatory.

6. § 23.1519 Weight and Center of Gravity. This regulation is self-explanatory.

7. § 23.1521 Powerplant Limitations. Reserved.

8. § 23.1523 Minimum Flight Crew. Reserved.

9. § 23.1523 Minimum Flight Crew.

a. Information. The following should be considered in determining minimum flight crew:

(1) *Basic Workload Functions*. The following basic workload functions should be considered:

(i) Flight path control;

(ii) Collision avoidance;

(iii) Navigation;

(iv) Communications;

(v) Operation and monitoring of aircraft controls;

(vi) Command decisions; and

(vii) Accessibility and ease of operation of necessary controls.

(2) *Workload Factors*. The following workload factors are considered significant when analyzing and demonstrating workload for minimum flight crew determination:

(i) The impact of basic airplane flight characteristics on stability and ease of flight path control. Some factors such as trimmability, coupling, response to turbulence, damping characteristics, control breakout forces and control force gradients should be considered in assessing suitability of flight path control. The essential elements are the physical effort, mental effort and time required to track and analyze flight path control features, and the interaction with other workload functions.

(ii) The accessibility, ease, and simplicity of operation of all necessary flight, power, and equipment controls, including emergency fuel shutoff valves, electrical controls, electronic controls, pressurization system controls, and engine controls.

(iii) The accessibility and conspicuity of all necessary instruments and failure warning devices such as fire warning, electrical system malfunction, and other failure or caution indicators. The extent to which such instruments or devices direct the proper corrective action is also considered.

(iv) The complexity and difficulty of operation of the fuel system, with particular consideration given to the required fuel management schedule necessitated by c.g., structural, or other airworthiness considerations. Additionally, the ability of each engine to operate continuously from a single tank or source that is automatically replenished from other tanks if the total fuel supply is stored in more than one tank.

(v) The degree and duration of concentrated mental and physical effort involved in normal operation and in diagnosing and coping with malfunctions and emergencies, including accomplishment of checklist, and location and accessibility of switches and valves.

(vi) The extent of required monitoring of the fuel, hydraulic, pressurization, electrical, electronic, de-icing, and other systems while en route. Also, recording of engine readings, and so forth.

(vii) The degree of automation provided in the event of a failure or malfunction in any of the aircraft systems. Such automation should ensure continuous operation of the system by providing automatic crossover or isolation of difficulties and minimize the need for flight crew action.

(viii) The communications and navigation workload.

(ix) The possibility of increased workload associated with any emergency that may lead to other emergencies.

(x) Passenger problems.

(3) *Kinds of Operation Authorized*. During minimum crew determination, consideration should be given to the kinds of operation authorized under § 23.1525. Inoperative equipment could result in added workload that would affect minimum crew. It may be determined that, due to minimum crew workload considerations, certain equipment must be operative for a specific kind of operation.

b. Acceptable Techniques.

(1) *General*.

(i) A systematic evaluation and test plan should be developed for any new or modified airplane. The methods for showing compliance should emphasize the use of acceptable analytical and flight test techniques. The crew complement should be studied through a logical process of estimating, measuring, and then demonstrating the workload imposed by a particular flight deck design.

(ii) The analytical measurements should be conducted by the manufacturer early in the airplane design process. The analytical process that a given manufacturer uses for determining crew workload may vary depending on flight deck configuration, availability of a suitable reference, original design or modification, and so forth.

(2) *Analytical Approach.*

(i) A basis for deciding that a new design is acceptable is a comparison of a new design with a previous design proven in operational service. By making specific evaluations and comparing new designs to a known baseline, it is possible to proceed with confidence that the changes incorporated in the new designs accomplish the intended result. When the new flight deck is considered, certain components may be proposed as replacements for conventional items, and some degree of rearrangement may be contemplated. New avionics systems may need to be fitted into existing panels, and newly automated systems may replace current indicators and controls. As a result of these evolutionary characteristics of the flight deck design process, there is frequently a reference flight deck design, which is usually a conventional airplane that has been through the test of operational usage. If the new design represents an evolution, improvement attempt, or other deviation from this reference flight deck, the potential exists to make direct comparisons. While the available workload measurement techniques do not provide the capacity to place precise numbers on all the relevant design features in reference to error or accident potential, these techniques do provide a means for comparing the new proposal to a known quantity. Service experience should be researched to assure that any existing problems are understood and not perpetuated.

(ii) After studying a new component or arrangement and exercising it in practical flight scenarios, a test pilot may not be able to grade that design in finer workload units than "better" or "worse than." If the pilot can say with reliability and confidence that it is or is not easier to see a display or to use an augmented control system than to use a functionally similar unit of a reference design, then these "better" or "worse than" judgments provide substantial evidence that workload is or is not reduced by the innovation. These “better” or “worse than” judgments should be corroborated b a reasonable sample of qualified pilots over various assumed flight regimes.

(A) If an early subjective analysis by FAA flight test personnel shows that workload levels may be substantially increased, a more in-depth evaluation of flight testing may be required to prove acceptability of the increased workload. In this case, there should be available workload latitude in the basic flight deck design to accommodate the increase.

(B) If the new design represents a "revolutionary" change in level of automation or pilot duties, analytic comparison to a reference design may have lessened value. Without a firm database on the time required to accomplish both normally required and contingency duties, more complete and realistic simulation and flight testing will be required.

(3) *Testing.*

(i) In the case of the minimum crew determination, the final decision is reserved until a panel of experienced pilots has flown the airplane, trained and qualified in the airplane. The training should be essentially that required for a type rating. When the applicant seeks single pilot approval, the evaluation pilots should be experienced and proficient in single pilot operations. Section 23.1523 contains the criteria for determining the minimum flight crew. These criteria contain basic workload functions and workload factors.

(ii) The workload factors are those factors that should be considered when evaluating the basic workload functions. It is important to keep in mind the key terms basic workload and minimum cues when analyzing and demonstrating workload. For example, an evaluation of communications workload should include the basic workload required to properly operate the airplane in the environment for which approval is sought. The goal of evaluating crew complement during realistic operating conditions is important to keep in mind if a consistent evaluation of minimum flight crew is to be accomplished.

(iii) The flight test program for showing compliance should be proposed by the applicant and should be structured to address the following factors:

(A) *Route*. The routes should be constructed to simulate a typical area that is likely to provide some adverse weather and Instrument Meteorological Conditions (IMC), as well as a representative mix of navigation aids and ATC services.

(B) *Weather*. The airplane should be test flown in a geographical area that is likely to provide some adverse weather, such as turbulence and IMC conditions, during both day and night operations.

(C) *Crew Work Schedule*. The crew should be assigned to a daily working schedule representative of the type of operations intended, including attention to passenger cabin potential problems. The program should include the duration of the working day and the maximum expected number of departures and arrivals. Specific tests for crew fatigue are not required.

(D) *Minimum Equipment Test*. Preplanned dispatch-inoperative items that could result in added workload should be incorporated in the flight test program. Critical items and reasonable combinations of inoperative items should be considered in dispatching the airplane.

(E) *Traffic Density*. The airplane should be operated on routes that would adequately sample high density areas, but should also include precision and nonprecision approaches, holdings, missed approaches, and diversion to alternate airports.

(F) *System Failures*. Consequences of changes from normal to failed modes of operation should be included in the program. Both primary and secondary systems should be considered.

(G) *Emergency Procedures.* A sampling of various emergencies should be established in the test program to show their effect on the crew workload.

Note: Before selecting the system failure and emergency procedures that will be evaluated in the flight test program, analytical studies of proposed abnormal and emergency procedures should be conducted. The acceptability of all procedures should be verified and the crew workload distribution during the execution of these procedures understood to assure selection of appropriate failure cases.

(4) *Determining Compliance*.

(i) The type certification team that serves as pilots and observers should be equipped with flight cards or other means that allow for record keeping of comments addressing the basic workload functions. These records should be accumulated for each flight or series of flights in a given day. In addition, the certification team should record the accuracy of using operational checklists. For the purposes of this data gathering, the airplane should be configured to allow the team evaluators to observe all crew activities and hear all communications both externally and internally.

(ii) Each subparagraph of paragraph 23.1523 summarizes an observation of pilot performance that is to be made. Judgment by the certification team members should be that each of these tasks has been accomplished within reasonable pre-established workload standards during the test flights. A holistic pilot evaluation rationale is needed in view of the wide variety of possible designs and crew configurations that makes it unfeasible to assume that ratings are made against every alternative and against some optimum choices. The regulatory criteria for determining minimum flight crew do not adapt well to finely-scaled measurements. Specific feature and activity pass-fail judgments should be made. Pass means that the airplane meets the minimum requirements.

10. § 23.1524 Maximum Passenger Seating Configuration. This regulation is self-explanatory.

11. § 23.1525 Kinds of Operation.

a. Explanation.

(1) *Required Equipment*. Refer to guidance under § 23.1583(h), paragraph 23.1583 of this AC, concerning required equipment for each certificated kind of operation.

(2) *Icing*. With respect to operations in icing conditions, it is important that operating limitations be established in order to specify the required equipment in § 23.1583(h) and to provide the proper placard required by § 23.1559 (flight in icing approved or prohibited).

12. § 23.1527 Maximum Operating Altitude.

a. Explanation.

(1) *Safe Operation*. Section 23.1527 requires the establishment of a maximum operating altitude for all turbine, turbo-supercharged, and pressurized airplanes based on operation limited by flight, structural, powerplant, functional or equipment characteristics. Section 23.1501(a) requires limitations necessary for safe operation be established. Thus, if an unsafe condition occurs beyond a particular operating altitude for any airplane, that altitude should be established as a limitation under § 23.1501(a).

(2) *Windshields and Windows*. As stated in § 23.1527(a), pressurized airplanes are limited to 25,000 feet unless the windshield/window provisions of § 23.775 are met.

(3) *Factors*. The maximum operating altitude listed in the AFM should be predicated on one of the following:

(i) The maximum altitude evaluated;

(ii) The restrictions, as a result of either unsatisfactory structures, propulsion, systems, or flight characteristics, or all of these; or

(iii) Consideration of § 23.775 for pressurized airplanes.

b. Procedures. Assuming that the structure has been properly substantiated, the flight evaluation should consist of at least the following:

(1) *Stall characteristics*. Stall characteristics per §§ 23.201 and 23.203 with wing flaps up, gear retracted, and power at the maximum power that can be attained at the maximum altitude, not to exceed 75 percent maximum continuous.

(2) *Stall warning*. Stall warning, cruise configuration only (§ 23.207).

(3) *Longitudinal stability*. Longitudinal stability, cruise configuration only (§§ 23.173 and 23.175).

(4) *Lateral and directional stability*. Lateral and directional stability, cruise configuration only (§§ 23.177 and 23.181).

(5) *Upsets*. Upsets, if required (§ 23.253).

(6) *Systems operation*. Systems operation, including icing system, if installed.

(7) *Propulsion operation*. Propulsion operation, including stall, surge, and flameout tests throughout the speed range from near stall to maximum level flight speed.

Section 2. Markings and Placards

1. § 23.1541 General.

a. Required Markings and Placards. The rule specifies which markings and placards must be displayed. Note that § 23.1541(a)(2) requires any additional information, placards, or markings required for safe operation. Some placard requirements are obscurely placed in other requirements. For example, § 23.1583(e)(4) requires a placard for acrobatic category airplanes concerning spin recovery. A checklist is provided in appendix 4 that may assist in determination of placards and markings required.

b. Multiple Categories. For airplanes certified in more than one category, § 23.1541(c)(2) requires all of the placard and marking information to be furnished in the AFM. This practice is encouraged for all airplanes.

c. Powerplant Instruments. AC 20-88A provides additional guidance on the marking of powerplant instruments.

2. § 23.1543 Instrument Markings: General. AC 20-88A provides guidance on the marking of powerplant instruments.

3. § 23.1545 Airspeed Indicator. This regulation is self-explanatory.

4. § 23.1547 Magnetic Direction Indicator. This regulation is self-explanatory.

5. § 23.1549 Powerplant Instruments. This subject is covered in AC 20-88A.

6. § 23.1551 Oil Quantity Indicator. Reserved.

7. § 23.1553 Fuel Quantity Indicator. Reserved.

8. § 23.1555 Control Markings.

a. Examples of Emergency Controls.

(1) *Reciprocating engine mixture controls and turbine engine condition levers*. Reciprocating engine mixture controls and turbine engine condition levers incorporating fuel stopcocks or fuel stopcocks themselves are considered to be emergency controls, since they provide an immediate means to stop engine combustion.

(2) *Quick-disconnect/interrupt switch*. Quick-disconnect/interrupt switch of an electric trim system.

b. Requirements. Section 23.1555(e)(2) covers the requirements for emergency controls.

9. § 23.1557 Miscellaneous Markings and Placards. Reserved.

10. § 23.1559 Operating Limitations Placard. Reserved.

11. § 23.1561 Safety Equipment.

a. Examples of Safety Equipment. Safety equipment includes such items as life rafts, flares, fire extinguishers, and emergency signaling devices.

b. Requirements. Sections 23.1411 through 23.1419 cover the requirements for safety equipment.

12. § 23.1563 Airspeed Placards. This regulation is self-explanatory.

13. § 23.1567 Flight Maneuver Placard. This regulation is self-explanatory.

Section 3. Airplane Flight Manual and Approved Manual Material

1. § 23.1581 General.

a. GAMA Specification No. 1. General Aviation Manufacturers Association (GAMA) Specification No. 1, Revision No. 1, dated September 1, 1984, provides broad guidance for contents of a Pilot's Operating Handbook (POH) that will fulfill the requirements of an AFM, for certain airplanes under 6,000 pounds, if the POH meets all of the requirements of §§ 23.1581 through 23.1589. There is no objection to the title, "Pilot's Operating Handbook," if the title page also includes a statement indicating that the document is the required AFM and is approved by the FAA.

b. Optional Presentations. Beginning with amendment 23-21, applicants are provided with an option for the presentation of the required procedures, performance, and loading information. The regulatory requirements of the two options are given in §§ 23.1581(b)(1) and 23.1581(b)(2). The options are as follows:

(1) *Section 23.1581(b)(1).* The AFM must have approved limitations, procedures, performance, and loading sections. These approved sections must be segregated, identified, and clearly distinguished from unapproved information furnished by the applicant if any unapproved information is furnished. Normally, FAA approval is indicated by the signature of the FAA Administrator, or appointed representative, on the cover page and a page effectivity table so that it is clear to the operational pilot exactly which pages are applicable and the date of approval.

(2) *Section 23.1581(b)(2).* The AFM must have an approved limitations section and this approved section must contain only limitations (no procedures, performance, or loading information allowed). The limitations section must be identified and clearly distinguished from other parts of the AFM. The remainder of the manual may contain a mixture of approved and unapproved information, without segregation or identification. However, the other required material (procedures, performance, and loading information) must be determined in accordance with the applicable requirements of part 23. The meaning of "acceptable," as used in § 23.1581(b)(2)(ii), is given in the preamble to amendment 23-21. The applicable portion of the amendment 23-21 preamble is as follows:

> "In finding that a manual is acceptable, the FAA would review the manual to determine that the required information is complete and accurate. The manual would also be reviewed to ensure that any additional information provided by the applicant is not in conflict with required information or contrary to the applicable airworthiness requirements."

(A) The indication of approval for the approved section should be as discussed in the preceding paragraph, paragraph (1). GAMA Specification No. 1 has been found to comply with the provisions of § 23.1581(b)(2).

c. Part 36 Noise Limitations or Procedures.

(1) *Section 23.1581(b)(1).* If the applicant chooses the § 23.1581(b)(1) option, operating limitations required by part 36 should be placed in the operating limitations portion of the AFM. Any part 36 procedures should be placed in the operating procedures portion of the AFM.

(2) *Section 23.1581(b)(2).* If the applicant chooses the § 23.1581(b)(2) option, the approved AFM should contain the following approved, but separate, portions:

(i) *Operating limitations prescribed in § 23.1583.* Note that § 23.1581(b)(2)(i) limits the information in this portion to that prescribed in § 23.1583. Since the present part 36 limitation is a weight limitation, the part 36 limitation may be included.

(ii) *Operating procedures prescribed by part 36*. Section 23.1581(a) requires part 36 procedures to be approved.

d. STC Procedures.

(1) *AFM Options*. STC applicants are responsible for preparing an AFM supplement when the airplane has been modified in such a manner that limitations, procedures, or performance has been changed. The supplement should be prepared in accordance with the guide provided in Appendix 5 and reflect the necessary supplemental information. Alternately, the applicant may choose to prepare a new AFM. If the applicant selects the latter option, the new AFM replaces the original AFM in its entirety.

(2) *Performance*. If the STC applicant does not want credit for any increased performance and demonstrates that the performance meets or exceeds all basic airplane performance, a general statement to that effect would be satisfactory. Some STC's that meet or exceed all performance requirements may also increase the fuel consumption reducing endurance. Applicants should add a note or change the performance information for endurance that clearly indicates this decrease to the pilot.

e. Additional Information. Some additional information items that are required for safe operation because of unusual design, operating, or handling characteristics are as follows:

(1) *Strobe lights.* Operation of strobe lights during flight through fog, clouds, or flying closely under an overcast;

(2) *Carburetor heat.* Use of carburetor heat;

(3) *Flaps.* Restricted use of flaps during sideslips;

(4) *Propeller pitch.* Management of propeller pitch when Beta Range is provided;

(5) *Sand screens and engine heaters.* Procedures for the temporary use of sand screens and engine heater devices;

(6) *Feathering.* Unusual feathering design where propeller will not feather with throttle closed;

(7) *Fuel flow.* Scheduling for fuel flow by engine mixture leaning procedure;

(8) *Spin recovery.* Unusual spin recovery techniques;

(9) *Wheelbarrowing.* Wheelbarrowing characteristics;

(10) *Oscillations.* Pilot-induced oscillations or oscillations caused by turbulence, particularly on swept-wing airplanes;

(11) *Depressurization.* Depressurization procedures prior to landing;

(12) *Automatic devices.* Procedures for operation of automatic devices; that is, wing levelers, Mach trim, yaw damper, and so forth; and

(13) *Flight guidance and control systems.* Procedures for operation of integrated flight guidance and control systems. This should include proper pilot response to cockpit warnings, diagnosis of system failures, discussion of possible pilot-induced flight control system problems, and use of the system in a safe manner.

(14) *Turbochargers.* Procedures for normal operation, if appropriate, and abnormal and emergency operations.

2. § 23.1583 Operating Limitations.

a. Limitations Section. The purpose of the limitations section is to present the limitations applicable to the airplane model by serial number, if applicable, as established in the course of the type certification process in determining compliance with parts 23 and 36. The limitations should be presented without explanation other than those explanations prescribed in parts 23 and 36. The operating limitations contained in the limitations section (including any noise limited weights) should be expressed in mandatory, not permissive, language. The terminology used in the AFM should be consistent with the relevant regulatory language.

b. GAMA Specification. GAMA Specification No. 1, Revision No. 1 dated September 1, 1984, section 2, provides guidance for the contents of the limitations section. Additional guidance is provided below for "Kinds of Operation," "Fuel Limitations," and "Commuter Category."

c. Kinds of Operation Equipment List (KOEL). The KOEL is to be placed in the limitations section of the AFM since the KOEL items form part of the limitations applicable to airplane operation. The sample KOEL given in Appendix 6 lists systems and equipment for a specific airplane in an acceptable format. Although the sample KOEL may contain items that are not applicable to all airplanes, it may be used as a guide.

(1) *Standardization*. Although there is no specific format required for the KOEL, we recommend, in the interest of standardization, that the KOEL be placed in columns and each item of equipment required for a specific type of operation for which the airplane is approved be noted in the appropriate column. Regardless of the format used, the KOEL should provide for:

(i) The kinds of operation for which the airplane was type certificated (that is, day or night VFR, day or night IFR, and icing conditions).

(ii) The identity of the systems and equipment upon which type certification for each kind of operation was predicated and must be installed and operable for the particular kind of operation indicated. Systems and equipment necessary for certification includes those:

(A) required under the basic airworthiness requirements;

(B) required by the operating rules;

(C) required by special conditions;

(D) required to substantiate equivalent safety findings;

(E) required by airworthiness directives (AD); and

(F) either items of equipment or systems not specifically required under items (i) through (v) of this paragraph, but used by the applicant in order to show compliance with the regulations.

(2) *The KOEL should not*:

(i) Contain those obvious components required for the airplane to be airworthy, such as wings, empennage, engines, landing gear, brakes, and so forth.

(ii) Contain an exceptions column.

d. Fuel Limitations. The fuel limitations information in GAMA Specification 1 may not be applicable, depending on the airplane certification basis.

e. Turbine Airplanes and Commuter Category Airplanes. For those performance weight limits that may vary with runway length, altitude, temperature, and other variables, the variation in weight limitation may be presented as graphs in the performance section of the manual and included as limitations by specific reference in the limitations section of the AFM.

3. § 23.1585 Operating Procedures.

a. Explanation. Refer to GAMA Specification 1.

b. Electronic Checklist Displays.

(1) *Background*. Checklists, both hard copy and electronic displays, are a method used by manufacturers to provide (in part) the normal and emergency operating procedures required by § 23.1585. Section 23.1581 is also applicable for the manner and format of presentation.

(2) *Display Content*. For those airplanes with approved AFMs, the wide variety of configurations and corresponding flight manual supplements within a single model may establish a virtually unique set of checklist procedures for each individual airplane. The responsibility for electronic checklist display contents rests with the operator. A hard copy of the AFM should be available to the operator for reference.

(3) *AFM Changes*. Incorporation of STC's could necessitate changes to the flight manual, flight manual supplements, or addition of new supplements. These supplements could require revision to the checklist for that particular airplane. Such changes should be made by the operator.

(4) *Operator Revisions*. Although it is not necessary for equipment manufacturers to store electronic checklist data in such a manner that it cannot be changed in the field, some equipment manufacturers have chosen to program checklist data in a manner that prevents field alternation. The operator would be responsible for ensuring the checklist data is revised as necessary upon installation of new/different equipment.

(5) *Disclaimers*. Electronic checklists are usually displayed on the same MFD as other electronic displays. Certain disclaimer statements may be appropriate. Presentation of a disclaimer statement each time the equipment is turned on will provide adequate notification to the pilot. This disclaimer should include statements that clearly state:

(i) Contents of the checklists are the responsibility of the operator

(ii) The approved AFM takes precedence and, for completeness, should be referred to as the primary information source.

(iii) The electronic checklist may not contain all the notes, cautions, and warnings associated with a procedure.

(6) *Automatic Display*. Automatic display of appropriate checklists during conditions of engine failure, generator failure, and so forth, will require a review based upon the

specific application involved. Approval of the checklist content, malfunction prioritization, and operation is required.

4. § 23.1587 Performance Information.

a. Performance Information. This section contains the airworthiness performance information necessary for operation in compliance with applicable performance requirements of part 23, applicable special conditions, and data required by part 36. Additional information and data essential for implementing special operational requirements may be included. Performance information and data should be presented for the range of weight, altitude, temperature, airplane configurations, thrust rating, and any other operational variables stated for the airplane. This information should include a discussion of icing operations, loss of performance possible, and any information to aid in recognition of icing conditions that may exceed the certificated capabilities of the aircraft ice protection systems.

b. Normal, Utility, and Acrobatic Category Airplanes. Refer to GAMA Specification 1.

c. Turbine Airplanes and Commuter Category Airplanes.

(1) *General*. Include all descriptive information necessary to identify the precise configuration and conditions for which the performance data are applicable. Such information should include the complete model designations of airplane and engines, the approved flap, sweep, or canard settings, definition of installed airplane features and equipment that affect performance, together with the operative status thereof (for example, antiskid devices, automatic spoilers, and so forth). This section should also include definitions of terms used in the performance section (that is, IAS, CAS, ISA, configuration, net takeoff flight path, icing conditions, and so forth), plus calibration data for airspeed (flight and ground), Mach number, altimeter, ambient air temperature, and other pertinent information.

(2) *Performance Procedures*. The procedures, techniques, and other conditions associated with attainment of the flight manual performance data should be included. Performance procedures may be presented as a performance subsection or in connection with a particular performance graph. In the latter case, a comprehensive listing of the conditions associated with the particular performance may serve the objective of "procedures" if sufficiently complete.

(3) *Thrust or Power Setting*. Thrust or power settings should be provided for at least takeoff and maximum continuous and the methods required to obtain the performance shown in the AFM. If appropriate, these data may be required to be shown for more than one thrust setting parameter.

(4) *Takeoff Speeds*. The operational takeoff speeds V_1, V_R, and V_2 should be presented together with associated conditions. Section 23.1587(d)(10) requires the speeds be given in CAS. Since the flightcrew flies IAS, the airspeeds should also be presented in IAS.

The V_1 and V_R speeds should be based upon "ground effect" calibration data; the V_2 speeds should be based upon "free air" calibration data.

(5) *Takeoff Distance.* Takeoff distance should be shown in compliance with § 23.59.

(6) *Climb Limited Takeoff Weight*. The climb limited takeoff weight, that is the most limiting weight showing compliance with § 23.67, should be provided.

(7) *Miscellaneous Takeoff Weight Limits*. Takeoff weight limits, for any equipment or characteristic of the airplane configuration which imposes an additional takeoff weight restriction, should be shown (that is, tire speed limitations, brake energy limitations, and so forth).

(8) *Takeoff Climb Performance*. For the prescribed takeoff climb airplane configurations, the climb gradients should be presented together with associated conditions. The scheduled climb speed(s) should be included.

(9) *Takeoff Flight Path Data*. The takeoff flight paths of § 23.61 or performance information necessary to enable construction of such paths, together with associated conditions (that is, procedures, speed schedules), should be presented for the configurations and flight path segments existing between the end of the prescribed takeoff distance and the point of attaining the en route climb configuration airspeed or 1500 feet, whichever is higher.

(10) *En Route Climb Data*. The climb gradients prescribed in § 23.67 should be presented together with associated conditions, including the speed schedule used.

(11) *Balked Landing Climb Limited Landing Weight.* The climb limited landing weight that is the most limiting weight showing compliance with § 23.77.

(12) *Approach Climb Limited Landing Weight*. The climb gradient determined in § 23.67(e)(3) should be presented. The required climb gradient may limit the landing weight.

(13) *Landing Approach Speeds*. The scheduled speeds associated with the approved landing distances should be presented together with associated conditions.

(14) *Landing Distance*. The landing distance from a height of 50 feet should be presented together with associated ambient temperature, altitude, wind conditions, and weights up to the maximum landing weight. Operational landing distance data should be presented for smooth, dry, and hard-surfaced runways. At the option of the applicant, with concurrence by the FAA, additional data may be presented for wet or contaminated runways and for other than smooth, hard-surfaced runways.

(15) *Headwinds/Tailwinds.* Where specified within § 23.1587, the effect of headwinds and tailwinds must be defined. When the performance gradient is positive, use 50 percent of the headwind component and 150 percent of the tailwind component. When the

performance gradient is negative, use 150 percent of the headwind component and 50 percent of the tailwind component.

5. § 23.1589 Loading Information. Refer to GAMA specification 1.

Appendix 1. Power Available

1. General. The purpose of this appendix is to provide guidance regarding the power considerations for various kinds of powerplants. The power output of each airplane/engine configuration requires special considerations when determining test day performance corrections and providing the performance expansions for the AFM. The types of powerplants discussed in this appendix are:

a. Reciprocating Engines.

(1) Normally aspirated engine with a fixed pitch propeller;
(2) Normally aspirated engine with a constant speed propeller; and
(3) Turbocharged engine with a constant speed propeller.

b. Turbopropeller Engines.

2. Reciprocating Engines.

a. Power Charts. The horsepower being developed by reciprocating engines is usually identified by horsepower charts that are provided by the engine manufacturer. These charts are developed from results of ground runs using a brake-type dynamometer in a test facility and may have no direct correlation to any particular airplane or flight condition. The variations of power with altitude and temperature are the result of theoretical relationships involving air density, fuel/air ratios, and so forth. These charts nearly always assume a “best power” fuel to air ratio that can rarely be consistently used in service under normal operating conditions. Many installations, for example, intentionally use fuel to air ratios that are on the fuel-rich side of best power so that the engine will not overheat. Providing sufficient cooling airflow over each cylinder to ensure adequate cooling may be more difficult than cooling with a rich fuel mixture. These horsepower charts were also developed while maintaining a constant temperature on each cylinder. This is not possible in service. The charts are developed assuming the following:

(1) There is no ram airflow due to movement through the air; or

(2) There are not losses due to pressure drops resulting from intake and air filter design; or

(3) There are no accessory losses.

b. Chart Assumptions. Regardless of the test stand conditions that are not duplicated in service, it is necessary to assume that each given pressure altitude temperature, engine speed, and manifold pressure combination will result in horsepower that can be determined from the engine power chart. To accomplish this requires certain procedures and considerations.

c. Tolerances. Each engine power chart specifies a horsepower tolerance from rated horsepower. These are commonly ±2 ½ percent, +5 percent, -2 percent, or +5 percent, -0 percent. This means that with all the variables affecting power being held constant (that is, constant manifold pressure, engine speed, temperature, and fuel to air ratio), the power could vary this much from engine to engine. For this reason, it is appropriate to account for these variations. Calibration of the test engine(s) by the engine manufacturer is one way to accomplishing this. During engine calibration, the test engine is run on a test stand at the engine manufacturer’s facility to identify how it compares with the power output at conditions under which it was rated. The result is a single point comparison to the rated horsepower.

d. Test Day Power.

(1) *Calibrated Engines*. If an engine, for example, is rated at 200 BHP, the calibration results might show the particular serial numbered engine to develop 198.6 BHP. This is 0.7 percent below the rated power. For this engine, each of the horsepower values obtained from the engine manufacturer's chart should be adjusted downward by 0.7 percent to obtain test day horsepower.

(2) *Uncalibrated Engines.* If the engine is not calibrated, an acceptable method of accounting for the unknown factors is to assume that the test engine is putting out rated horsepower plus the plus tolerance. For example, if the rated horsepower was 350 and the tolerance was ±2 ½ percent, test day sea level chart horsepower would be assumed to be 350 + .025 (350), or 358.8.

(3) *Humidity.* Section 23.45(e) requires performance to be based on 80 percent relative humidity on a standard day. Experience has shown that conditions such as 80 percent relative humidity on a standard day at sea level have a very small effect on engine power because this condition results in a very low specific humidity. The engine is affected directly by specific humidity (pounds of water per pounds of air) rather than relative humidity. For test day power, dry air should be assumed unless the applicant has an approved method for measuring and determining the effect of humidity.

e. Chart Brake Horsepower. A chart brake horsepower (BHPc) should be determined for expansion of the flight test data in the AFM. BHPc is the horsepower at a particular pressure altitude, manifold pressure and r.p.m. Appropriate inlet temperature corrections should be applied, in accordance with the manufacturer's engine power chart. An 80 percent relative humidity correction should be applied if the engine manufacturer has an acceptable method and the correction is significant.

f. Variations in Methods. Peculiarities of the various types of reciprocating engines require special considerations or procedures to determine installed power. These procedures are discussed in subsequent paragraphs.

3. Normally Aspirated Engines with Constant Speed Propellers.

a. Manifold Pressure Versus Altitude. As a first step to determine installed horsepower, flight tests should be conducted to determine manifold pressure versus pressure altitude for the engine installation. The test manifold pressures would be compared to the engine manufacturer's chart values, as shown on Figure A1-1. Figure A1-1 shows an example of test manifold pressure and chart manifold pressures versus pressure altitude. In this example, the observed manifold pressures are lower than the chart values. This means that the induction system pressure losses exceed the ram pressure rise. An induction system in which manifold pressures exceed the zero ram chart values would reflect an efficient induction system. The term chart brake horsepower indicates that the horsepower values have yet to be corrected for inlet temperature conditions.

b. Example Calculation. The overall corrections to determine installed test day brake horsepower and chart brake horsepower (BHPc) to be used in the expansion of performance would be as follows (refer to Figure A1-1):

Known:

Pressure Altitude	4,000 feet
Manifold Pressure	24.9 in Hg.
Outside Air Temperature	+55 ºF
Inlet Temperature	+63 ºF
Engine Speed	2,650 r.p.m.
Engine Calibration	-0.7 %
Engine Tolerance	±2 ½ %

Calculated Test Day BHP for a Calibrated Engine:

Standard Temperature @ 4,000 ft. .... 44.7 ºF
Installed Chart Brake Horsepower .... 335 BHP
(from Figure A1-1)
Engine Calibration Correction = (335)(-.007) .... -2.3 BHP
Correcting for Inlet Temperature

$$\text{Test Day BHP} = (335-2.3)\sqrt{\frac{460+44.7}{460+63.0}} \ldots\ldots 326.8 \text{ BHP}$$

Calculated Test Day BHP for an Uncalibrated Engine:

Standard Temperature @ 4,000 ft. .... 44.7 ºF
Installed Chart Brake Horsepower .... 335 BHP
(from Figure A1-1)

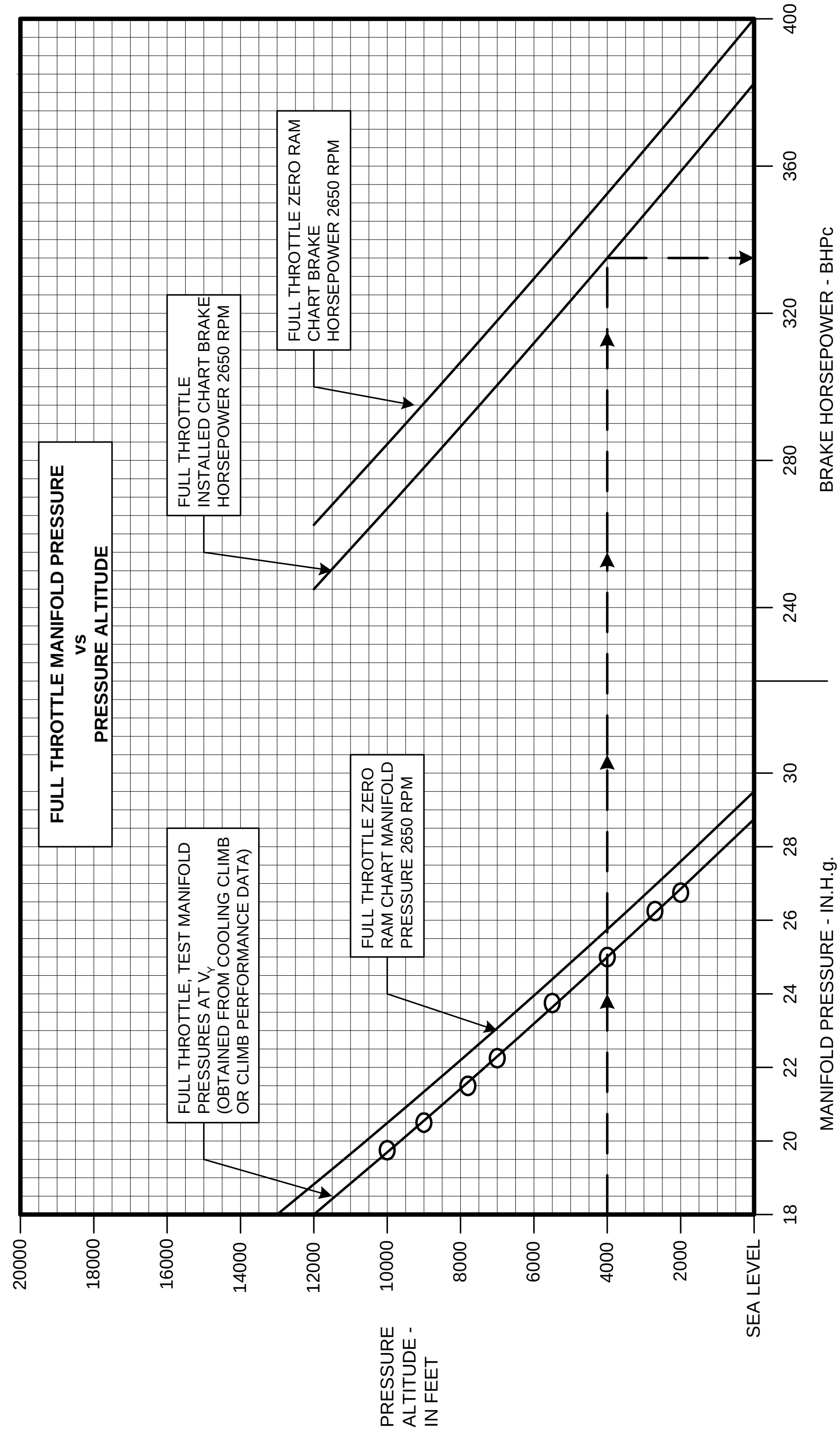
$$\text{Test Day BHP} = [335 + .025(335)]\sqrt{\frac{460+44.7}{460+63}} \ldots\ldots 337.3 \text{ BHP}$$

Calculated BHPc for Test Day Density Altitude (Hd):

Hd at 4,000 ft. and 55 ºF .... 4,670 ft.
Installed BHPc (from Figure A1-1) .... 326 BHP
Standard Temperature at 4,670 ft. .... 42 ºF
Correcting for Inlet Temperature Rise

$$\text{BHPc} = 326\sqrt{\frac{460+42}{460+42+8}} \ldots\ldots 323.4 \text{ BHP}$$

Figure A1-1 – Brake Horsepower Versus Pressure Altitude



Calculated Test Day BHPc for the AFM Expansion:

For the Same Conditions as Test Day,...335 BHP
BHP (from Figure A1-1)..335 BHP
Correcting for Inlet Temperature,
expansion

$$BHP - 335\sqrt{\frac{460+44.7}{460+63}}$$ ....329.1 BHP

4. Turbocharged Engines with Constant Speed Propellers.

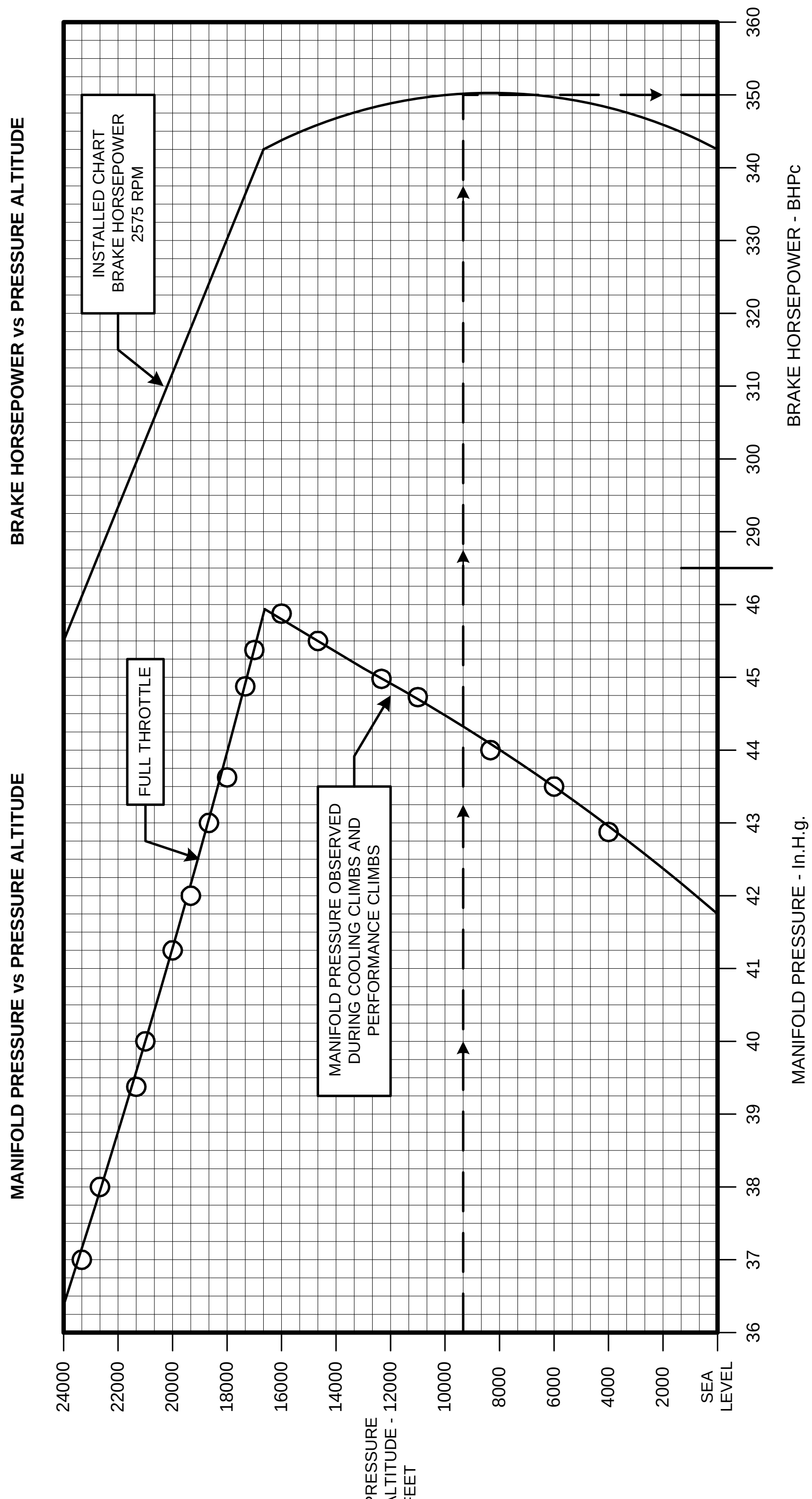
a. Manifold Pressure Versus Altitude. From flight tests, it is appropriate to plot manifold pressure versus pressure altitude used to demonstrate satisfactory cooling and climb performance demonstrations. The engine manufacturer's chart brake horsepower should be entered at these manifold pressure values. The result is the chart brake horsepower to be utilized in data expansion. For some installations, the manifold pressure and fuel flows are limited by the airplane manufacturer's design schedule. For these, the full throttle values must be identified. Whenever the manifold pressures and fuel flows must be manually set to a schedule, corresponding limitations must be established.

b. Horsepower. Refer to Figure A1-2 for an illustration of manifold pressure and horsepower versus pressure altitude. It is rare for the horsepower values to be constant below the critical altitude. The horsepower ratings are not necessarily limited and it is common to observe chart horsepower values at the intermediate altitudes higher than rated power. As with normally aspirated engines, the term chart brake horsepower indicates that the horsepower values have yet to be corrected for inlet temperature conditions. The corrections for temperature are usually greater for turbocharged than normally aspirated. A 1 percent decrease in power for each 10 ºF increase in temperature above standard temperature conditions at a constant specific fuel consumption (SFC) is common. The apparent effects for a particular installation could be more or less than this. Manufacturer's data for the particular engine should be used.

c. Example Calculation. The overall corrections to determine installed test brake horsepower and brake horsepower to be used in the expansion of performance would be as follows (refer to Figure A1-2):

Known:
Pressure Altitude..9,500 feet
Manifold Pressure..44.3 in. Hg.
Outside Air Temperature..53.0 ºF
Compressor Inlet Temperature..............................67 ºF
Engine Speed...2,575 r.p.m.
Engine Calibration..+1.7%
Engine Tolerance..±2 1/2%

Figure A1-2 - Turbocharged Brake Horsepower Versus Altitude



Calculated Test Day BHP for a Calibrated Engine:

Standard Temperature @ 9,500 ft..25.1 ºF
Power Correction Due to Temperature
at 1%/10 ºF...-4.2%
(Temperature rise = 67º -25.1 ºF)
Installed Chart Brake Horsepower
(from Figure A1-2)..351 BHP
Engine Calibration Correction (351)(.017)......................................+5.97 BHP
Test BHP = (351 + 5.97) - (.042)(356.97).....................................332.1 BHP

Calculated Test Day BHP for an Uncalibrated Engine:

Standard Temperature @ 9,500 ft..25.1 ºF
Power Correction at 1%/10 ºF...-4.2%
Installed Chart Brake Horsepower..351
(from Figure A1-2)
Test BHP = 351 - (351)(.042) + 351(.025).....................................335.3

Calculated BHPc for Test Day Density Altitude (Hd):

Hd at 9,500 ft and 53 ºF..11,280 ft
Installed BHPc (from Figure A1-2)..350 BHP
Power Correction Due to Inlet
Temperature Rise at 1%/10 ºF
(temperature rise = 14 ºF)...-1.4%
BHPc = 350-(350)(.0233)...341.8 BHP

Calculated BHPc for the AFM Expansion:

For the Same Conditions as Test Day,..351 BHP
BHPc (from Figure A1-2)
Temperature Correction to BHPc =..326.5 BHP
350-(.042)(351)

5. Normally Aspirated Engines with Fixed Pitch Propellers. (Reserved).

6. Turbopropeller Engines.

a. Power Measurement. Turbopropeller engines (turboprops) are gas turbine engines that drive a propeller. Power output is a function of the gas turbine airflow, pressure, and temperature. Power measurement is made by measurement of the propeller shaft speed and torque, from which the shaft horsepower can be obtained by a simple calculation. Torque is measured by an integral device that may be mechanical, hydraulic, or electrical and connects to the indicator required by Part 23, § 23.1305(m). Shaft horsepower is the same as brake horsepower, that is, the power developed at the propeller shaft. The total thrust horsepower, or equivalent shaft horsepower (ESHP) is the sum of the shaft horsepower and the nominal horsepower equivalent of the net exhaust thrust.

b. Power Available. The prediction of power available is obtained from the engine manufacturer as a computer program. Each installation must be evaluated to identify:

Generator Loads (all engine and one engine inoperative)
Bleed Air Extractions (with and without ice protection)
Accessory Pad Extractions
Engine Air Inlet Efficiency (with and without ice protection)
Engine Exhaust Efficiency
Effect of Specific Humidity

With these values as input to the computer program, installed power available and fuel flows at various airspeeds, temperatures, and altitudes can be calculated.

Appendix 2. Climb Data Reduction

1. Drag Polar Method. This is one method to develop the airplane's drag polar equation directly from climb flight test data. It is a simplified method that assumes climb speeds where the compressibility drag is negligible (usually Mach numbers below 0.6), climb angles of less than 15 degrees, and no propeller slipstream effects on the wing lift and drag characteristics.

a. Cautions. Propeller airplanes are susceptible to slipstream drag, and all airplanes are susceptible to trim drag. This is most noticeable on airplanes with wing-mounted engines and when one engine is inoperative. Care should be given so that drag results are not extended from one flight condition to another. Examples of this are:

(1) Drag obtained in level cruise configuration cannot be extended to a climb configuration.

(2) Two-engine climb data cannot be extended to the one-engine-inoperative case.

In summary, the power and trim conditions must remain very close to those existing for the actual test conditions. Drag results are only as accurate as the available power information and propeller efficiency information. The cooling airflow through the engine is also a factor.

b. Calculation of C_D and C_L. Flight test data for various climb airspeeds, weights, and altitudes should be used to calculate C_D and C_L. The equations are as follows:

$$C_D = \left[BHP_T(\eta_P) - \frac{T_{AT}(AF)(R/C_O W_T)}{(T_{AS})33{,}000}\right]\left[\frac{96209\sqrt{\sigma}}{(V_e)^3 S}\right]$$

$$C_L = \frac{295(W_T)\sqrt{1-\left[\frac{\sqrt{\sigma}}{(101.27V_C)}\frac{T_{AT}(AF)R/C_O}{T_{AS}}\right]^2}}{(V_e)^2 S}$$

Where:

BHP_T = test day horsepower (see Appendix 1)

η_P = propeller efficiency (obtain from propeller manufacturer or may be estimated)

T_{AT} = test air temperature - ºKelvin

T_{AS} = standard air temperature - ºKelvin

R/C_O	=	observed rate of climb - feet/minute
W_T	=	airplane test weight - pounds
V_e	=	equivalent airspeed - knots
S	=	wing area - square feet
σ	=	atmospheric density ratio (see Appendix 7, figure 1)
AF	=	acceleration factor (may be insignificant at lower speeds)

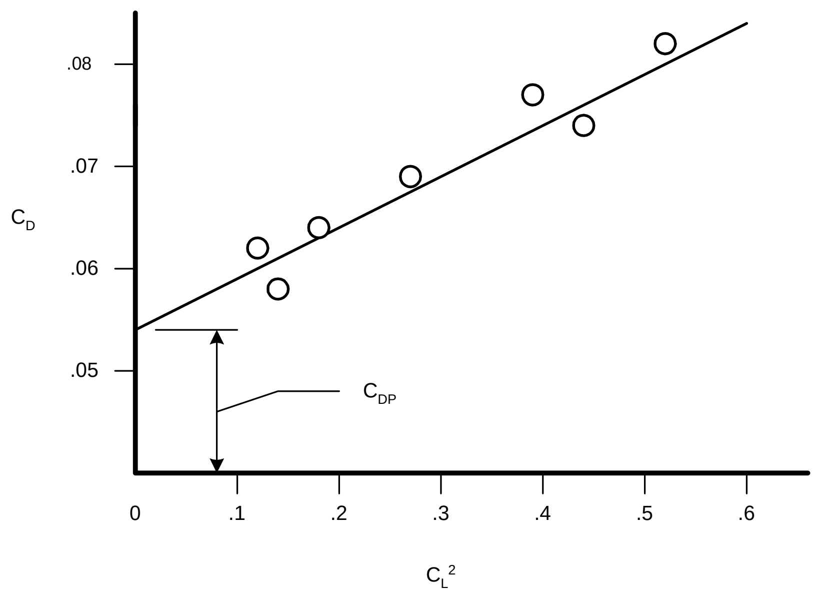
$$AF = \frac{\left(1 + 0.2M^2\right)^{3.5} - 1}{\left(1 + 0.2M^2\right)^{2.5}} - 0.133M^2 + 1$$

Where: M = Mach number

V_C is constant, altitude below 36,089 feet

c. Data Plotting. Once C_D and $C_L{}^2$ are calculated from various climb tests at many altitudes, weights, and airspeeds, a plot is made of C_D versus $C_L{}^2$. This choice of parameters reduces the parabolic drag polar ($C_{L\ vs.}\ C_D$) to a straight line relationship. These procedures should be used to establish C_{DP} and e for each configuration where climb data is obtained.

Figure A2-1 - Coefficient of Drag Versus Coefficient of Lift



From this plot, the profile drag coefficient (C_{DP}) can be determined graphically and Oswald's efficiency factor (e) can be calculated.

$$e = \frac{C_L^2}{(C_D - C_{DP})3.1416\left(\frac{b^2}{S}\right)} \qquad \text{or} \qquad e = \frac{\Delta C_L^2 / \Delta C_D}{3.1416\left(\frac{b^2}{S}\right)}$$

Where: b = wing span - feet S = wing area - square feet

d. Standard Day Correction. Since the C_L^2 versus C_D data was developed from test day conditions of weight, altitude, temperature, and power, calculations will be required to determine standard day conditions.

$$R/C = \frac{(THP_A - THP_R)33{,}000}{W_C(AF)}$$

Where: THP_A = thrust horsepower available
THP_R = thrust horsepower required
W_C = aircraft weight to which correction is to be made (pounds)
AF = acceleration factor (see paragraph b)

THP_A = BHPc (η_P)

Where: BHPc = chart brake horsepower at test day density altitude (see Appendix 1)
η_P = propeller efficiency

$$THP_R = \frac{\sigma(V_T)^3 C_{DP} S}{96209} + \frac{(0.2883)(W_C)^2}{e\sigma b^2 V_T}$$

Where: σ = atmospheric density ratio
V_T = true airspeed - knots
C_{DP} = profile drag coefficient
S = Wing area - square feet
e = efficiency factor
b = wing span - feet
W_C = aircraft weight to which correction is to be made - pounds

e. Expansion to Non-standard Conditions. The methods in paragraph “d” can be used to expand the climb data by choosing weight, altitude, temperature, and the corresponding power available.

f. References. The following references may be of assistance in cases where compressibility drag is a factor, climb angles are greater than 15 degrees, or if the reader wishes to review the basic derivations of the drag polar method:

(1) "Airplane Aerodynamics and Performance" by C. Edward Lan and Jan Roskam. Published and sold by:

Roskam Aviation and Engineering Corporation
Route 4, Box 274
Ottawa, Kansas 66067

(2) Air Force Technical Report No. 6273, "Flight Test Engineering Handbook," by Russell Herrington, et al., dated May 1951. Corrected and revised June 1964-January 1966. Refer to NTIS No. AD 636.392. Available from:

National Technical Information Service (NTIS)
5285 Port Royal Road
Springfield, Virginia 22161

2. Density Altitude Method. This method is an alternate to the Drag Polar Method. The Density Altitude Method is subject to the same cautions as the Drag Polar Method. Item numbers 1, 2, 6, 9, 12, 17, 18, and 19 are observed during flight tests and the remaining items are calculated.

Item No.	Item
1	Pressure Altitude (Hp) – feet
2	Outside Air Temperature – °F
3	Atmospheric Density Ratio – σ
4.	Density Altitude (Hd) – feet. $Hd = 145539\left[1-\left(\sqrt{\sigma}\right)^{.4699}\right]$
5.	Std. Temp. @ Hp (T_S) – °F + 460
6.	IAS – knots
7.	CAS – knots
8.	TAS = $\dfrac{7}{\sqrt{3}}$
9.	Observed rate of climb – ft/min
10.	$T/T_S = \dfrac{2 + 460}{5}$

11. Actual R/C = 9 * 10

12. Test Weight, 2- lbs.

13. $\Delta R/C\Delta_{W} = 11 \; (I - \frac{12}{Wc}$

Where W_C = aircraft weight to which correction is to be made

14. $q\pi eb^2 = 7 \; 2 \; \frac{\pi eb^2}{295}$

Where: b = wing span in feet
e = Oswald's efficiency factor (0.8 may be used if a more exact value cannot be determined)

15. $\Delta D_8 = \frac{(Wc - 12)^2}{14}$

16. $\Delta(R/C)\ \Delta D_i = \frac{101.27 \; 15 \; 8}{W_S}$

17. Calibrated RPM (reciprocating engine)

18. Calibrated MP (reciprocating engine)
19. Inlet air temperature
20. Test day BHP corrected for temperature from Appendix 1 at Hd
21. η_P -- propeller efficiency (obtain from propeller manufacturer or may be estimated)

22. $\Delta THP = (22 - 21)\ 20$

23. $\Delta(R/C)\ \Delta P = \frac{23 \times 33{,}000}{W_C}$

24. $R/C_{STD} = 11 - 13 - 16 + 24$

Items 4, 7, and 24 are used to plot figure 25-2.

Appendix 3. Static Minimum Control Speed Extrapolation to Sea Level

1. General. The purpose of this appendix is to identify one method of extrapolating minimum control speeds (V_{MC}) observed during flight tests, to sea level, standard temperature conditions. There is a geometric relationship between the yawing moment about the c.g. caused by the operating engine, and the rudder deflection necessary to offset this tendency and cause an equilibrium.

2. Calculation Method. This method involves calculating a geometric constant (C_2) for each observed test value, averaging the results, and calculating a sea level V_{MC}. The equations are as follows:

$$V_{MC} = [(C_2)(\sqrt{\sigma})(THP)]^{1/3}$$

or;

$$C_2 = \frac{V_{MC}^{\ 3}}{(\sqrt{\sigma})(THP)}$$

Where: C_2 = a geometric constant

$\sqrt{\sigma}$ = the square root of the density ratio

THP = thrust horsepower (test shaft horsepower or brake horsepower times propeller efficiency)

3. Cautions and Assumptions. This method has the following associated cautions and assumptions:

a. This method is limited to airplanes with a V_{MC} due to lack of directional control. Each test value of V_{MC} must be observed with full rudder deflection. If, for example, the test conditions result in reaching the force limit (150 pounds rudder force) prior to achieving full rudder deflection, then observed V_{MC} values would require special consideration.

b. The effects of wing lift in the 5 degree bank angle are ignored.

c. Do not use this method for fixed-pitch or windmilling propellers.

d. Any altitude effects that may result from drag on a rotating feathered propeller on the inoperative engine are ignored.

e. Computing a V_{MC} value at sea level involves raising to the power of 1/3 (use 0.33333333). The number of significant digits used affects the resulting computations. For this reason, use at least 8 significant digits.

f. Propeller efficiencies should be reasonable. They may be obtained from propeller efficiency charts provided by the propeller manufacturer, or from other acceptable sources.

4. Sample Calculations. Test data from two-engine turbopropeller airplanes have been used for illustration. Observations for one takeoff flap setting are presented. The procedures should be repeated for each additional approved takeoff flap setting. Table A3-1 presents five data points that were collected at various altitude and temperature conditions, and the resulting C_2 values that were calculated. For these tests, the inoperative propeller was feathered (auto-feather available).

Table A3-1 – Flight Test Data

RUN	PRESSURE ALTITUDE (FEET)	O.A.T. (°F)	TORQUE (FT-LB)	PROPELLER RPM	V_{MC} (KCAS)	$\sqrt{\sigma}$	SHAFT HORSE-POWER	η_p (2)	C_2
1	3500	86.3	3219	1700	91.2	.914243	1041.95	.590	1349.657
2	4200	88.3	3219	1700	91.2	.900795	1041.95	.585	1381.516
3	4800	87.3	3219	1700	90.7	.891588	1041.95	.580	1384.786
4	5500	85.2	3219	1700	90.7	.881668	1041.95	.575	1412.544
5	6300	83.2	3219	1700	90.7	.870083	1041.95	.570	1443.907

(1) Calculated from observed torque and propeller rpm

(2) Obtained from propeller manufacturer

The propeller efficiencies were obtained from power coefficient versus advance ratio map, which was obtained from the propeller manufacturer. The 4-blade propellers were assumed for these calculations to have an activity factor = 80; and an integrated lift coefficient = 0.700.

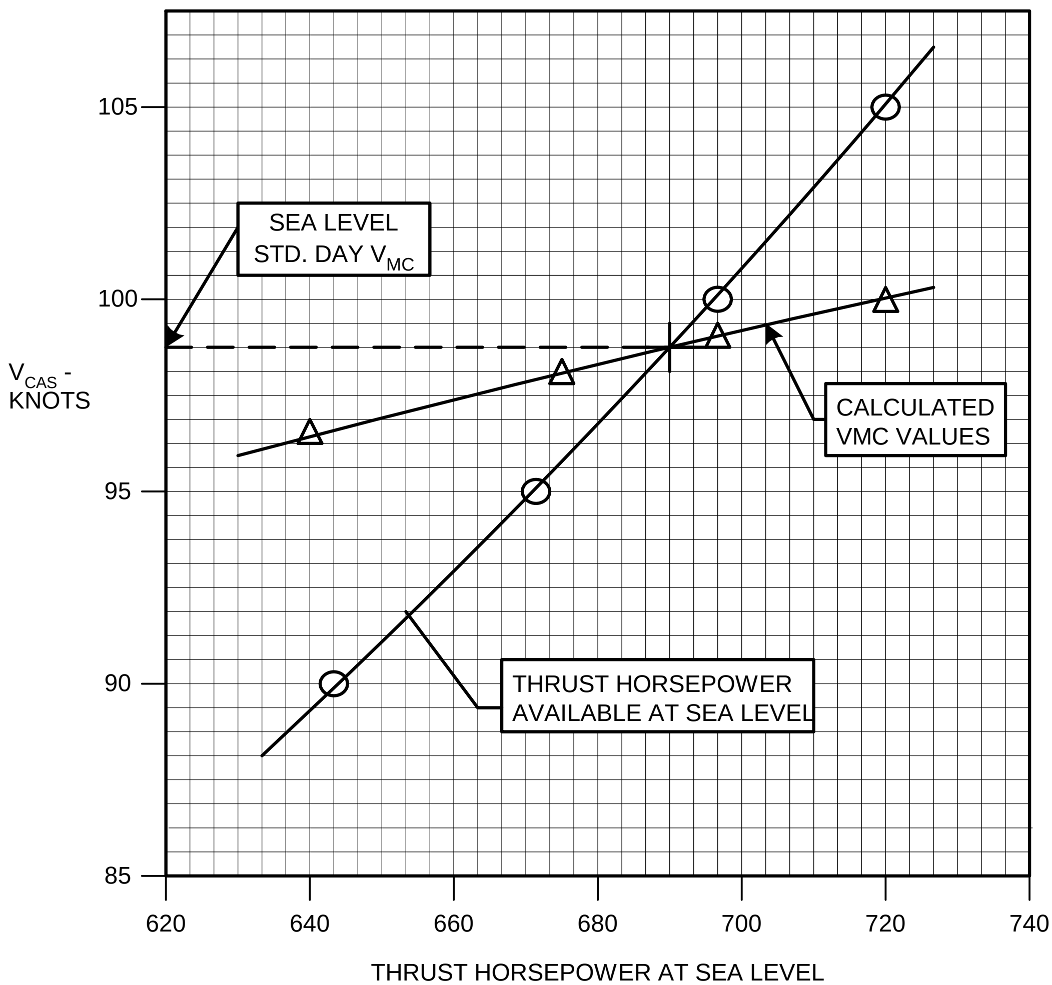
The five C_2 values from Table A3-1 were averaged as 1394.482. The sea level, standard temperature maximum shaft horsepower was 1050. At low speeds, the propeller efficiency changes fairly significantly with speed. For this reason, it is appropriate to determine propeller efficiencies at several speeds near the estimated sea level V_{MC} value. Table A3-2 presents the thrust horsepower values determined for calibrated airspeeds of 90, 95, 100, and 105 knots and the V_{MC} values calculated using these thrust horsepower values and the average C_2 (1394.482).

Figure A3-1 illustrates the plot of airspeed versus thrust horsepower. One curve is of thrust horsepower available versus airspeed. The other represents the calculated V_{MC} values versus thrust horsepower available at sea level. The intersection of the two curves represents the V_{MC} value associated with sea level, standard temperature conditions. These calculations resulted in a final V_{MC} value of 98.8 knots calibrated airspeed.

Table A3-2 - Tabulated Thrust Horsepower Available and Calculated V_{Mc}

V_C (KCAS)	SHAFT HORSEPOWER	η_P	THRUST HORSEPOWER AVAILABLE AT SEA LEVEL	CALCULATED V_{MC} $C_2 = 1394.482$
90	1050	.610	640.5	96.3
95	1050	.640	672.0	97.9
100	1050	.665	698.3	99.1
105	1050	.688	722.4	100.2

Figure A3-1 - Thrust Horsepower at Sea Level



Appendix 4 FAR-23 Manuals, Markings, & Placards Checklist

Primary FAR	Support FAR	Description	Manual	Mark	Placard	Sign
23.25(a)(2)	23.1557(b)	Occupant weight less than 170 lb (normal and commuter) or 190 lb (utility and aerobatic)			X	
23.31(a)	23.1557(a)	Marking for placement of removable ballast		X		
23.31(b)		Ballast content and weight limitations	X	X	X	
23.373(a)		Placard for maximum speed for extended speed control devices			X	
23.415(c)		Maximum weight for tie-down	X			
23.671(b)		Identification of controls		X		
23.672(c)(2)		Practicable operational flight envelope after system failure	X			
23.677(a)		Direction of movement and position of trim device		X		
23.685(d)		Marking of control system elements		X		
23.733(b)		Marking of specially constructed tires		X		
23.777(a)	23.1555(a)	Identification of cockpit controls		X		
23.777(h)(1)	23.995	Indication of selected position for mechanical fuel selector		X		
23.777(h)(2)	23.995	Indication of tank or function selected for electronic fuel selector. Closed position indicated in red		X		
23.777(h)(3)	23.995	Red marking of OFF position of fuel valve selector		X		
23.783(c)(3)-(4)	23.811	Marking of means of opening external doors		X		
23.785(h)		Placard for seats in utility and aerobatic airplanes which won't accommodate an occupant wearing a parachute			X	
23.787(a)(1)		Placard for maximum weight capacity of baggage or cargo compartment			X	
23.791		Passenger information signs required for commuter category airplanes if flight crew cannot observe other seats				X
23.807(b)(3)		Marking of emergency exit location and operation		X		
23.811(a)		External marking of means of opening doors and exits		X	X	
23.811(b)		Internal sign for exits and doors for commuter category airplanes				X
23.841(b)(7)		Warning placard if maximum differential cabin pressure and landing loads exceed limit			X	
23.853(c),(c)(2)		Placard or illuminated sign prohibiting smoking if/when applicable			X	X
23.853(d)(1)		"No cigarette disposal" placard on/near each disposal receptacle door for commuter category			X	
23.853(d)(2)		"No smoking" placards required for lavatories for commuter category			X	
23.903(d)	23.1581(a)(2)	Marking or placard for piston engine start techniques and limitations	X		X	
23.903(e)(1)	23.1581(a)(2)	Marking or placard for turbine engine start techniques and limitations	X		X	
23.903(e)(3)	23.1581(a)(4)	Marking or placard for turbine engine in-flight restart techniques and limitations	X		X	

23.905(f)		Marking such that pusher propeller disk is conspicuous		X		
23.909(e)	12.1581(a)(2)	Turbocharger operating procedures and limitations	X			
23.955(d)(2)	23.1555(c)(3)	Placard for operating instructions for use of auxiliary fuel tank			X	
23.973(a)	23.1557(c)	Marking of fuel tank filler		X		
23.1001(g)		Placard for fuel jettisoning means if prohibited in some aerodynamic configurations			X	
23.1013(c)	23.1557(c)	Marking oil filler tank connections		X		
23.1045(a)	23.1041	Compliance with § 23.1041 must be shown for all flight phases with the procedures established in AFM (turbines)	X			
23.1047	23.1041	Compliance with §23.1041 must be shown for the climb/descent with the procedures established in AFM (pistons)	X			
23.1061(c)		Marking coolant tank filler connections		X		
23.1141(a)	23.1555(a)	Marking of powerplant controls		X		
23.1301(b)		Labeling of equipment as to its identification, function and/or operating limitations		X		
23.1311(a)(7)		Instrument markings on electronic displays		X		
23.1325(b)(3)	23.1541(a)(2)	Provision of alternate static correction card, if required		X		
23.1327(b)	23.1547(e)	Placard for magnetic indicator deviations of more than 10^0			X	
23.1329(d)		Marking of direction of motion of autopilot controls		X		
23.1337(b)		Marking of appropriate units on fuel quantity indicator		X		
23.1357(d)		Marking of essential circuit breakers and fuses		X		
23.1367(d)		Marking of switches as to operation and circuit controlled		X		
23.1419(a)	23.1585(a)	Recommended procedures for use of ice protection equipment	X			
23.1450(c)		Placard for oxygen flow, duration and warning of hot generator element			X	
23.1501	23.1541-23.1589	Operating limitations and other information necessary for safe operation should be established and furnished to the crew	X			
23.1541(a)(1)	23.1545-23.1567	Markings and placards specified by §§23.1545-23.1567		X	X	
23.1541(a)(2)		Additional information, markings and placards required for safe operation	X	X	X	
23.1541(b)		Specifies characteristics of markings and placards		X	X	
23.1541(c)(1)		Select one category for basis for markings and placards for multi-category airplanes	X	X	X	
23.1541(c)(2)		Placards and marking information for all certified categories must be furnished in the AFM	X	X	X	
23.1543		Alignment and visibility of instrument markings		X		
23.1545(a)		Marking of speeds on ASI		X		
23.1545(b)		Marking of VNE, caution range, flap operating range, OEI en-route climb/descent speed for pistons less than 6000 lb, VMC for pistons less than 6000 lb.		X		
23.1545(c)		Indication of variation of VNE or VNO with altitude		X		
23.1545(d)		Indication of variation of VMO/MMO with altitude or lowest value		X		

23.903(e)(1)	23.1581(a)(2)	Marking or placard for turbine engine start techniques and limitations	X		X	
23.903(e)(3)	23.1581(a)(4)	Marking or placard for turbine engine in-flight restart techniques and limitations	X		X	
23.905(f)		Marking such that pusher propeller disk is conspicuous		X		
23.909(e)	12.1581(a)(2)	Turbocharger operating procedures and limitations	X			
23.955(d)(2)	23.1555(c)(3)	Placard for operating instructions for use of auxiliary fuel tank			X	
23.973(a)	23.1557(c)	Marking of fuel tank filler		X		
23.1001(g)		Placard for fuel jettisoning means if prohibited in some aerodynamic configurations			X	
23.1013(c)	23.1557(c)	Marking oil filler tank connections		X		
23.1045(a)	23.1041	Compliance with § 23.1041 must be shown for all flight phases with the procedures established in AFM (turbines)	X			
23.1047	23.1041	Compliance with §23.1041 must be shown for the climb/descent with the procedures established in AFM (pistons)	X			
23.1061(c)		Marking coolant tank filler connections		X		
23.1141(a)	23.1555(a)	Marking of powerplant controls		X		
23.1301(b)		Labeling of equipment as to its identification, function and/or operating limitations		X		
23.1311(a)(7)		Instrument markings on electronic displays		X		
23.1325(b)(3)	23.1541(a)(2)	Provision of alternate static correction card, if required		X		
23.1327(b)	23.1547(e)	Placard for magnetic indicator deviations of more than 10^0			X	
23.1329(d)		Marking of direction of motion of autopilot controls		X		
23.1337(b)		Marking of appropriate units on fuel quantity indicator		X		
23.1357(d)		Marking of essential circuit breakers and fuses		X		
23.1367(d)		Marking of switches as to operation and circuit controlled		X		
23.1419(a)	23.1585(a)	Recommended procedures for use of ice protection equipment	X			
23.1450(c)		Placard for oxygen flow, duration and warning of hot generator element			X	
23.1501	23.1541-23.1589	Operating limitations and other information necessary for safe operation should be established and furnished to the crew	X			
23.1541(a)(1)	23.1545-23.1567	Markings and placards specified by §§23.1545-23.1567		X	X	
23.1541(a)(2)		Additional information, markings and placards required for safe operation	X	X	X	
23.1541(b)		Specifies characteristics of markings and placards		X	X	
23.1541(c)(1)		Select one category for basis for markings and placards for multi-category airplanes	X	X	X	
23.1541(c)(2)		Placards and marking information for all certified categories must be furnished in the AFM	X	X	X	
23.1543		Alignment and visibility of instrument markings		X		
23.1545(a)		Marking of speeds on ASI		X		
23.1545(b)		Marking of VNE, caution range, flap operating range, OEI en-route climb/descent speed for pistons less than 6000 lb, VMC for pistons less than 6000 lb.		X		
23.1545(c)		Indication of variation of VNE or VNO with altitude		X		

23.1545(d)		Indication of variation of VMO/MMO with altitude or lowest value		X		
23.1547(a)		Marking of conditions for, and calibration of, magnetic direction indicator		X	X	
23.1549(a)		Marking of powerplant instruments-red radial line for maximum and minimum operating limits		X		
23.1549(b)		Marking of powerplant instruments - green arc for normal range		X		
23.1549(c)		Marking of powerplant instruments-yellow arc for caution and take-off range		X		
23.1549(c)		Marking of powerplant instruments-red arc for restricted vibration range		X		
23.1551		Marking of oil quantity indicator		X		
23.1553	23.1337(b)(1)	Red radial marking at specified zero reading		X		
23.1555(a)		Marking of cockpit control as to function and method of operation		X		
23.1555(b)		Marking of secondary controls		X		
23.1555(c)(1)		Marking of powerplant fuel controls-fuel selector position		X		
23.1555(c)(2)		Marking of powerplant fuel controls-fuel tank sequence		X		
23.1555(c)(3)	23.955(d)(2)	Placard stating conditions under which maximum usable fuel may be used from restricted usage tank			X	
23.1555(c)(4)		Marking of powerplant fuel controls-multi-engine fuel selector position		X		
23.1555(d)(1)		Marking of usable fuel at indicator, if applicable		X		
23.1555(d)(2)		Marking of usable fuel at selector, if applicable		X		
23.1555(e)(1)		Marking of landing gear position indicator		X		
23.1555(e)(2)		Marking of emergency controls red and of method of operation		X		
23.1557(a)		Placard for baggage, cargo and ballast for weight and content			X	
23.1557(b)	23.25(c)(2)	Placard for seats not capable of carrying more than 170 lb.			X	
23.1557(c)(1)(i)	23.973(a)	Marking of fuel filler openings (piston)		X		
23.1557(c)(1)(ii)	23.973(a)	Marking of fuel filler openings (turbine) and AFM requirement	X	X		
23.1557(c)(2)		Marking of oil filler openings and AFM requirement	X	X		
23.1557(c)(3)		Marking of coolant filler openings		X		
23.1557(d)		Placard for emergency exits and controls			X	
23.1557(e)		Marking of system voltage of each DC installation		X		
23.1559(a)(1)		Placard stating that airplane must be operated in accordance with AFM			X	
23.1559(a)(2)		Placard stating the certified category to which placards apply			X	
23.1559(b)		For multi-category airplanes, a placard stating that other limitations are contained in the AFM			X	
23.1559(c)	23.1525	Placard specifying the kinds of operation			X	
23.1561(a)		Marking of safety equipment as to method of operation		X		

23.1561(b)		Marking of stowage provisions for safety equipment		X		
23.1563(a)		Placard of VA close to ASI			X	
23.1563(b)		Placard of VLO close to ASI			X	
23.1563(c)	23.1525	Placard of VMC close to ASI for pistons greater than 6,000 lb and turbines			X	
23.1567(a)		Placard prohibiting aerobatic maneuvers, including spins, for normal category airplanes			X	
23.1567(b)(1)		Placard listing approved aerobatic maneuvers for utility category airplanes			X	
23.1567(b)(2)		Placard stating "spins prohibited" for utility category airplanes that do not meet the aerobatic spin requirements			X	
23.1567(c)		Placard listing approved aerobatic maneuvers and recommended entry airspeed; also stating if inverted maneuvers are not allowed			X	
23.1567(d)		Placard listing conditions and control actions for recovery from a spin			X	
23.1581(a)	23.1583-23.1589	Requires AFM be submitted to the Authority. AFM must contain information required by §§23.1583-23.1589, other information necessary for safe operation and information necessary to comply with the operating rules	X			
23.1581(b)(1)	23.1583-23.1589	Information required by §§23.1583-12.1589 must be approved and segregated from unapproved information	X			
23.1581(b)(s)(i)	23.1583	Operating limitations must be approved and clearly distinguished from other parts of the AFM (does not apply to pistons less than or equal to 6000 lb)	X			
23.1581(b)(2)(ii)	23.1585-23.1589	Procedures, performance and loading information must be presented in a manner acceptable to the Authority (does not apply to pistons less than or equal to 6000 lb)	X			
23.1581(c)		Units in the AFM must be the same as those marked on the appropriate instruments and placards	X		X	
23.1581(d)		All AFM operational airspeeds must, unless other wise specified, be presented as indicated airspeeds	X			
23.1581(e)		Provisions must be made for stowing the AFM in a suitable fixed container readily accessible to the pilot	X			
23.1581(f)		Each AFM must contain a means for recording the incorporation of revisions and/or amendments	X			
23.1583		Each AFM must contain operating limitations, including the following:	X	X		
23.1583(a)(1)	23.1545	Information necessary for the marking of airspeed limits as required in §23.1545	X	X		
23.1583(a)(2)		The speeds VMC, VA, VLE and VLO and their significance	X			

23.1583(a)(3)(i)		VMO/MMO and a statement that this speed must not be deliberately exceeded without authorization (for turbine powered commuters)	X			
23.1583(a)(3)(i)		If an airspeed limitation is based on compressibility effects, a statement to this effect, further information and the recommended recovery procedure (for further powered commuters)	X			
23.1583(a)(3)(ii)		The airspeed limits must be shown in terms of VMO/MMO for (turbine powered commuters)	X			
23.1583(b)(1),(2)	23.1521	Powerplant limitations required by § 23.1521 and explanations, when appropriate	X			
23.1583(b)(3)	23.1549-23.1553	Information necessary for marking powerplant instruments required in §23.1549 to §23.1553	X			
23.1583(c)(1)		Maximum weight	X			
23.1583(c)(2)		Maximum landing weight (if less than maximum weight)	X			
23.1583(c)(3)	23.63(c)(1)	MTOW for each airdrome altitude and temperature selected by the applicant at which the airplane complies with §23.63(c)(1) (not for pistons less than 6000 lb and commuters)	X			
23.1583(c)(4)	23.63(d)(1), 23.55,23.59(a) 23.59(b)	For commuter airplanes, the MTOW for each airdrome altitude and temperature selected by the applicant at which the airplane complies with the climb requirements of §23.63(d)(1), the accelerate-stop distance determined in §23.55 is acceptable, the take-off distance determined in §23.59(a) is acceptable and, optionally, the take-off run determined in §23.59(b) is acceptable	X			
23.1583(c)(5)	23.63(d)(2), 23.75,23.343	For commuter airplanes, the maximum landing weight for each airdrome altitude selected by the applicant at which the airplane complies with the climb requirements of §23.63(d)(2), the landing distance determined in §23.75 is acceptable and the maximum zero wing fuel weight established in §23.343	X			
23.1583(d)		The established center of gravity limits	X			
23.1583(e)	23.221(c)	Authorized maneuvers, appropriate airspeed limitations, recommended entry speeds, spin recovery procedures and unauthorized maneuvers according to category	X			
23.1583(f)		Positive limit load factors and, for aerobatic airplanes, the negative limit load factors	X			
23.1583(g)	23.1523	Number and functions of the minimum flight crew	X			
23.1583(h)	23.1525	Lists of kinds of operation according to §23.1525, installed equipment affecting any operating limitation and identification as to equipment's required operational status	X			
23.1583(I)	23.1527	Maximum operating altitude	X			
23.1583(j)		Maximum passenger seating configuration	X			
23.1583(k)		Maximum allowable lateral fuel loading differential, if less than the maximum possible	X			
23.1583(l)		Maximum allowable load and maximum intensity of loading for baggage and cargo compartments or zones	X			
23.1583(m)		Any limitations on the use of airplane systems and equipment	X			
23.1583(n)		Where appropriate, maximum and minimum ambient temperatures for operation	X			

23.1583(o)		Any restrictions on smoking in the airplane	X			
23.1583(p)	23.45(g), 23.1587(a)(5)	Types of surface on which operation may be conducted (see §34.45(g) and §23.1587(a)(5)	X			
23.1585(a)		Information concerning normal, abnormal and emergency procedures and other information necessary for safe operation and achievement of scheduled performance, including	X			
23.1585(a)(1)		Explanation of significant or unusual flight or ground handling characteristics	X			
23.1585(a)(2)		Maximum demonstrated values of crosswind for take-off and landing and associated procedures	X			
23.1585(a)(3)		A recommended speed for flight in rough air	X			
23.1585(a)(4)	23.903(f)	Procedures for restarting any engine in flight, including the effects of altitude	X			
23.1585(a)(5)	23.73, 23.75	Procedures, speeds and configurations for making a normal approach and landing in accordance with §23.73 and §23.75 and transition to the balked landing condition	X			
23.1585(b)	23.71	For all single-engine airplanes, procedures, speeds and configurations for a glide following engine failure and the subsequent forced landing	X			
23.1585(c)(1)		For all twin-engine airplanes, procedures, speeds and configurations for making an approach and landing with one engine inoperative	X			
23.1585(c)(2)		For all twin-engine airplanes, procedures, speeds and configurations for making a go-around with one engine inoperative, the conditions under which it can be performed safely or a warning against attempting a go-around	X			
23.1585(d)(1)	23.51(a),(b) 23.53(a),(b) 23.65,23.69(a)	For all normal, utility and aerobatic airplanes, procedures, speeds and configurations for making a normal take-off (§§23.51(a),(b) 23.53(a),(b)) and subsequent climb (§§23.65, 23.69(a))	X			
23.1585(d)(2)		For all normal, utility and aerobatic airplanes, procedures for abandoning a take-off	X			
23.1585(e)(1)		For all normal, utility and aerobatic twin-engine airplanes, procedures and speeds for continuing a take-off following engine failure, the conditions under which it can be performed safely or a warning against continuing the take-off	X			
23.1585(e)(2)	23.67,23.69(a)	For all normal, utility and aerobatic twin-engine airplanes, procedures and speeds for continuing a climb following engine failure after take-off (§23.67) or en-route (§23.69(b))	X			
23.1585(f)(1)		For commuter category airplanes, procedures, speeds and configurations for making a normal take-off	X			
23.1585(f)(2)	23.55	For commuter category airplanes, procedures and speeds for carrying out an accelerate-stop				
23.1585(F)(3)	23.57, 23.59(a)(1), 23.61(a)	For commuter category airplanes, procedures and speeds for continuing a take-off following engine failure (§23.59(a)(1) and for following the flight path (§§23.57, 23.61(a))	X			
23.1585(g)	23.953	For twin-engine airplanes, information and instructions regarding fuel supply independence	X			

23.1585(h)	23.1353(g)(2), 23.1353(g)(3)	For each airplane showing compliance with §23.1353(g)(2) or (g)(3), the procedures for disconnecting the battery from its charging source	X			
23.1585(i)		Information on the total quantity of usable fuel for each tank and the effect pump failure	X			
23.1585(j)		Procedures for the safe operation of the airplane's systems and equipment, in normal use and in the event of malfunction	X			
23.1587	23.45(b)	Unless other wise presented, performance information must be provided over the altitude and temperature ranges required by §23.45(b)	X			
23.1587(a)(1)	23.49	Stalling speeds V_{SO} and V_{S1} at maximum weight with landing gear and wing flaps retracted and the effect on these stalling speeds of bank angles up to 60^0	X			
23.1587(a)(2)	23.69(a)	Steady rate and gradient of climb with all engines operating	X			
23.1587(a)(3)	23.75	The landing distance for each airdrome altitude and standard temperature and the type of surface for which it is valid	X			
23.1587(a)(4)	23.45(g)	The effect on landing distance of operation on other than smooth hard surfaces, when dry	X			
23.1587(a)(5)		The effect on landing distance of runway slope, 50% of the headwind component and 150% of the tailwind component	X			
23.1587(b)	23.77(a)	For normal, utility and aerobatic piston airplanes of 6000 lb or less, the steady angle of climb/descent	X			
23.1587(c)(1)	23.53	For normal, utility and aerobatic airplanes, the take-off distance and the type of surface for which it is valid	X			
23.1587(c)(2)	23.45(g)	The effect on take-off distance of operation on other than smooth hard surfaces, when dry	X			
23.1587(c)(3)		The effect on take-off distance of runway slope, 50% of the headwind component and 150% of the tailwind component	X			
23.1587(c)(4)	23.66	For twin piston airplanes of more than 6000 lb MTOW and turbine airplanes, the one-engine inoperative take-off climb/descent gradient	X			
23.1587(c)(5)	23.69(b)	For twin-engine airplanes, the en-route rate and gradient of climb/descent with one-engine inoperative	X			
23.1587(c)(6)	23.71	For single-engine airplanes, the glide performance	X			
23.1587(d)(1)	23.55	For commuter airplanes, the accelerate-stop distance	X			
23.1587(d)(2)	23.59(a)	For commuter airplanes, the take-off distance	X			
23.1587(d)(3)	23.59(b)	For commuter airplanes, the take-off run at the applicant's option	X			
23.1587(d)(4)	23.45(g)	For commuter airplanes, the effect on accelerate-stop distance, take-off distance and, if determined, take-off run of operation on other than smooth hard surfaces, when dry	X			

23.1587(d)(5)		For commuter airplanes, the effect on accelerate-stop distance, take-off distance and, if determined, take-off run of runway slope, 50% of the headwind component and 150% of the tailwind component	X			
23.1587(d)(6)	23.61(b)	For commuter airplanes, the net take-off path	X			
23.1587(d)(7)	23.69(b)	For commuter airplanes, the en-route gradient of climb/descent with one engine inoperative	X			
23.1587(d)(8)		For commuter airplanes, the effect on the net take-off path and the en-route gradient of climb/descent with one engine inoperative, of 50% of the headwind component and 150% of the tailwind component	X			
23.1587(d)(9)	23.63(d)(2), 75	For commuter airplanes, overweight landing performance information (the maximum weight at which the airplane complies with §23.63(d)(2) and the landing distance in §23.75)	X			
23.1587(d)(10)	23.1323(b),(c)	For commuter airplanes, the relationship between IAS and CAS	X			
23.1587(d)(11)	23.1325(e)	For commuter airplanes, the altimeter system calibration	X			
23.1587(d)(7)	23.69(b)	For commuter airplanes, the en-route gradient of climb/descent with one engine inoperative	X			
23.1589(a)	23.25	The weight and location of each item of equipment that can be easily removed and was installed when the airplane was weighed	X			
23.1589(b)	23.23, 23.25	Appropriate loading instructions for each permissible loading condition of weight and cg	X			
App. G23-2,3,4	23.1529	Instructions for continued airworthiness	X			

Appendix 5 –Guide for Preparing Airplane Flight Manual and Pilots's Operating Handbook Supplements

1. Introduction. An applicant is responsible for preparing an Airplane Flight Manual (AFM) supplement when the airplane has been modified in such a manner that limitation, procedures, performance, or loading information have changed. The supplement should be prepared to reflect this supplemental information. If there is no change in one of the sections, it should so state.

a. Pilot's Operating Handbook Supplements. Refer to GAMA Specification No. 1, Revision No. 1.

b. AFM Supplements. Refer to paragraph 2 below and sample AFM.

2. General.

a. Enter name and address of applicant and document number (if used).

b. Enter make and model of the airplane. Multiple models may be used.

c. Enter registration number. **Note:** If more than one airplane is to be approved under this supplemental type certificate, leave this space blank on the master copy of the supplement so it can be filled in for each airplane as the modification is accomplished.

d. Enter airplane serial number. This number is on the airplane data plate. **Note:** If more than one airplane is to be approved under this supplemental type certificate, leave this space blank on the master copy of the supplement so it can be filled in for each airplane as the modification is accomplished. If only one airplane is to be approved, add "only" after the serial number.

e. Enter original AFM date or reissue date (if applicable).

f. Enter the type of modification or equipment installed.

g. Enter approval basis such as: Form 337, specification item number, Supplemental type Certificate Number, and so forth.

h. Enter any changed or additional limitations as a result of the modification. Follow the format of the basic AFM. If no change, state "NO CHANGE".

i. Enter any change in or additional procedures as a result of the modification. Follow the format of the basic AFM. This section may be divided into Normal and Emergency Procedures, if necessary. If no change, state "NO CHANGE".

j. Enter any change in performance as a result of the modification. If no change, state "NO CHANGE". In some cases, it is possible to show a statement similar to the following. "The performance of this airplane equipped with the Continental E-225-8 engine and Beech Model 215 propeller is equal to or better than the performance as listed in the original FAA-approved AFM."

k. Enter any change in the loading instructions, if necessitated by the change.

l. Copy this item, as shown on the sample AFM Supplement, leaving a blank space for typing of the ACO Manager's name below the signature line. This item needs to be coordinated with the ACO prior to submitting because in some ACO's the manager does not sign the AFM.

m. Type as shown on sample AFM Supplement, leaving a blank space so date of approval can be added.

n. If the supplement requires more than one page, a cover page should be prepared in accordance with page 3 of this appendix, except that items (h), (u), (j), and (k) should be on page 2 or subsequent. Each page should have: (1) the name and address of applicant and document number; (2) AFM supplement for Make and Model; (3) "FAA-approved" and "date" of approval; and (4) page number as (Page 1 of 3).

o. For those airplanes without flight manuals, and placards are not appropriate, the document should be labeled a Supplemental Airplane Flight Manual and arranged and worded as necessary with reference to the appropriate markings and placards. Identification of the material as Limitations, Procedures, or Performance should be clearly presented.

p. If applicant revises the AFM supplements, pertaining to one airplane model, a log of revisions may be added, as follows: (This revision log also needs a signature block.)

LOG OF REVISIONS

Revision No.	Pages Affected	Description	FAA-Approved	Date

Note: The revision page should immediately follow the cover page.

q. Vertical bars should be placed in the margin of the revised pages to indicate changed material.

Name ____ (a)

Address ____

Supplement No.____

FAA-APPROVED

AIRPLANE FLIGHT MANUAL SUPPLEMENT

FOR

__________(b) ________
Make and Model Airplane

Reg. No.______(c)_____

Ser. No._______(d)_____

This supplement must be attached to the FAA- approved Airplane Flight Manual dated __(e)____when (f)___________ is installed in accordance with _____________(g)__________. The information contained in this document supplements or supersedes the basic manual only in those areas listed. For limitations, procedures, performance, and loading information not contained in this supplement, consult the basic Airplane Flight Manual.

I. LIMITATION: (h)

II. PROCEDURES: (i)

III. PERFORMANCE: (j)

IV. LOADING INFORMATION: (k)

FAA-Approved _____________(1)___________

Manager, Aircraft Certification Office
Federal Aviation Administration
City, State

DATE _______(m)__________

Revised____________________
(If applicable)

Page 1 of ___(n)________

Appendix 6. Sample Kinds of Operating Equipment List

This airplane may be operated in day or night VFR, day or night IFR, and known or forecast icing conditions when the appropriate equipment is installed and operable.

The following equipment list identifies the systems and equipment upon which type certification for each kind of operation was predicated. The following systems and items of equipment must be installed and operable for the particular kind of operation indicated.

The ATA numbers refer to equipment classifications of Air Transport Association Specification Code 100.

	VFR Day				
		VFR Night			
			IFR Day		
				IFR Night	
					Icing Conditions
Communications (ATA-23)					
1. Communication Radio (VHF)	0	0	1	1	1
Electrical Power (ATA-24)					
1. Battery	1	1	1	1	1
2. D.C. Generator	2	2	2	2	2
3. D.C. Loadmeter	2	2	2	2	2
4. D.C. Generator Warning Light	2	2	2	2	2
5. Inverter	2	2	2	2	2
6. Inverter Warning Light	1	1	1	1	1
7. Feeder Limiter Warning Light	1	1	1	1	1
8. Battery Monitor system	1	1	1	1	1
9. AC Volt Meter	1	1	1	1	1
Equipment/Furnishings (ATA-25)					
1. Exit Signs - Self-Illuminated	4	4	4	4	4
Fire Protection (ATA-26)					
1. Engine Fire Detector System	2	2	2	2	2
2. Firewall Fuel Shutoff System	2	2	2	2	2

	VFR Day				
		VFR Night			
			IFR Day		
				IFR Night	
					Icing Condition
Flight Controls (ATA-27)					
. Flap System	1	1	1	1	1
2. Flap Position Indicator	1	1	1	1	1
3. Horizontal Stabilizer Trim System – Main	1	1	1	1	1
4. Horizontal Stabilizer Trim System – Standby	1	1	1	1	1
5. Stabilizer out-of-trim Aural Warning Indicator	1	1	1	1	1
6. Trim-in-Motion Aural Indicator	1	1	1	1	1
7. Horizontal Stabilizer Position Indicator	1	1	1	1	1
8. Stall Warning Horn	1	1	1	1	1
9. Trim Tab Indicator – Rudder	1	1	1	1	1
10.Trim Tab Indicator Aileron	1	1	1	1	1
Fuel (ATA-28)					
1. Fuel Boost Pumps (4 are installed)	PER	AFM	Limitations		
2. Fuel Quantity Indicator	2	2	2	2	2
3. Fuel Quantity Gauge Selector Switch	1	1	1	1	1
4. Nacelle Not-Full Warning Light	2	2	2	2	2
5. Crossfeed Light	1	1	1	1	1
6. Fuel Boost Pump Low Pressure Warning Light	2	2	2	2	2
7. Fuel Flow Indicator	2	2	2	2	2
8. Jet Transfer Pump	2	2	2	2	2
Ice and Rain Protection (ATA-30)					
1. Engine Inlet Scoop Deicer Boot	2	2	2	2	2
2. Indicator – Propeller/Inlet Deicer	1	1	1	1	1
3. Engine Inertial Anti-Icing System	2	2	2	2	2
4. Pitot Heat	0	0	2	2	2
5. Alternate Static Air Source	0	0	1	1	1
6. Engine Auto-Ignition System (if installed)	2	2	2	2	2
7. Propeller Deicer System	0	0	0	0	1
8. Windshield Heat (Left)	0	0	0	0	1
9. Surface Deicer System	0	0	0	0	1
10. Stall Warning Mounting Plate Heater	0	0	0	0	1
11. Wing Ice Light (Left)	0	0	0	0	1
12. Windshield Wiper (Left)	1	1	1	1	1

	VFR Day	VFR Night	IFR Day	IFR Night	Icing Condition
Instruments (ATA-31)					
1. Clock	0	0	1	1	1
Landing Gear (ATA-32)					
1. Landing Gear Position Indicator Lights	3	3	3	3	3
2. Flap-Controlled Landing Gear Aural Warning	1	1	1	1	1
3. Nose Steering Disconnect Actuator	1	1	1	1	1
4. Landing Gear Hydraulic Pump	1	1	1	1	1
Lights (ATA-33)					
1. Cockpit and Instrument (Required Illumination)	0	1	0	1	0
2. Anti-Collision	0	2	0	2	0
3. Landing Light	0	2	0	2	0
4. Position Lights	0	3	0	3	0
5. Cabin Door Warning Light (Note)	1	1	1	1	1
6. Baggage Door Warning Light (Note)	1	1	1	1	1
Note: Where combined into one cabin/baggage annunciator – one (1) is required for all conditions.					
Navigation (ATA-34)					
1. Altimeter	1	1	1	1	1
2. Airspeed	1	1	1	1	1
3. Magnetic Compass	1	1	1	1	1
4. Outside Air Temperature	1	1	1	1	1
5. Attitude Indicator (Gyro stabilized)	0	0	1	1	1
6. Directional Indicator (Gyro stabilized)	0	0	1	1	1
7. Sensitive Altimeter	0	0	1	1	1
8. Turn and Bank Indicator or Turn Coordinator	0	0	1	1	1
9. Vertical Speed Indicator	0	0	1	1	1
10. Navigation Radio (VHF)	0	0	1	1	1
Vacuum System					
1. Suction or Pressure Gauge	1	1	1	1	1
2. Instrument Air System	1	1	1	1	1

	VFR Day	VFR Night	IFR Day	IFR Night	Icing Conditions
Propeller (ATA-61)					
1. Autofeather System	2	2	2	2	2
2. Low Pitch Light	2	2	2	2	2
3. Do Not Reverse Warning Light	1	1	1	1	1
. Propeller Reversing	2	2	2	2	2
Engine Indicating (ATA-77)					
1. Tachometer Indicator (Propeller)	2	2	2	2	2
2. Tachometer Indicator (Gas Generator)	2	2	2	2	2
3. ITT Indicator	2	2	2	2	2
4. Torque Indicator	2	2	2	2	2
Engine Oil (ATA-79)					
1. Oil Temperature Indicator	2	2	2	2	2
2. Oil Pressure Indicator	2	2	2	2	2
3. Low Oil Pressure Light	2	2	2	2	2
4. Engine Chip Detector System	2	2	2	2	2

Note 1: The zeros (0) used in the above list mean that either the equipment or system, or both were not required for type certification for that kind of operation.

Note 2: The above system and equipment list is predicated on a crew of one pilot.

Note 3: Either equipment or systems in addition to those listed above may be required by the operating regulations.

Note 4: Further information may be drawn from an approved Minimum Equipment List (MEL), if applicable.

Appendix 7. Useful Information

Figure A7-1 – U.S. Standard Atmosphere (1962)

Geopotential Altitude h ft	Temp. °F	Temp. T °R	°C	Temp. Ratio θ	Press. p psi	Press. Ratio δ	Density ρ slug/ft³	Density Ratio σ	Speed of Sound V_a ft/sec
0	59.0	518.7	15.0	1.000	14.70	1.000	2.3768×10^{-3}	1.000	1116.4
1000	55.4	515.1	13.0	.9932	14.17	.9644	2.3081	.97106	1112.6
2000	51.9	511.5	11.0	.9863	13.66	.9298	2.2409	.94277	1108.7
3000	48.3	508.0	9.1	.9794	13.17	.8962	2.1751	.91512	1104.9
4000	44.7	504.4	7.1	.9725	12.69	.8637	2.1109	.88809	1101.0
5000	41.2	500.8	5.1	.9657	12.23	.8320	2.0481	.86167	1097.1
6000	37.6	497.3	3.1	.9588	11.78	.8014	1.9868	.83586	1093.2
7000	34.0	493.7	1.1	.9519	11.34	.7716	1.9268	.81064	1089.2
8000	30.5	490.1	−0.9	.9450	10.92	.7428	1.8683	.78602	1085.3
9000	26.9	486.6	−2.8	.9382	10.50	.7148	1.8111	.76196	1081.4
10000	23.3	483.0	−4.8	.9313	10.11	.6877	1.7553	.73848	1077.4
11000	19.8	479.4	−6.8	.9244	9.720	.6614	1.7008	.71555	1073.4
12000	16.2	475.9	−8.8	.9175	9.346	.6360	1.6476	.69317	1069.4
13000	12.6	472.3	−10.8	.9107	8.984	.6113	1.5957	.67133	1065.4
14000	9.1	468.7	−12.7	.9038	8.633	.5875	1.5451	.65003	1061.4
15000	5.5	465.2	−14.7	.8969	8.294	.5643	1.4956	.62924	1057.3
16000	1.9	461.6	−16.7	.8900	7.965	.5420	1.4474	.60896	1053.2
17000	−1.6	458.0	−18.7	.8831	7.647	.5203	1.4004	.58919	1049.2
18000	−5.2	454.5	−20.7	.8763	7.339	.4994	1.3546	.56991	1045.1
19000	−8.8	450.9	−22.6	.8694	7.041	.4791	1.3100	.55112	1041.0
20000	−12.3	447.3	−24.6	.8625	6.754	.4595	1.2664	.53281	1036.8
21000	−15.9	443.8	−26.6	.8556	6.475	.4406	1.2240	.51497	1032.7
22000	−19.5	440.2	−28.6	.8488	6.207	.4223	1.1827	.49758	1028.5
23000	−23.0	436.6	−30.6	.8419	5.947	.4046	1.1425	.48065	1024.4
24000	−26.6	433.1	−32.5	.8350	5.696	.3876	1.1033	.46417	1020.2
25000	−30.2	429.5	−34.5	.8281	5.454	.3711	1.0651	.44812	1016.0

Figure A7-1 – U.S. Standard Atmosphere (1962) (Continued)

Geopotential Altitude h ft	Temp. T °F	°R	°C	Temp. Ratio θ	Press. p psi	Press. Ratio δ	Density ρ slug/ft³	Density Ratio σ	Speed of Sound V_a ft/sec
26000	-33.7	426.0	-36.6	.8213	5.220	.3552	1.0280	.43250	1011.7
27000	-37.3	422.4	-38.5	.8144	4.994	.3398	.9919	.41730	1007.5
28000	-40.9	418.8	-40.5	.8075	4.777	.3250	.9567	.40251	1003.2
29000	-44.4	415.3	-42.5	.8006	4.567	.3107	.9225	.38812	999.0
30000	-48.0	411.7	-44.4	.7938	4.364	.2970	.8893	.37413	994.7
31000	-51.6	408.1	-46.4	.7869	4.169	.2837	.8569	.36053	990.3
32000	-55.1	404.6	-48.4	.7800	3.981	.2709	.8255	.34731	986.0
33000	-58.7	401.0	-50.4	.7731	3.800	.2586	.7950	.33447	981.6
34000	-62.2	397.4	-52.4	.7663	3.626	.2467	.7653	.32199	977.3
35000	-65.8	393.9	-54.3	.7594	3.458	.2353	.7365	.30987	972.9
36000	-69.4	390.3	-56.4	.7525	3.297	.2243	.7086	.29811	968.5
37000	-69.7	390.0	-56.5	.7519	3.142	.2138	.6759	.28435	968.1
38000	-69.7	390.0	-56.5	.7519	2.994	.2038	.6442	.27101	968.1
39000	-69.7	390.0	-56.5	.7519	2.854	.1942	.6139	.25829	968.1
40000	-69.7	390.0	-56.5	.7519	2.720	.1851	.5851	.24617	968.1
41000	-69.7	390.0	-56.5	.7519	2.592	.1764	.5577	.23462	968.1
42000	-69.7	390.0	-56.5	.7519	2.471	.1681	.5315	.22361	968.1
43000	-69.7	390.0	-56.5	.7519	2.355	.1602	.5065	.21311	968.1
44000	-69.7	390.0	-56.5	.7519	2.244	.1527	.4828	.20311	968.1
45000	-69.7	390.0	-56.5	.7519	2.139	.1455	.4601	.19358	968.1
46000	-69.7	390.0	-56.5	.7519	2.039	.1387	.4385	.18450	968.1
47000	-69.7	390.0	-56.5	.7519	1.943	.1322	.4180	.17584	968.1
48000	-69.7	390.0	-56.5	.7519	1.852	.1260	.3983	.16759	968.1
49000	-69.7	390.0	-56.5	.7519	1.765	.1201	.3796	.15972	968.1
50000	-69.7	390.0	-56.5	.7519	1.682	.1145	.3618	.15223	968.1

°Rankine = °F + 459.7°
°Kelvin = °C + 273.2°

Figure A7-2 – Temperature Conversion Chart

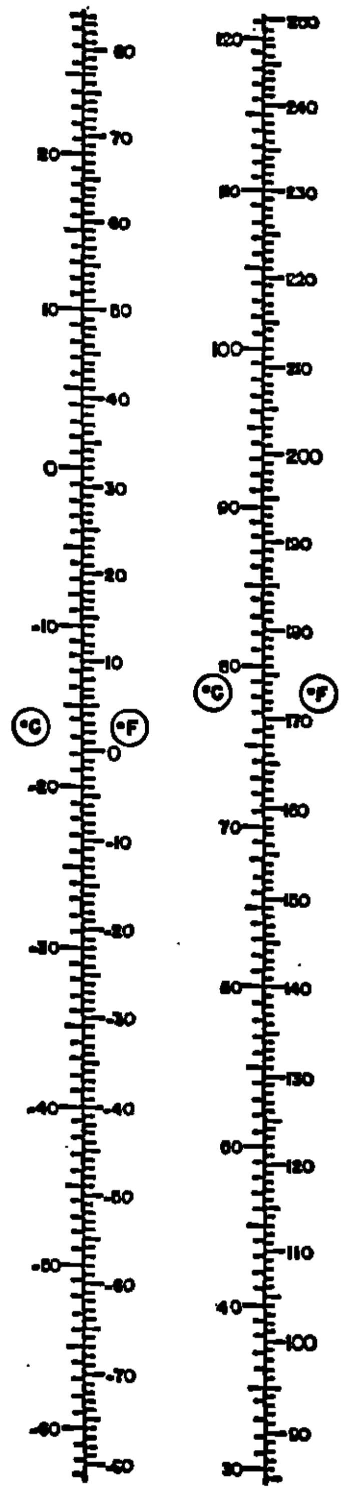


Figure A7-3 – Determination of Air Temperature in Relation to International Standard Atmosphere

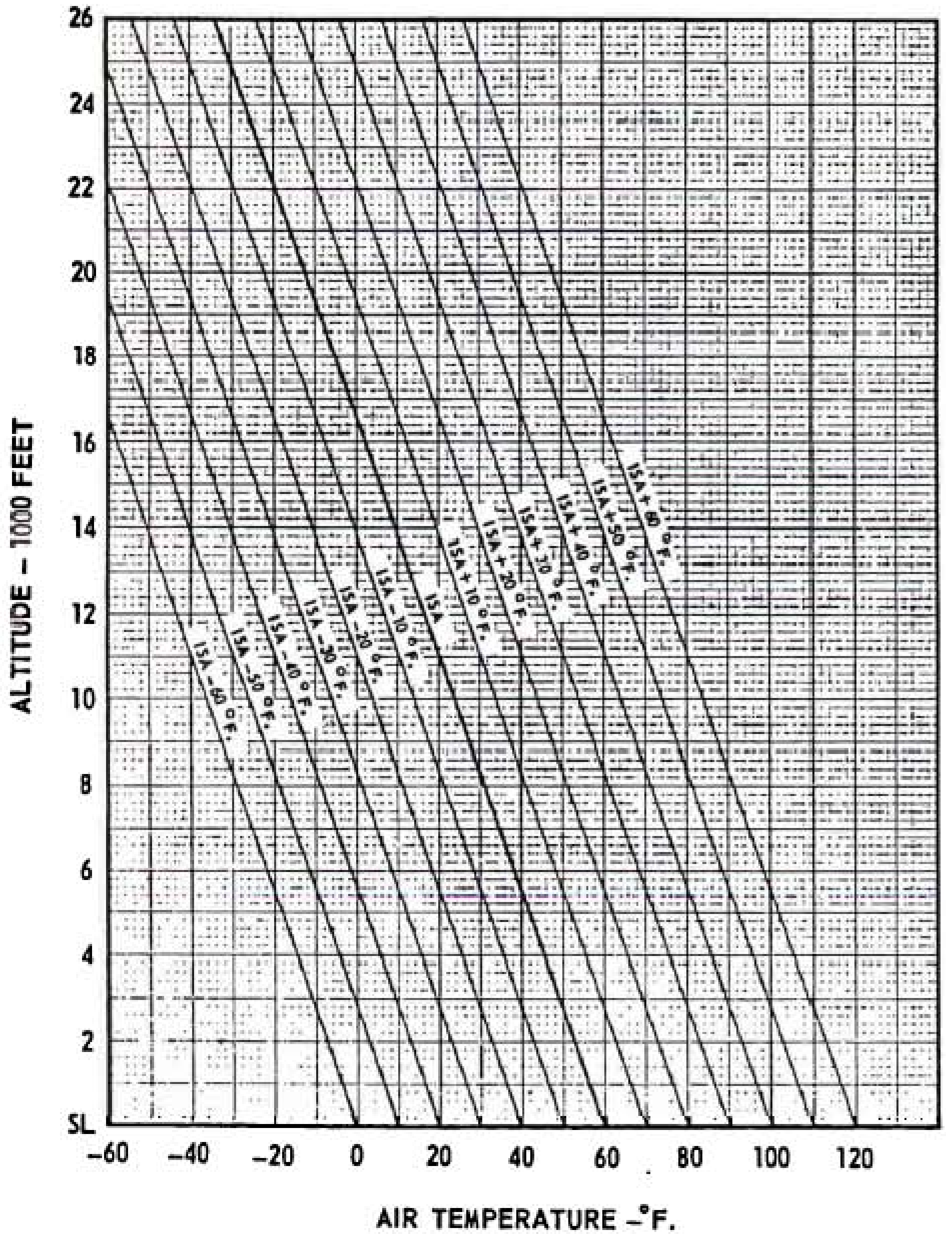
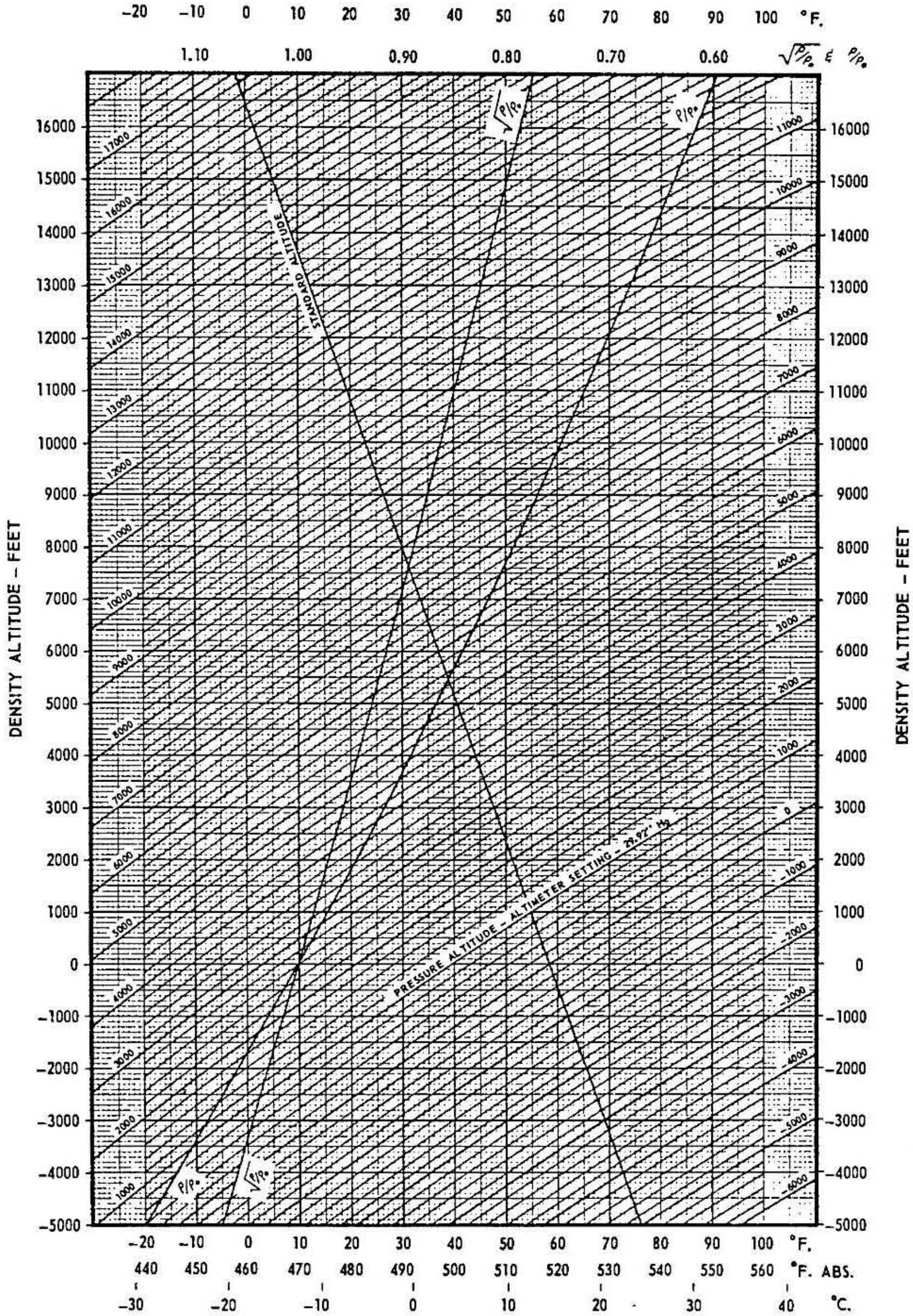


Figure A7-4 – Density/Pressure Altitude Conversion



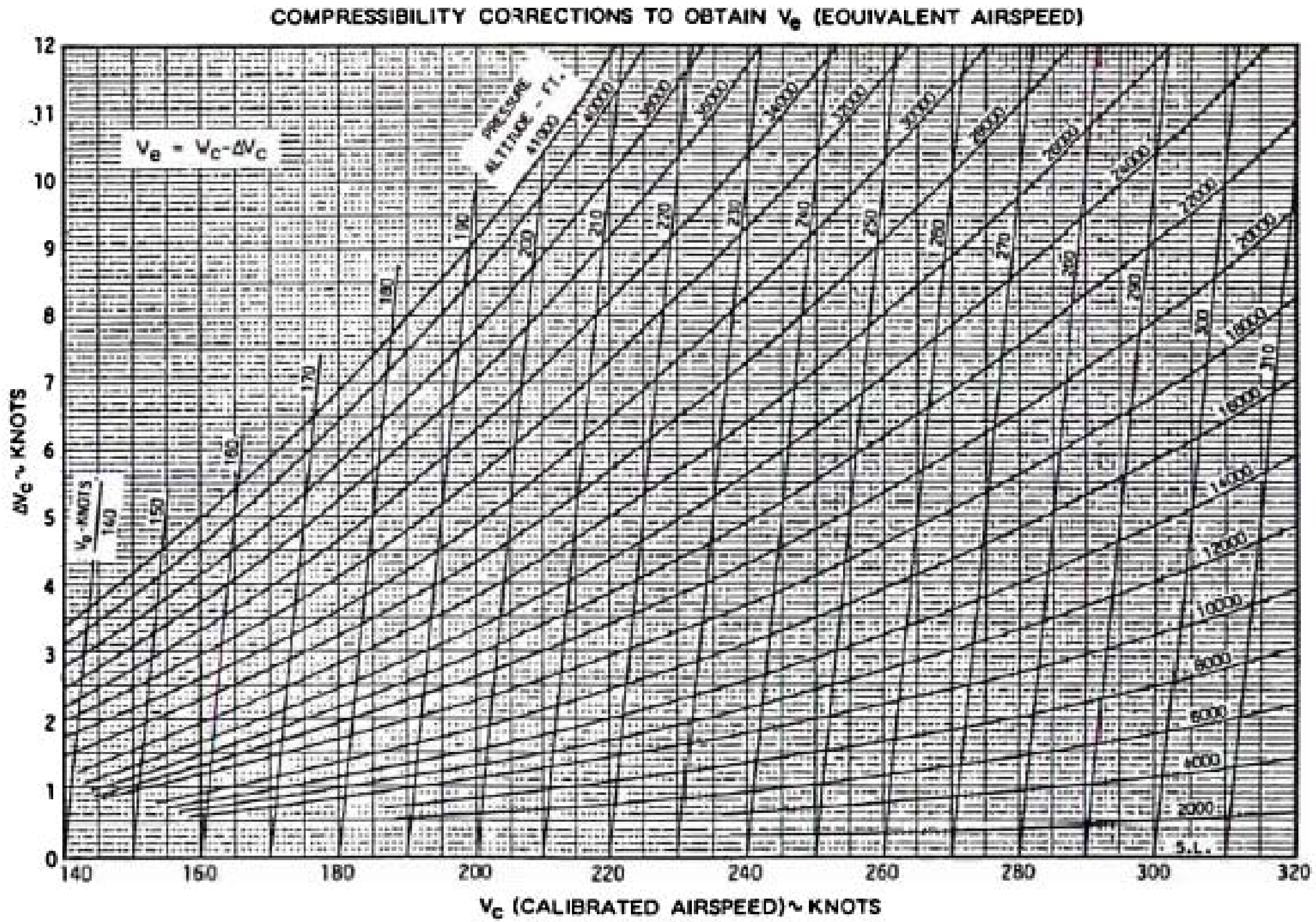


Figure A7-5 – Compressibility Correction CAS

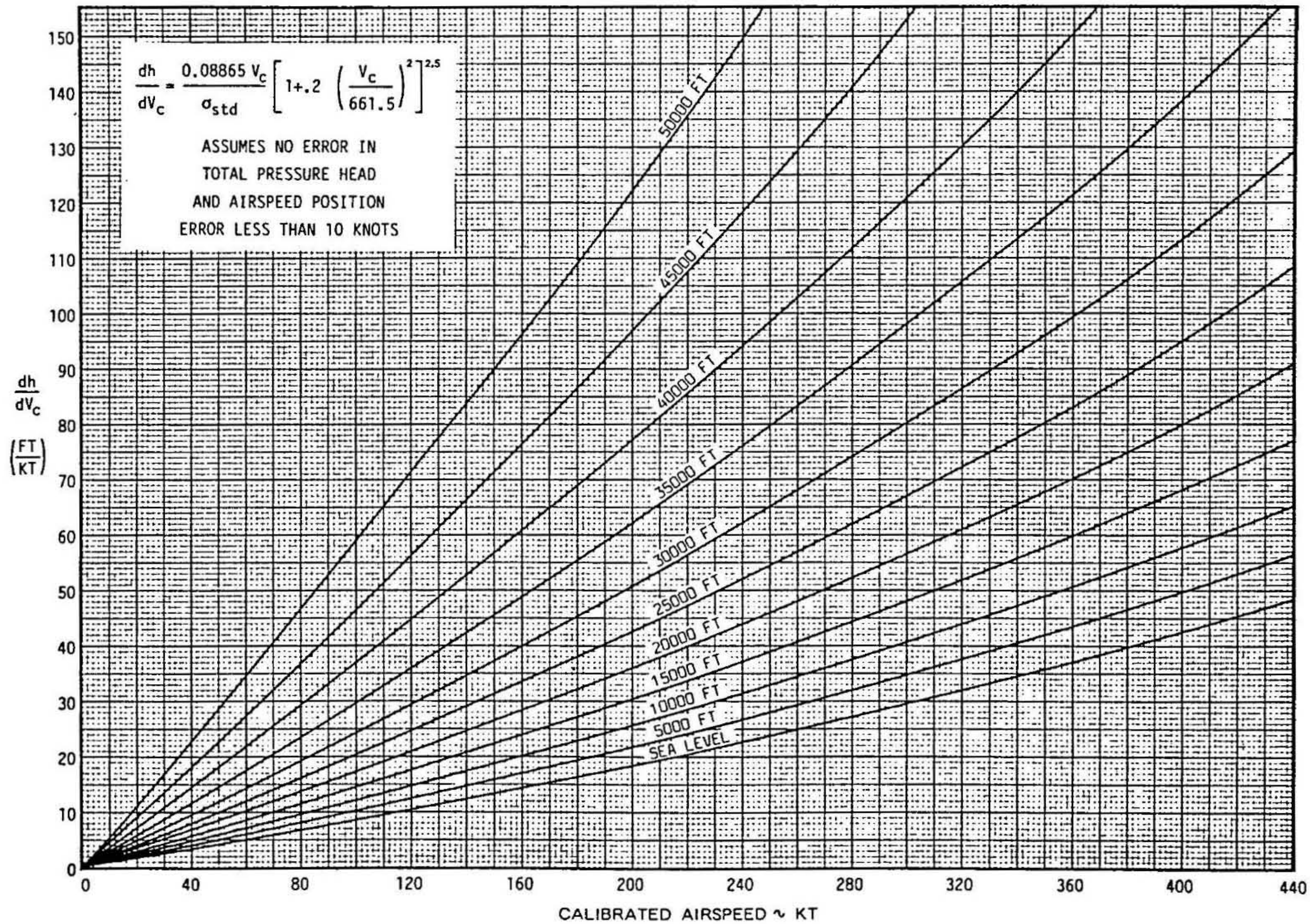


Figure A7-6 – Altimeter Error vs. CAS

$$\frac{\text{Indicated Temp. (°K)}}{\text{Outside Air Temp. (°K)}} = 1 + (\text{recovery factor}) \frac{\text{mach number}^2}{5}$$

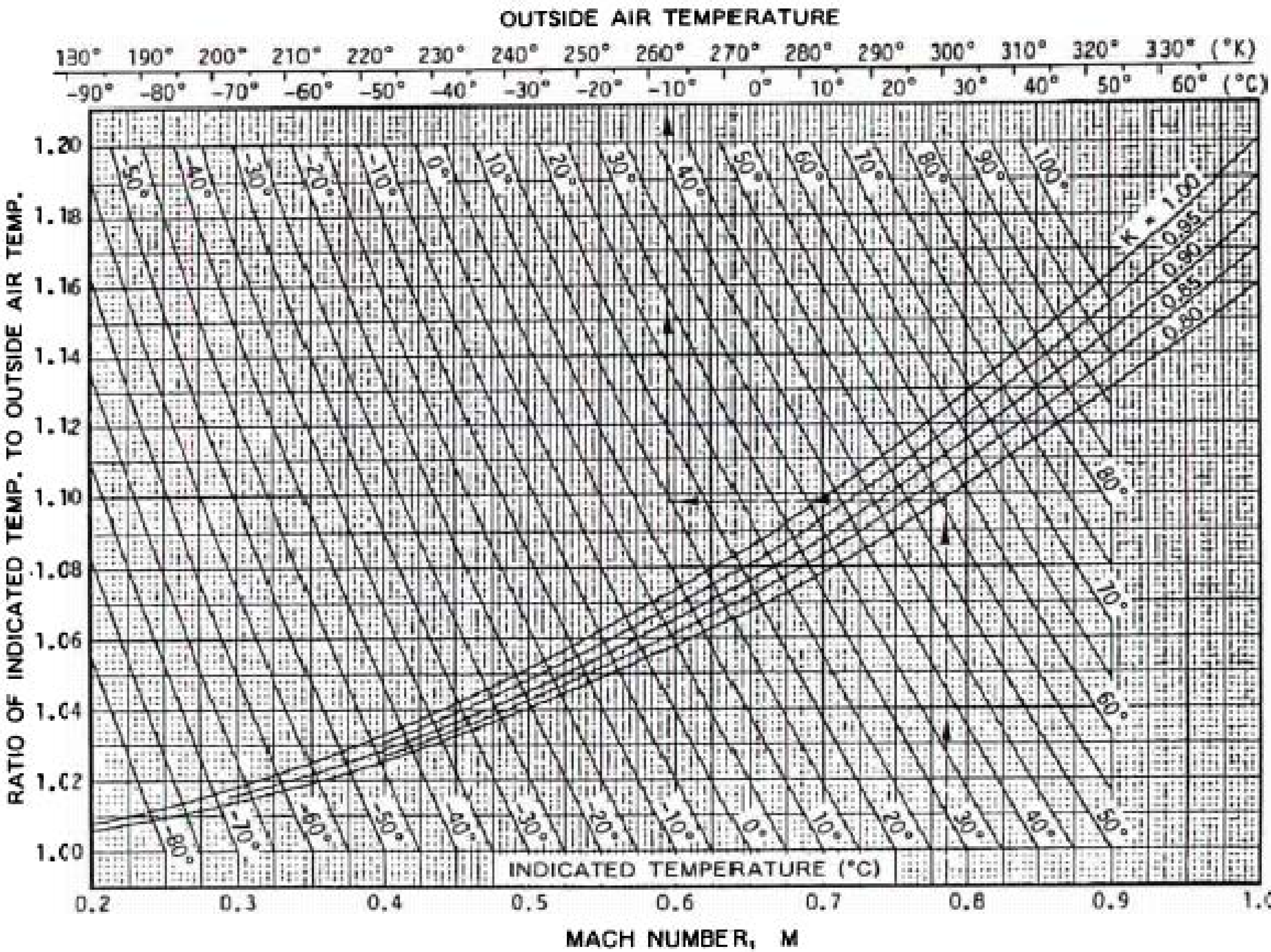


Figure A7-7 – Temperature RAM Rise

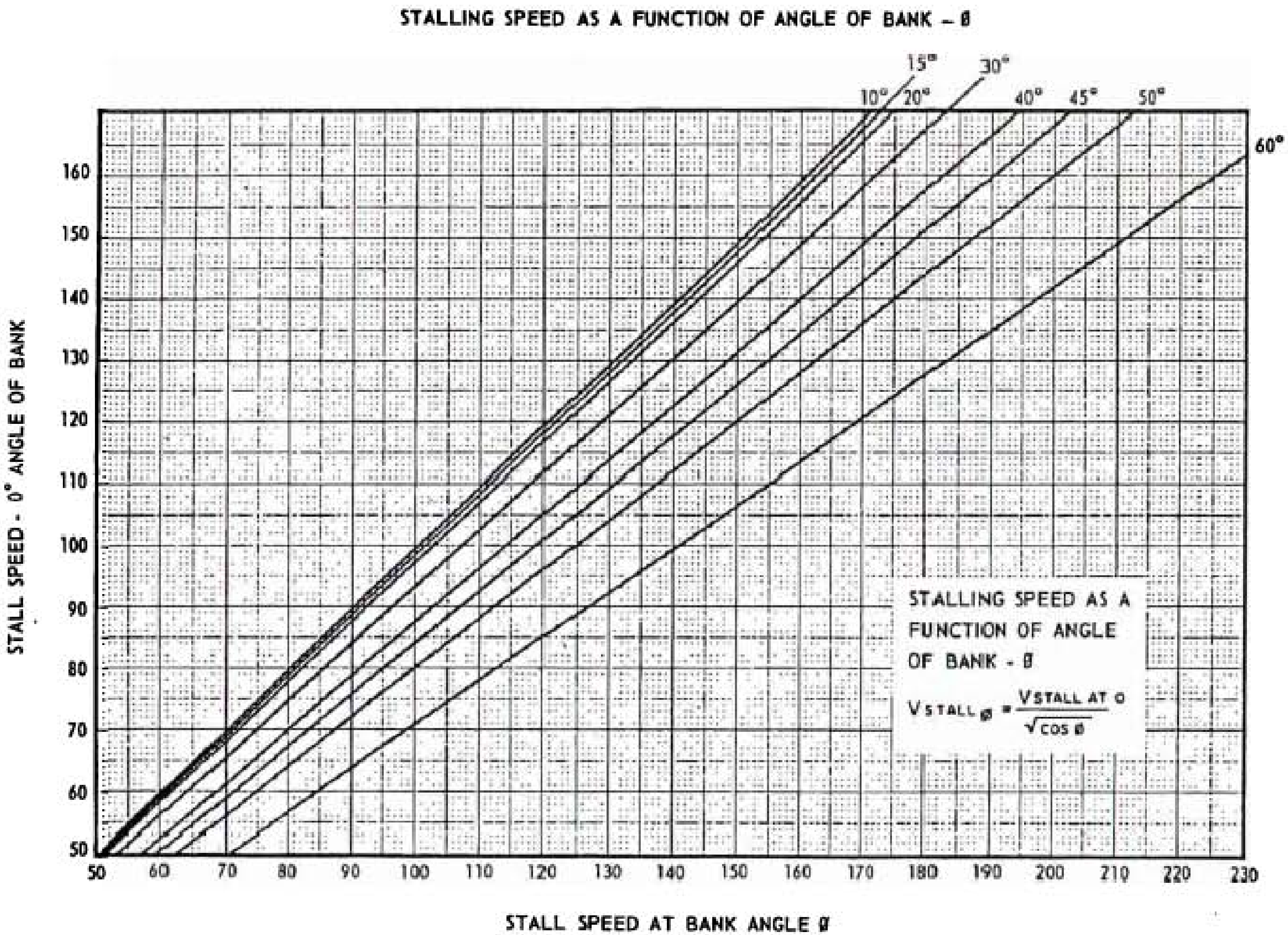


Figure A7-8 – Stalling Speed as a Function of Angle of Bank

Figure A7-9 – Vectoral Acceleration Versus Angle of Bank

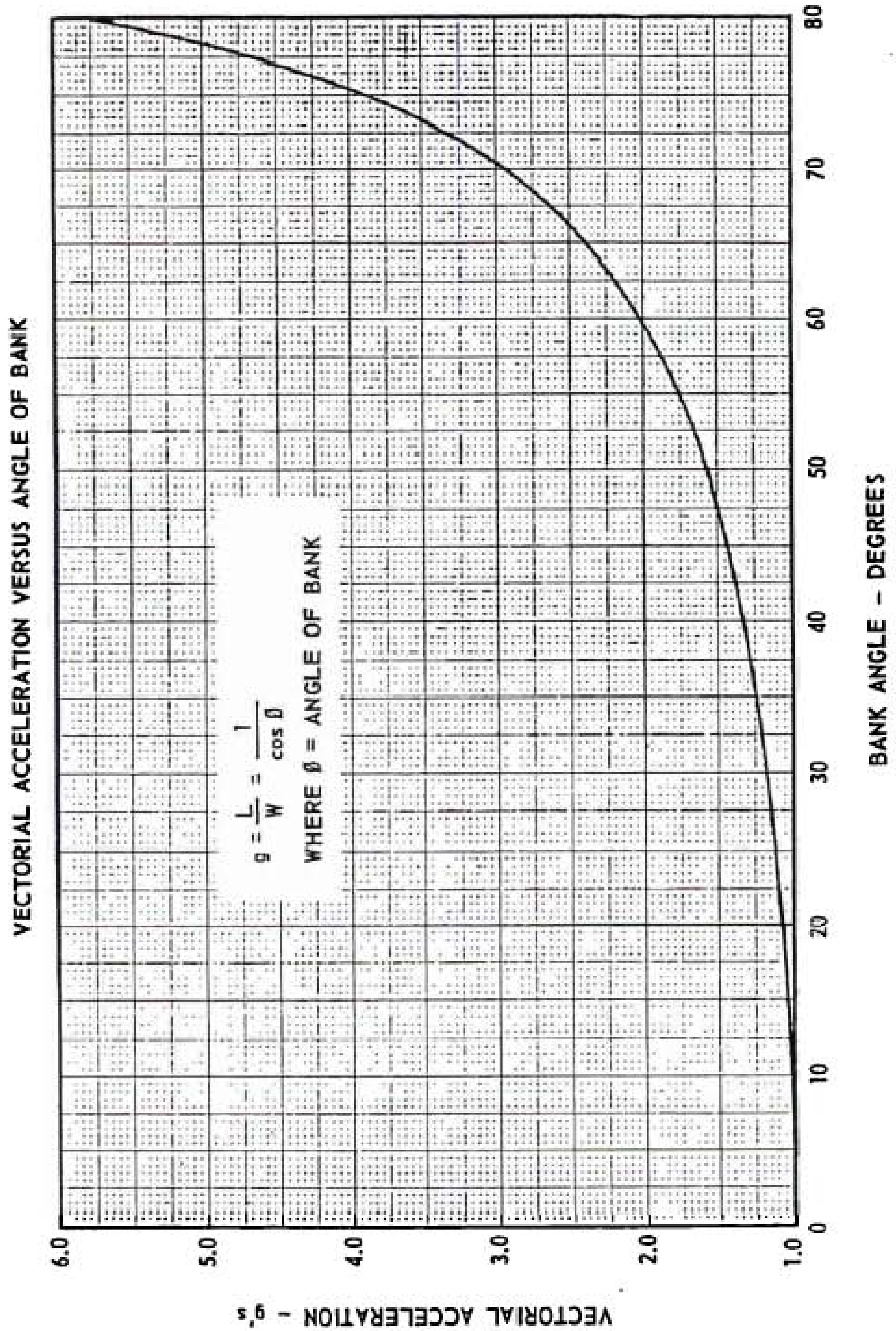


Figure A7-10

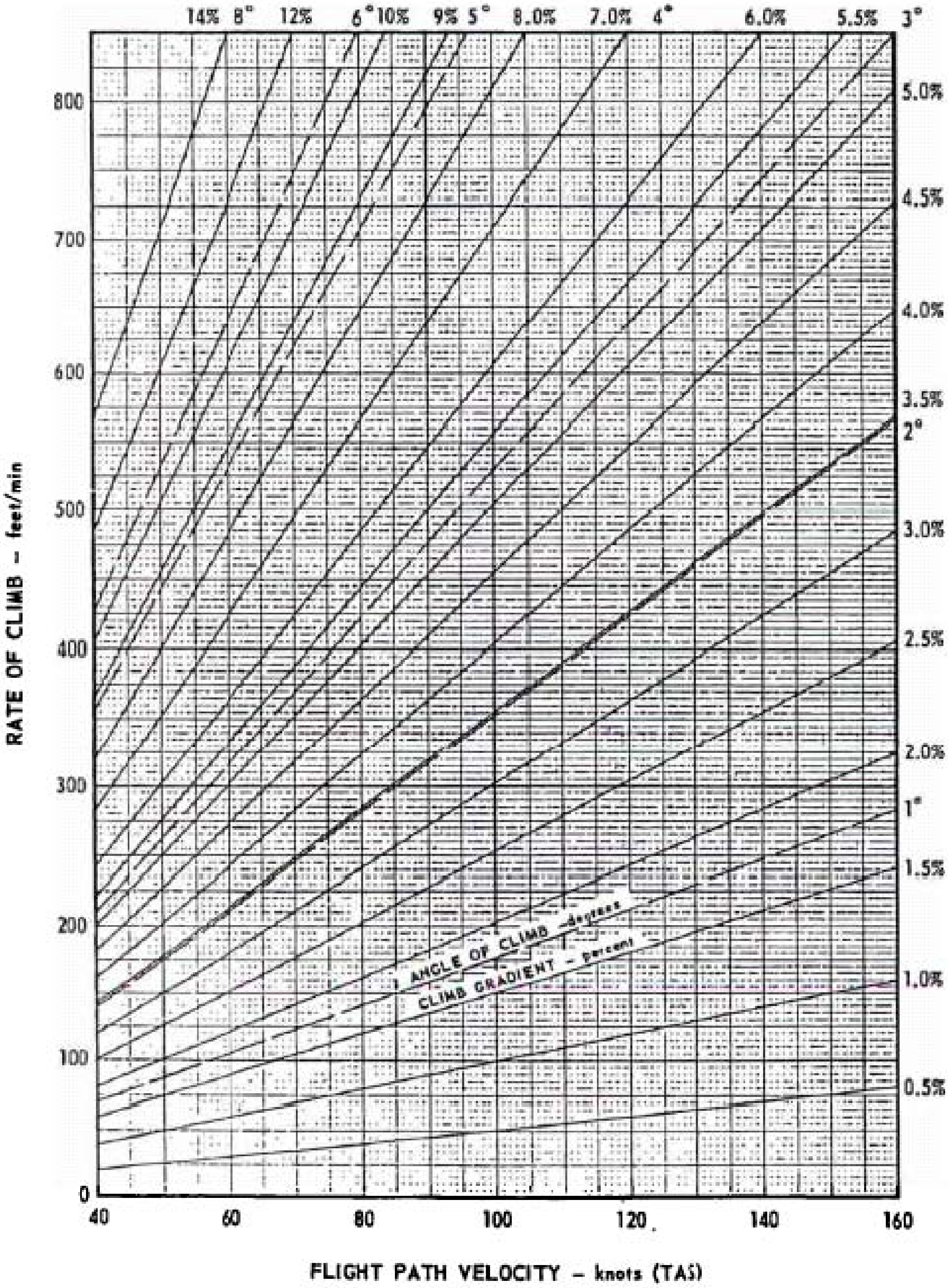

14% 8° 12% 6° 10% 9% 5° 8.0% 7.0% 4° 6.0% 5.5% 3°
5.0%
4.5%
4.0%
3.5%
2°
3.0%
2.5%
2.0%
1°
1.5%
1.0%
0.5%
800
700
600
500
400
300
200
100
0
40
60
80
100
120
140
160
RATE OF CLIMB – feet/min
FLIGHT PATH VELOCITY – knots (TAS)
ANGLE OF CLIMB – degrees
CLIMB GRADIENT – percent

Figure A7-10 (continued)

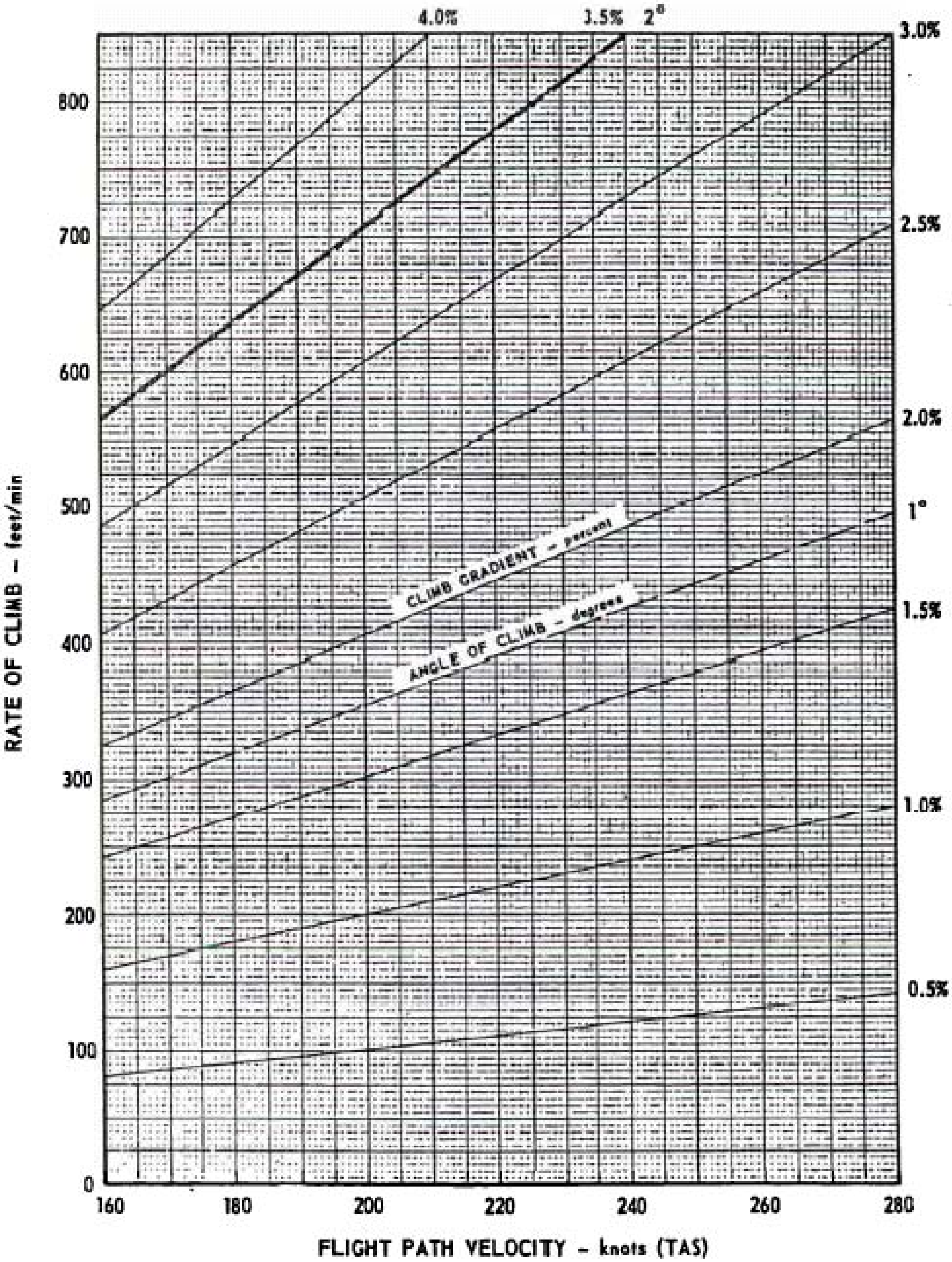
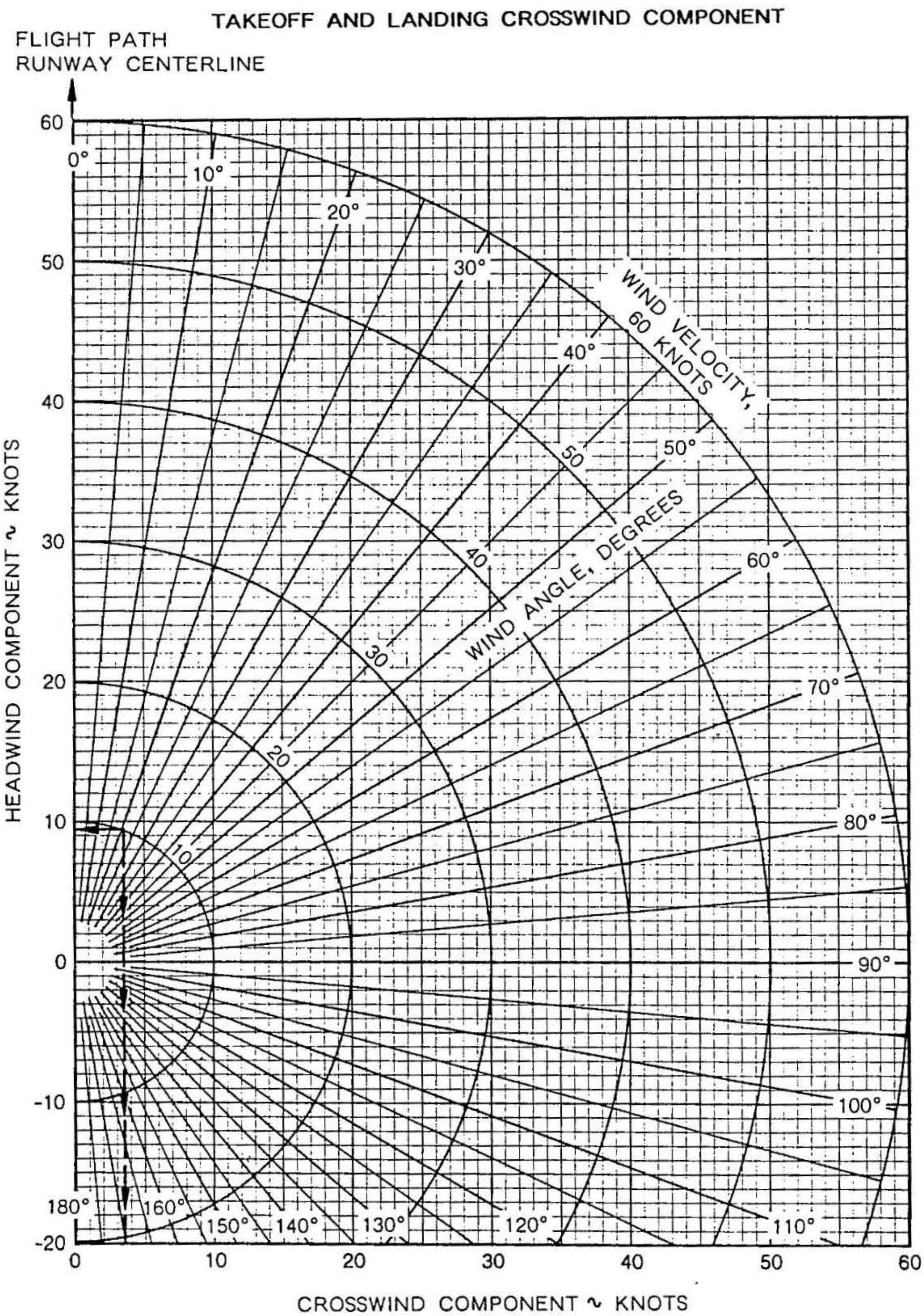


Figure A7-11 – Takeoff and Landing Crosswind Component Chart



Appendix 8. Conversion Factors Table

LENGTH

Multiply	By	To Obtain
Centimetres	0.3937	Inches
	0.03281	Feet
	.01	Meters
Kilometres	3281	Feet
	0.6214	Miles
	0.5399	Nautical Miles
	1093.6	Yards
Meters	39.37	Inches
	3.281	Feet
	1.0936	Yards
Statute Miles	5280	Feet
	0.8690	Nautical Miles
	1760	Yards
Nautical Miles	6076.1	Feet
	1.1508	Statute Miles

WEIGHT

Multiply	By	To Obtain
Grams	0.03527	Ounces (advp)
	0.002205	Pounds (advp)
	1000	Milligrams
	0.001	Kilograms
Kilograms	2.205	Pounds (advp)
	35.27	Ounces (advp)
	1000	Grams
Pounds (advp)	7000	Grains
	16.0	Ounces
	1.215	Pounds (troy)

VOLUME

Multiply	By	To Obtain
Cubic Centimetres	10^{-3}	Litres
	0.0610	Cubic Inches
Cubic Feet	28317	Cubic Centimeters
	1728	Cubic Inches
	0.03704	Cubic Yards
	7.4805	Gallons (U.S.)
	28.32	Litres
Cubic Inches	4.329×10^{-3}	Gallons (U.S.)
	0.01732	Quarts (U.S.)
	0.0164	Litres
Cubic Meters	61023	Cubic Inches
	35.31	Cubic Feet
	264.17	Gallons (U.S.)
	1.308	Cubic Yards
Gallons Imperial	277.4	Cubic Inches
	1.201	Gallons (U.S.)
	4.546	Litres
Gallons, U.S.	231	Cubic Inches
	0.1337	Cubic Feet
	3.785	Litres
	0.8327	Imperial Gallons
	128	Fluid Ounces
Fluid Ounces	29.59	Cubic Centimeters
	1.805	Cubic Inches
Litres	61.02	Cubic Inches
	0.2642	Gallons (U.S.)
	1.057	Quarts (U.S.)

AREA

Multiply	By	To Obtain
Square Centimetres	0.1550	Square Inches
	0.001076	Square Feet
Square Feet	144	Square Inches
	0.1111	Square Yards
Square Inches	645.16	Square Millimeters
Square Kilometres	0.3861	Square Statute Miles
Square Meters	10.76	Square Feet
	1.196	Square Yards
Square Statute Miles	2.590	Square Kilometers

VELOCITY

Multiply	By	To Obtain
Feet per Minute	0.01136	Miles Per Hour
	0.01829	Kilometers Per Hour
	0.5080	Centimeters Per Second
	0.01667	Feet Per Second
Feet Per Second	0.6818	Miles Per Hour
	1.097	Kilometers Per Hour
	30.48	Centimeters Per Second
	0.3048	Meters Per Second
	0.5921	Knots
Knots	1.0	Nautical Miles Per Hour
	1.6878	Feet Per Second
	1.1508	Miles Per Hour
	1.852	Kilometers Per hour
	0.5148	Meters Per Second
Meters Per Second	3.281	Feet Per Second
	2.237	Miles Per Hour
	3.600	Kilometers Per Hour
Miles Per Hour	1.467	Feet Per Second
	0.4470	Meters Per Second
	1.609	Kilometers Per Hour
	0.8690	Knots
Radians Per Second	57.296	Degrees Per Second
	0.1592	Revolutions Per Second
	9.549	Revolutions Per Minute

PRESSURE

Multiply	By	To Obtain
Atmospheres	29.921	Inches of Mercury
	14.696	Pounds Per Square Inch
	2116.2	Pounds Per Square Foot
Inches of Mercury	0.03342	Atmospheres
	0.4912	Pounds Per Square Inch
	70.727	Pounds Per Square Foot
Inches of Water	0.00246	Atmospheres
(at 4°C)	0.07355	Inches of Mercury
	0.03613	Pounds Per Square Inch
	5.204	Pounds Per square Foot
Pounds Per Square Inch	6.895	Kilo Pascals

POWER

Multiply	By	To Obtain
BTU Per Minute	12.96	Foot Pounds Per Second
	0.02356	Horsepower
Horsepower	33000	Foot Pounds Per Minute
	550	Foot Pounds Per Second
	0.7457	Kilowatts

TEMPERATURE

Degrees Kelvin = Degrees Celsius Plus 273.2
Degrees Rankine = Degrees Fahrenheit Plus 459.7

Multiply	By	To Obtain
Fahrenheit	5/9 (F-32)	Celsius
Celsius	9/5 C+32	Fahrenheit

ANGULAR DISPLACEMENT

Multiply	By	To Obtain
Degrees	1.745×10^{-2}	Radians
Radians	57.3	Degrees

FORCE

Multiply	By	To Obtain
Pounds	4.448	Newtons

Appendix 9. Airspeed Calibrations

Introduction

The airspeed and altimeter systems on an aircraft depend upon accurate measurements of ambient static pressure and total pitot pressure. Static and pitot pressures are sensed by the pitot static tube, which gives true readings in an undisturbed freestream when aligned with the flow streamlines; however, when attached to the aircraft, which generates a pressure when flying, the pitot and the static reading will be affected by the aircraft pressure field and the flow angularity. The errors, caused by the pressure field and by flow angularity are called position errors due to the sign and magnitude of the errors, which are a function of the position of the pitot-static probe on the aircraft. The position errors are a function of aircraft angle of attack and Mach number and are determined from flight test.

In this text, corrections are used rather than errors. Normally, errors are subtracted and corrections are added with the result that the position error corrections (PEC) are added to the aircraft pitot-static data to get the ambient conditions of static and pitot pressures. The ambient static pressure is defined as PS_{ref} and the ambient pitot pressure is defined as P_{Pref}. The position error correction of the static source ΔP_S is defined as

$$\Delta P_S = P_{Sref} - P_{SA/C}$$

and ΔP_P the position error correction for the pitot pressure is defined as

$$\Delta P_p = P_{\mathrm{Pr}ef} - P_{PA/C}$$

The total position error correction for a pitot static system to be used for an airspeed system is ΔP_d where

$$\Delta P_d = \Delta P_P - \Delta P_S$$

General Discussion of the Various Flight Test Techniques

Each of the flight test techniques (FTT's) that are described in this appendix have certain limitations and instrumentation accuracy criteria that must be considered prior to selecting a flight test technique.

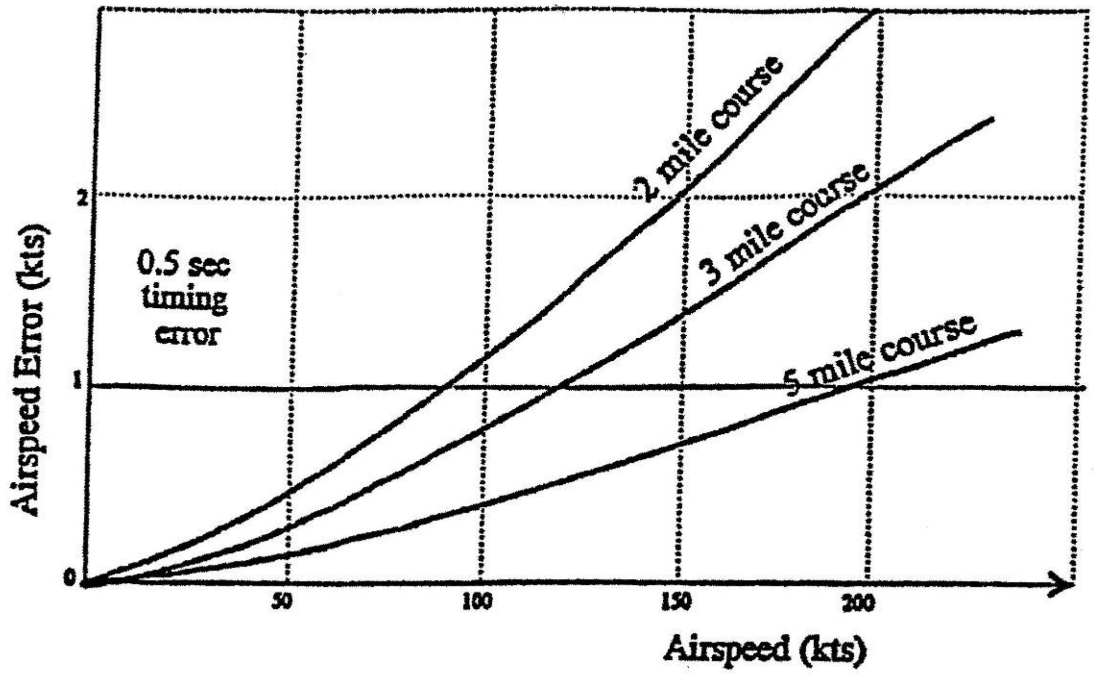
The trailing bomb method only calibrates the aircraft static source. The bomb must be stable when flying below and behind the aircraft, any oscillations will make the reference static pressure invalid. At high speeds the bomb tends to rise up into the wake of the aircraft, which causes bomb oscillations; therefore, the trailing bomb has an upper airspeed limit. The trailing bomb is useful for most speeds up to approximately 200 knots and is particularly useful for helicopters. In addition, the trailing bomb can also be used down to stall speeds. The trailing bomb deployed behind and below helicopters tends to keep the bomb and the attaching tube clear of the tail rotor; however, care must be taken when expanding the speed envelope.

The trailing cone method is capable of a much higher speed range than the trailing bomb and is a favorite method with the large aircraft manufacturers. The trailing cone method only calibrates the aircraft static pressure system.

The speed course method calibrates the airspeed indicator and considers the position error correction for both the static and pitot pressures. Use of the speed course data to calibrate the altimeter makes the assumption that the total position errors of both the pitot and the static sources are in the static source only. This assumption may not be correct. The main source of error in the ground course FTT is in timing since a stopwatch is used to record the time. Figure A9-1 shows the effect of aircraft airspeed on airspeed error with various length ground courses due to a 0.5 second timing error. Obviously, if the maximum error is limited to one knot, then the maximum speed for a three mile ground course would be about 120 knots. Essentially, the ground course method is suitable for slow moving aircraft.

The Global Positioning System (GPS) method is essentially the same as the speed course method except that the GPS unit replaces the stopwatch and, therefore, the timing errors are not an issue. Satisfactory results have been obtained with a wide variety of inexpensive, handheld GPS units. The best indication of the validity of data gathered using this method is the calculated wind. Wind speed and direction are calculated as a by-product of the method. If the calculated wind is constant over a range of test points, then the calculated true airspeed can be considered valid. A significant advantage of this method is that it can be done at higher altitudes, allowing tests near stall speed. A disadvantage is that the relatively small speed error obtained will be the result of subtracting two larger numbers (actual true airspeed less the indicated airspeed correct to true). At higher speeds, small percentage errors in true airspeed will have a larger impact on the position error.

Figure A9-1 - Error Analysis of Ground Course Method



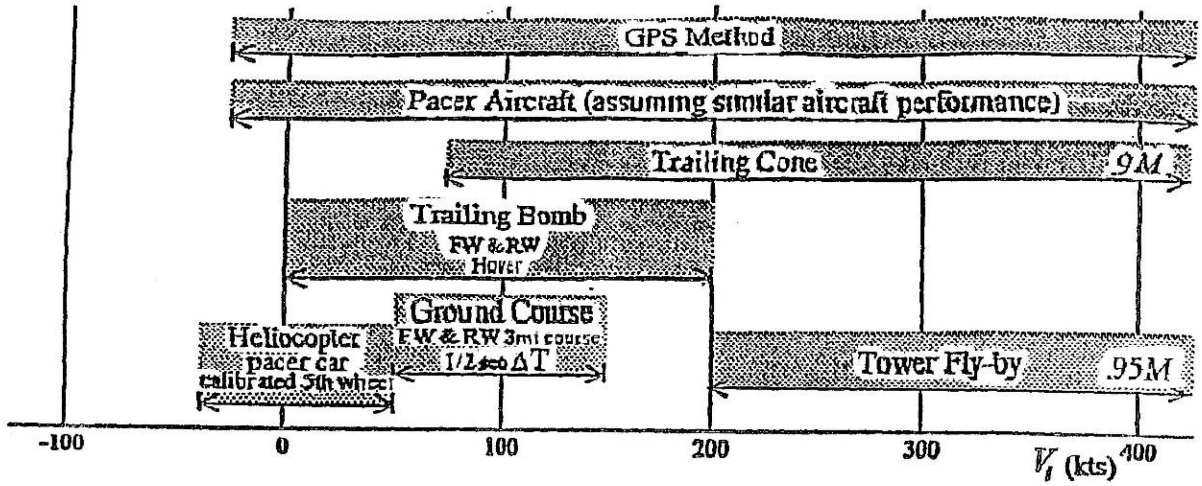
The pace aircraft technique for pitot static calibration is often the initial calibration method for the first flight of a new aircraft or the first flights of extensively modified aircraft. The problem with the pace aircraft method is the accuracy of reading both the altimeter and airspeed indicators in both aircraft simultaneously, and any errors in the pace aircraft are transferred to the test aircraft.

The pitot-static boom method is a standard for small aircraft; however, prior to use, it must be established that the boom static source is outside the pressure field of the aircraft and the pitot tube is unaffected by the flow angularity at the boom.

The tower fly-by method only calibrates the aircraft static source and, if the data are used to calibrate the airspeed systems, the assumption is that the pitot has no errors. Accuracy problems exist with the tower fly-by method if altimeters are used in the tower and in the aircraft. The reading accuracy of an altimeter is generally ± 10 feet; therefore, the combined error of both altimeters could be ± 20 feet, which is very close to the FAR/JAR limits of ± 30 feet per 100 knots. The use of sensitive pressure transducers in the tower and the aircraft considerably improve the reading accuracy. An additional improvement in accuracy can be obtained by taking aircraft ground block data at the base of the fly-by tower, i.e., record the altimeter and temperature and compare the tower data taking into consideration the height o the tower. The tower fly-by method is also useful as measuring the recovery factor of temperature measuring systems. The serious limitations of the tower fly-by method are: the requirement for an instrumented tower and a fly-by line, the hazard of flying near the stall speeds and the Mach limits of the aircraft close to the ground and the time consuming procedure of one data point per aircraft circuit.

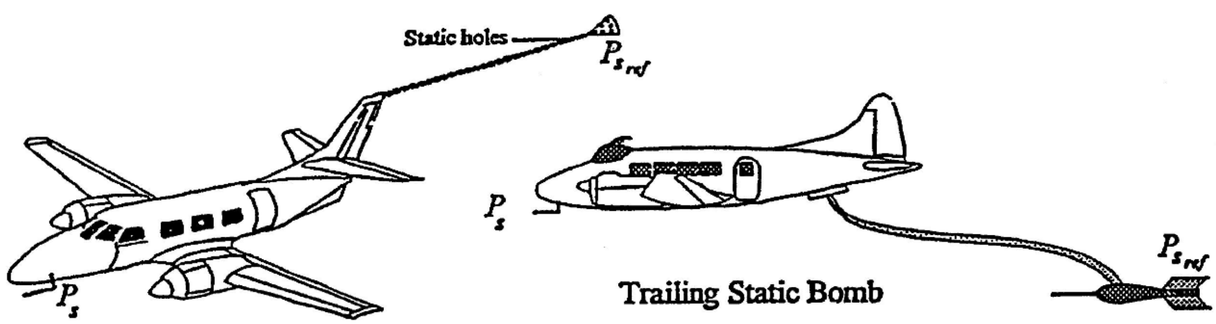
A summary of the speed ranges for various PEC flight test techniques is shown in Figure A9-2.

Figure A9-2 - Summary of PEC Test Methods



1. Trailing Bomb or Cone Method. A trailing bomb or cone, as depicted in Figure A9-3 is used to measure the static pressure of the ambient air about the aircraft. The trailing bomb is sufficiently behind and below the aircraft and the trailing cone is sufficiently far behind the aircraft to be unaffected by the pressure field around the aircraft and can, therefore, be referred to as the reference static pressure ($P_{S_{ref}}$).

Figure A9-3 - Sketches of Trailing Static Bomb and the Trailing Static Cone (not to scale)



A trailing bomb or cone can be used to calibrate the aircraft static source or to determine the Position Error Correction (PEC's) for the altimeter. The use of the reference static sources to calibrate the airspeed systems assumes that the errors in the total head (pitot tube) are zero. The reference static sources could be connected to the altimeter, which would read the pressure altitude of the aircraft. The difference between the reference altitude from the trailing cone or bomb and the aircraft altitude, both corrected for instrument errors, would be the position error correction for the altimeter ΔH_{pec} for a particular aircraft configuration and speed.

$$\Delta H_{pec} = (H_{ref} + \Delta H_{ic}) - (H_{iA/C} + \Delta H_{ic})$$

Where H_{ref} is Reference altitude
ΔH_{ic} is the instrument correction to the altimeter
$H_{iA/c}$ is the indicated aircraft altitude

The above altimeter method is simple but suffers from the difficulty of accurately reading an altimeter, with altimeter calibration errors and hysterisis. Hysterisis is the difference in altimeter calibration with the altitude increasing and decreasing.

A more accurate technique is to connect the trailing static source and the aircraft static source to a pressure differential gauge so that the pressure difference ΔP_s can be read directly, i.e.,

$$\Delta P_s = P_{sref} - P_{sA/C}$$

where P_{sref} is the reference static pressure and
$P_{sA/C}$ is the aircraft static source pressure

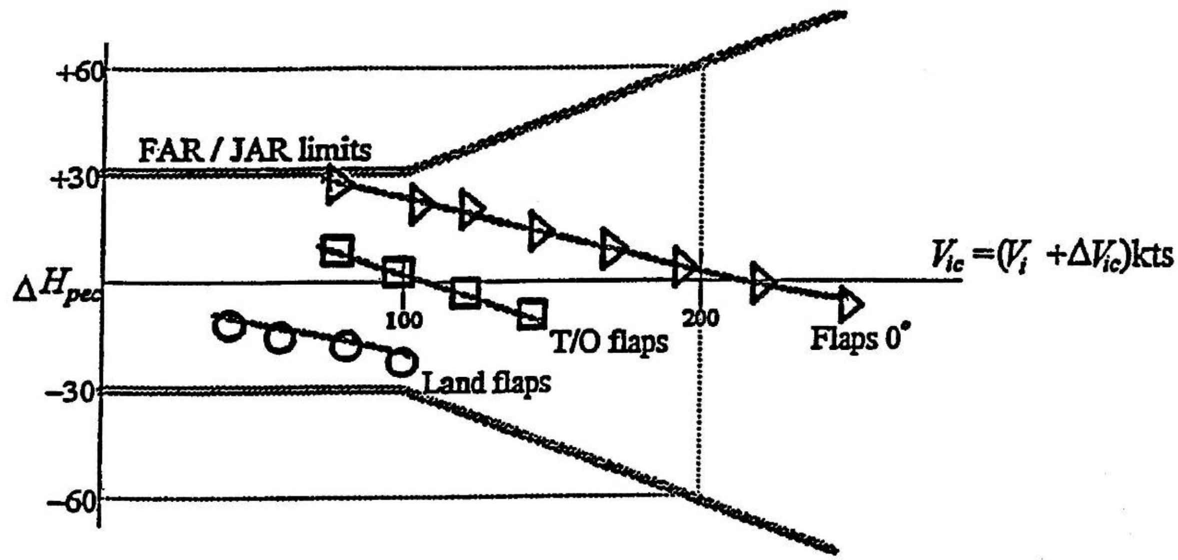
Note that the (ΔP_S) as expressed above is a correction which must be added to the aircraft static pressure (P_S) to get the reference static pressure. The (ΔP_s) data in lb/ft^2 can be converted to ΔH_{pec} data in feet by the use of the pressure static equation:

$$\Delta P_S = -\rho g \Delta H_{pec} or \Delta H_{pec} = -\frac{\Delta P_S}{\rho g}$$

Units ΔP_S in lb/ft^2
H in ft
ρ in slugs/ft^3

Where g is the gravitational constant 32.2 ft/sec^2 and ρ is the density of the air in which the aircraft is flying. ΔH_{pec} can be determined throughout the speed range of the aircraft in all configurations and plotted as shown in Figure A9-4:

Figure A9-4 - Typical Position Error Correction Data for an Aircraft



The FAR/JAR 23.1325 limits of ±30 feet per 100 knots are also shown on Figure A9-4.

The Trailing Static bomb and cone can be used to calibrate the airspeed systems, if it is assumed that the total head (pitot tube) has no errors. The total position error correction for a pitot-static system is defined as ΔP_d where

$$\Delta P_d = \Delta P_p - \Delta P_S$$

where ΔPp is the pressure correction for the total head due to flow angularity

$$\Delta P_p = P_{P_{ref}} - P_{PA/C}$$

If ΔP_P is assumed to zero, then

$$\Delta P_d = -\Delta P_S = \frac{1}{2}\rho o V_C^2\left(1+\frac{M_C^2}{4}+\frac{M_C^4}{40}+\right)-\frac{1}{2}\rho o V_{ic}^2\left(1+\frac{M_{ic}^2}{4}+\frac{M_{ic}^4}{40}+\right)$$

where V_c and V_{ic} are in ft/sec.

For low speed aircraft that fly at speeds of less than 200 knots and at altitudes less than 10,000 feet, the compressibility corrections can be ignored and the above equation reduces to:

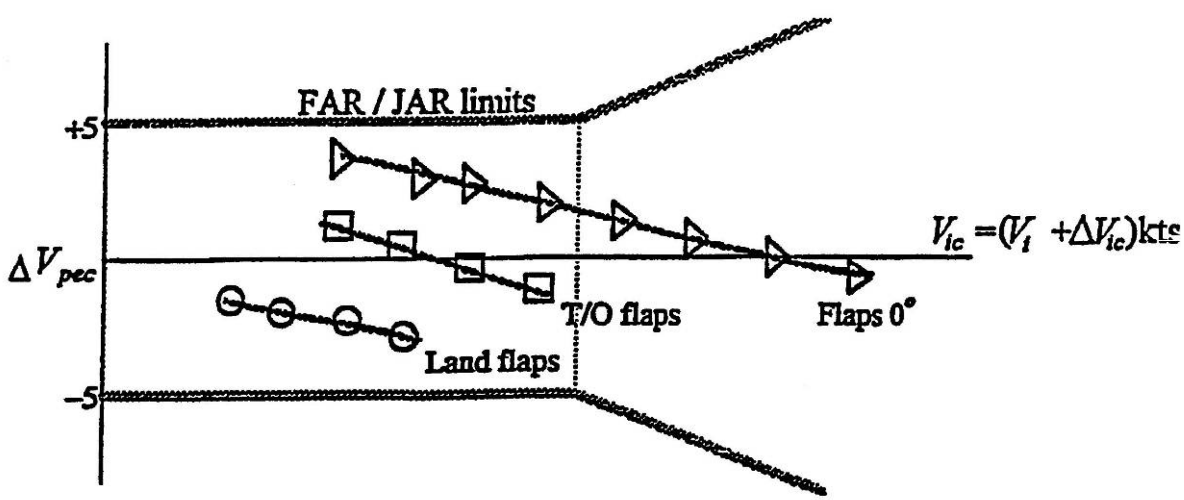
$$\Delta P_d = -\Delta P_S = \frac{1}{2}\rho_o\left(V_c^2 - V_{ic}^2\right)$$

Where V_{ic} is the indicated airspeed of the aircraft corrected for instrument errors and V_c is the calibrated airspeed corrected for instrument and position errors.

$$\Delta V_{pec} = V_c - V_{ic}$$

Knowing the ΔPs for each indicated speed of the aircraft (V_i), then plots of position error corrections for the airspeed system can be generated as shown in Figure A9-5.

Figure A9-5 Typical Position Error Corrections Data for an Aircraft



The FAR/JAR 23.1323 limits of ±5 knots or ±3 percent, whichever is greater are also shown in Figure A9-5.

a. Test Conditions.

(1) *Air Quality*. Smooth, stable air is needed for calibrating the airspeed indicating system using a trailing bomb or trailing cone.

(2) *Weight and C.G*. Same as speed course method. See paragraph 2a(2) of this appendix.

(3) *Speed Range*. The calibration should range from 1.2 V_{STALL} to V_{MO}/V_{NE} or maximum level flight speed, whichever is greater. If the trailing bomb becomes unstable at high airspeed, the higher airspeed range may be calibrated using another accepted method; that is, trailing cone or pace method.

(4) *Use of Bomb*. Care should be exercised in deploying the bomb and flying the test to ensure that no structural damage or control interference is caused by the bomb or the cable. At higher speeds, the bomb may become unstable and porpoise or oscillate. A means for a quick release of the trailing bomb should be provided, in the event an emergency arises. Flight tests using a bomb should be conducted over open (unpopulated) areas.

(5) *Free Stream Air*. The bomb hose should be of adequate length to assure bomb operations in free stream air. This should include consideration of all airplane test configurations that could possibly impart body interference upon the bomb. It will usually require that the bomb be at least one-half wing span away from the airplane.

(6) *Qualifications For Use*. Under stabilized flight conditions at constant airspeed and altitude, trailing cones and airspeed bombs are considered excellent airspeed reference systems. See paragraph 17b of this AC for additional discussion.

b. Test Procedures.

(1) Stabilize airplane in level flight approximately 30 seconds just above stall with flaps and gear retracted. Record data.

(2) Repeat step (1) at sufficient increments to provide an adequate calibration curve for each of the configurations.

c. Data Acquisition. Data to be recorded at each test point:

Altimeter Method	**Pressure Differential Method**
1. Airplane Airspeed (V_i)	1. Airplane Airspeed (V_i)
2. Airplane indicated altitude ($H_{iA/C}$)	2. Airplane indicated altitude ($H_{iA/C}$)
3. Trailing Cone/Bomb altitude (H_{iref})	3. Pressure Differential $\Delta P_S = P_{Sref} - P_{SA/C}$
4. Flap position	4. Flap position
5. Landing gear position	5. Landing gear position
6. Fuel used	6. Fuel used

d. Data Analysis. The data are analyzed according to the methods and equations presented above. The data could be presented in the form as shown in Figures A9-3 and A9-4. Data that fall outside the FAR/JAR limits fail the airworthiness codes.

2. Speed Course Method. The speed course method consists of using a ground reference to determine variations between indicated airspeed and ground speed of the airplane. An accurately measured ground course is required. The course distance should be selected to be compatible with the airspeeds being flown. Excessively long times to traverse the course will degrade the test results.

Generally, airspeeds above 250 knots should be flown over a 5-mile course. Below 100 knots, limit the course to 1 mile. Perpendicular "end lines" (roads, powerlines, etcetera) should be long enough to allow for drift and accurate sighting of end line passage. A one-second error at 200k is 6k on a 2-mile course.

a. Test Conditions.

(1) *Air Quality*. The air should be as smooth as possible with a minimum of turbulence and wind. The wind velocity, while conducting the test, should not exceed approximately 10 knots.

(2) *Weight and C.G*. Airspeed calibrations are usually not c.g. sensitive but may be weight sensitive, especially at low airspeeds (higher angles-of-attack). Initial airspeed calibration tests should be conducted with the airplane loaded at or near maximum takeoff gross weight. Additional tests should be conducted at near minimum weight and at low airspeeds to spot check the maximum weight airspeed calibration results. If differences exist, an airspeed system calibration should be accomplished at minimum weight.

(3) *Altitude*. When using a visual reference on the airplane for timing, the altitude throughout the test run should be as low as practical but should be maintained at least one and one-half wing spans above the highest ground elevation so that the airplane remains out of ground effect. When conditions permit using the airplane shadow for timing, speed course altitudes of 500-2000 feet AGL can be used. All run pairs should be conducted at the same altitude.

(4) *Speed Range*. The speed should range from 1.3 V_{S1} to the maximum level flight speed, to extrapolate to V_D.

(5) *Run Direction*. Reciprocal runs should be made at each speed to eliminate wind effects, and the ground speed obtained in each direction should be averaged to eliminate wind effects. Do not average the time flown in each direction.

(6) *Heading*. The heading should be maintained constant and parallel to the speed course throughout the run, allowing the airplane to "drift," if necessary, so that the effect of crosswinds can be eliminated.

(7) *Configuration*. The airspeed system should be calibrated in each landing gear and wing flap configuration required in §§ 23.45 through 23.77. This normally consists of gear up/flaps up, gear up/flaps takeoff and gear down/flaps down.

b. Test Procedures.

(1) Stabilize airplane in level flight at test speed, with gear and flaps in the desired configuration, prior to entering the speed course.

(2) Maintain constant speed, altitude, and heading through speed course. Record data.

(3) Repeat steps (1) and (2) of this paragraph on the reciprocal speed run.

(4) Repeat steps (1) through (3) of this paragraph at sufficient increments (minimum of five) to provide an adequate calibration curve for each of the configurations.

c. Data Acquisition and Reduction. Data to be recorded during each run:

(1) Time to make run;

(2) Pressure altitude;

(3) Total air temperature (airplane indicator) corrected to static air temperature (SAT);

(4) Indicated airspeed;

(5) Wing flap position;

(6) Landing gear position; and

(7) Direction of run.

d. Sample Speed Course Data Reduction (Refer to Table A9-1).

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

$$1\ \text{Knot} = \frac{6076.1\ \text{feet/nautical mile}}{3600\ \text{second/hour}} = 1.6878\ \text{feet/second}$$

$$\text{Ground Speed} = \frac{10560}{(1.6878)(47.1)} = \frac{.5925\ (10560)}{47.1} = 132.8\ \text{knots}$$

$$GS_{AVG}\ (TAS) = \frac{132.8 + 125.6}{2} = 129.2\ \text{knots}$$

Sample Speed Course Data and Data Reduction.

a. Weight ____________________ C.G. ____________________

b. Course Distance 10,560 Ft.

c. Pressure Altitude 1,600 Ft. (Altimeter set to 1013 m.b.)

Flap Position Degrees	Gear Position (Up or Down)	Time Seconds	I.A.S. (Knots)	Pressure Altitude Feet	SAT. Degrees Fahrenheit	Ground Speed* Knots	Average Ground Speed Knots	Factor**	Calibrated Air Speed Knots	Average I.A.S. Knots	Airspeed System	Instrument	Position
0	Fixed	47.1	128.0	1610	55	132.8	129.2	0.975	126.0	128.5	2.5	1	1.5
		49.8	129.0	1600	55	125.6							
		44.5	135.0	1600	55	140.5	136.7	0.975	133.3	136	2.7	0	2.7
		47.1	137.0	1600	55	132.8							
		40.5	148.0	1600	55	154.2	149.3	0.975	145.6	148	2.4	-1	3.4
		43.3	148.0	1600	55	144.3							

$$* \text{ Ground Speed} = \frac{C \times \text{Course Distance (Ft)}}{\text{Time (Seconds)}}$$

C = 0.5925 for course speed in kts

or use: C = 0.6818 for M.P.H.

$$** \text{ Factor} = \sqrt{\rho / \rho_o = 4.16\sqrt{\frac{\text{ObservedPressure(In.Hg.)}}{559.7 + \text{ObservedTemperature}}}} \text{ (or read from } ^{O}\text{F chart)}$$

Table A9-1 - Sample Speed Course Data and Data Reduction

(1) *Density Altitude*. TAS is greater than CAS if density altitude is above sea level. For density altitudes below 5000 feet and calibrated airspeeds below 200 knots, it is considered acceptable to use the term CAS = EAS = TAS $\sqrt{\rho / \rho_o}$. In this case, density altitude is obtained from figure A7-4 in Appendix 7. At 1600 ft. pressure altitude and SAT 55 °F, we read a density altitude of about 1700 feet. This density altitude intercepts $\sqrt{\rho / \rho_o}$ at a value of .975. CAS = 129.2 (0.975) = 126.0 knots.

AVERAGE					
GS			ERROR		
(TAS)	CAS	IAS	System =	Instrument +	Position
129.2	126.0	128.5	+2.5	+1	+1.5
			(CAS-IAS)	V_{inst}	V_{pos}

(2) *Required Accuracy*. Instrument error is determined by applying standard pitot and static pressures to the airspeed instrument and developing a calibration curve. IAS corrected for +1 instrument error = 127.5 knots. The position of the static source is causing +1.5 error.

Section 23.1323(b) requires the system error, including position error, but excluding instrument error, not to exceed 3 percent of CAS or 5 knots, whichever is greater, in the designated speed range.

(3) *Compressibility*. For many years CAS was used for design airspeeds. However, as speeds and altitudes increased, a compressibility correction became necessary because airflow produces a total pressure on the pitot head that is greater than if the flow were incompressible. We now use EAS as a basis for design airspeeds (§ 23.235). Values of CAS versus EAS may be calculated or you may use the chart in Appendix 7, figure A7-5, to convert knots CAS to EAS.

3. GPS Method. The Global Positioning System (GPS) method consists of using a GPS unit to determine ground speed, which is then used to calculate true airspeed. Any commercial GPS unit can be used that produces consistent results. Once true airspeed is calculated, the data reduction is nearly identical to the speed course method described previously. One difference is that the scale altitude correction factor (ΔV_c the difference between CAS and EAS as shown in figure A7-5) may be significant at higher altitudes and speeds that may be flown with this method. Specifically, you will solve the following equation for (ΔV_{pec}):

$$V_i + \Delta V_{ic} + \Delta V_{pec} + \Delta V_c = V_{true} * \sqrt{\sigma}$$

And then, assuming that all of the pitot-static error is in the static port, you may calculate the altitude position, error, ΔH_{pec}, as described in the Trailing Bomb/Cone Method.

a. Test Conditions.

(1) *Air Quality*. The air should be as smooth as possible with a minimum of turbulence. The wind velocity and direction must be constant for this method to give correct results.

(2) *Weight and C.G.* Same as the speed course method.

(3) *Altitude*. The altitude is not critical, but it should be chosen where the air is smooth and the winds are constant.

(4) *Speed Range.* Any speed at which the aircraft can be stabilized in level flight (see Figure A9-2).

(5) *Runs* . Three runs per airspeed are required to calculate one true airspeed. The three runs must be done at the same indicated speed and altitude on different headings. The headings should be 60 to 120 degrees apart.

(6) *Configuration*. Same as the speed course method.

b. Test Procedures.

(1) Stabilize the airplane in steady level flight at the desired test speed configuration. Record the indicated airspeed, pressure altitude (29.92 set), outside air temperature and configuration of the aircraft.

(a) Record both ground track and ground speed from the GPS unit once the values are stable (this can take up to 10 seconds after stabilizing).

(b) Turn 60 to 120 degrees either direction and record the new ground track and speed once restabilized at the same airspeed and altitude on the new heading. Minor variations in altitude (up to 100 feet) are much preferred to any variation in airspeed from the initial value. A one knot change in indicated airspeed will cause at least a one knot change in true airspeed, but 100 feet of altitude only causes on the order of 1/2 of 1 percent change in the density ratio, σ.

(c) Turn another 60 to 120 degrees in the same direction and record a third set of ground track and speeds.

(2) Once you have three sets of ground track and speed for a given indicated airspeed and configuration, repeat steps (1)(a) through (1)(c) above at sufficient increments, to provide an adequate calibration curve for each of the configurations.

c. Data Reduction. The best way to calculate true airspeed from the three sets of ground tracks and speeds is with a personal computer spreadsheet. The following solution was developed assuming that the three legs flown had the same true airspeed (indicated airspeed, OAT, and pressure altitude were identical) and that the wind did not change during the three legs. The table shows the spreadsheet equations for one popular spreadsheet program that will solve the problem. Note that wind speed and direction are intermediate outputs. If a series of points are done at nearly the same time, altitude and geographic location, then the consistency of the calculated wind speed and direction will be an indicator of the validity and accuracy of the calculated true airspeeds.

	A	B	Result
1	Ground Speed 1	184	184
2	Track 1	265	265
3	Ground Speed 2	178	178
4	Track 2	178	178
5	Ground Speed 3	185	185
6	Track 3	82	82
7	X1	=B1*SIN(PI()*(360-B2)/180)	183.3
8	Y1	=B1*COS(PI()*(360-B2)/180)	-16.0
9	X2	=B3*SIN(PI()*(360-B4)/180)	-6.2
10	Y2	=B3*COS(PI()*360-B4)/180)	-177.9
11	X3	=B5*SIN(PI()*(360-B6)/180)	-183.2
12	Y3	=B5*COS(PI()*(360-B6)/180)	25.7
13	M1	=-1*(B9-B7)/(B10-B8)	-1.17
14	B1	=(B8+B10)/2-B13*(B7+B9)/2	6.71
15	M2	=-1*(B11-B7)/(B12-B8)	8.77
16	B2	=(B8+B12)/2-B15*(B7+B11)/2	4.42
17	Wx	=(B14-B16)/(B15-B13)	0.2
18	Wy	=B13*B17+B14	6.4
19	Wind Speed	=SQRT(B17^2+B18^2)	6.4
20	Wind Direction	=MOD(540-(180/PI()*ATAN2(B18,B17)),360)	177.9
21	True Airspeed	=SQRT((B7-B17)^2+(B8-B18)^2)	184.4

4. Pace Airplane Method. An airplane whose pitot static systems have been calibrated by an acceptable flight test method is used to calibrate the pitot static systems of a test aircraft.

a. Test Conditions. Smooth ambient flight conditions

b. Test Procedures. The pace airplane is flown in formation with the test airplane at the same altitude and speed. The aircraft must be close enough to ensure that the relative velocity is zero yet far enough away so that the pressure fields of the two airplanes do not interact. Readings are coordinated by radio.

c. Data to be recorded

(1) Test Airplane airspeed (V_{iT}) kts

(2) Test Airplane Pressure Altitude (H_{iT}) ft

(3) Pace Airplane airspeed (V_{ip}) kts

(4) Pace Airplane Pressure Altitude (H_{ip}) ft

(5) Configuration for both airplanes

(6) Fuel used in both airplanes

d. Data Reduction. Correct all the instrument readings for instrument errors and the pace aircraft readings for the known position error.

$$\Delta V_{pecT} = (V_{ip} + \Delta V_{icp} + \Delta V_{pec}) - (V_{iT} + \Delta V_{icT})kts$$
$$\Delta H_{pecT} = (H_{ip} + \Delta H_{icp} + \Delta H_{pec}) - (H_{iT} + \Delta H_{icT})\,ft$$

Calculate ΔV_{pecT} and ΔH_{pecT} for all data points in each configuration and plot in a manner similar to Figure A9-4 and Figure A9-5.

5. Pitot-Static Boom Data. If a flight test Pitot-Static boom is mounted on an airplane such that the pitot tube (total head) is not affected by flow angularity and the static source is outside the pressure field of the aircraft, then it can be assumed that the boom data is without position errors. The boom data can then be taken as the pace data. The Pitot-Static boom should be calibrated for high alpha and high speed.

a. Test Conditions. Smooth ambient flight conditions

b. Test Procedures. The nose or wing-mounted boom is flown in formation with the test airplane at the same altitude and speed. The aircraft must be close enough to ensure that the relative velocity is zero yet far enough away so that the pressure fields of the two airplanes do not interact. Readings are coordinated by radio.

c. Data to be recorded

(1) Test Airplane airspeed (V_{iT}) kts

(2) Test Airplane Pressure Altitude (H_{iT}) ft

(3) Nose or wing-mounted boom airspeed (V_{ip}) kts

(4) Nose or wing-mounted boom Pressure Altitude (H_{ip}) ft

(5) Configuration for both airplanes

(6) Fuel used in both airplanes

d. Data Reduction.

$$\Delta V_{pect} = (V_{iB} + \Delta V_{icB} + \Delta V_{pec}) - (V_{iT} + \Delta V_{icT}) \text{ kts}$$
$$\Delta H_{pect} = (H_{iB} + \Delta H_{icB} + \Delta V_{pec}) - (H_{iT} + \Delta H_{icT)} \text{ kts ft}$$

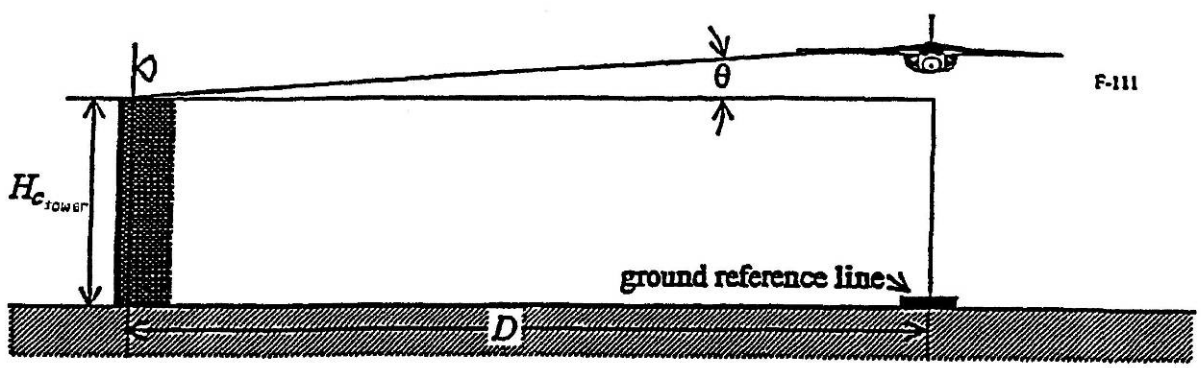
ΔV_{pecT} and ΔH_{pecT} are calculated throughout the speed range in each configuration and plotted as shown in figures 3 and 4.

6. Tower Fly-by Method. The tower fly-by method is one of the methods which results in a direct determination of static error in indicated pressure altitude.

Since the altimeter and airspeed system use the same static source, it is possible to correlate the altimeter position error directly to the airspeed error. This correlation assumes that there is no error in the total head system.

The tower fly-by method can be modified to use radar altimeter or differential GPS to determine geometric/tapeline height above a ground based pressure measuring station.

Figure A9-6 Tower Fly-By Method



a. Procedures and Test Conditions for Tower Fly-by

(1) *Air Quality.* Smooth, stable air is needed for determining the error in pressure altitude.

(2) *Weight and C.G.* Same as for calibrations of the airspeed indicating system.

(3) *Speed Range.* The calibration should range from 1.3 V_{SO} to 1.8 V_{S1}. Higher speeds up to V_{MO} or V_{NE} are usually investigated so that errors can be included in the AFM for a full range of airspeeds.

(4) *Test Procedures*.

(i) The test technique is to fly the aircraft along a ground reference line, past the tower, in stabilized flight at a constant airspeed and at the approximate height of the tower. The primary piloting task is to maintain a constant indicated altitude during the run. The tower is equipped with a sensitive altimeter and a means of determining the relative angle (θ) of the aircraft. The data recorded during each run are the indicated pressure altitude of the tower, (H_{itower}), the angle (θ), and the aircraft's indicated pressure altitude, airspeed and temperature ($H_{iA/C}$, $V_{iA/C}$, and $T_{iA/C}$) as it passes the tower. Note that the tower altimeter must be at the zero grid line position in the tower.

(ii) Repeat step (i) at various airspeeds in increments sufficient to cover the required range at each flap setting.

(5) *Data Acquisition*. Data to be recorded at each test point:

(i) Airplane Airspeed $V_{iA/C}$ knots.

(ii) Airplane indicated pressure attitude, $H_{iA/C}$ knots.

(iii) Tower observer indicated pressure altitude, $H_{itower.}$

(iv) Angle θ of aircraft above the tower.

(v) Wing flap position.

(vi) Landing gear position.

(vii) Fuel used in airplane.

(viii) $T_{iA/C}$ and T_{itower}

(6) *Data Reduction.* The actual pressure altitude of the aircraft is H_{cref} where

$$H_{cref} = (H_{itower} + \Delta H_{ictower}) + D \tan \theta \ \frac{T_s}{T_t}$$

Where T_s is the standard day absolute temperature at the test altitude and T_t is the test day temperature in absolute units.

The $\frac{T_s}{T_t}$ temperature correction is to convert the geometric height of the aircraft above the reference zero grid line in the tower (D tan θ) to a pressure height that can be added to the pressure altitude of the tower H_{ctower}. The difference between the actual reference pressure altitude of the aircraft and the aircraft's instrument-corrected pressure altitude is the position error correction.

$$\Delta H_{pec} = H_{cref} - (H_{iA/C} + \Delta H_{icA/C})$$
$$= [(H_{itower} + \Delta H_{ictower}) + D \tan \theta \ \frac{T_s}{T_t}] - (H_{iA/C} + \Delta H_{icA/C})$$

ΔH_{pec} is calculated for every speed and aircraft configuration flown past the tower and the data are plotted as per Figure A9-4.

The airspeed system position error corrections can be obtained from the tower fly-by method if it is assumed that the pitot tube (total head) errors are zero.

The hydrostatic equilibrium equation states that the pressure error correction at the static source is $\Delta\ p_s = -\rho g \Delta H_{pc}$ and from Section 3.

$$\Delta p_d = \Delta p_p - \Delta p_s = \frac{1}{2}\rho_o V_c^2 \left(1 + \frac{M_c^2}{4} + \frac{M_c^4}{40} + ...\right) - \frac{1}{2}\rho o V_{ic}^2 \left(1 + \frac{M_{ic}^2}{4} + \frac{M_{ic}^4}{40} + ...\right)$$

Since it is assumed that $\Delta\rho_p = 0$ and for low speed aircraft, compressibility effects can be ignored, then $\Delta p_d = -\Delta p_s = \frac{1}{2}\rho_o (V_c^2 - V_{ic}^2)$

The above equation is used to calculate V_C at every test point, then $\Delta V_{pec} = V_c - V_{ic}$. The data are then plotted as per Figure A9-5.

7. Ground Run Airspeed System Calibration. The airspeed system is calibrated to show compliance with commuter category requirements of § 23.1323(c) during the accelerate-takeoff ground run, and is used to determine IAS values for various V_1 and V_R speeds. The airspeed system error during the accelerate-takeoff ground run may be determined using a trapped static source reference or a distance measuring unit that provides readouts of ground speed that can be converted into CAS.

a. Definitions.

(1) *Ground Run System Error*. System error during the accelerate-takeoff ground run is the combination of position error, instrument error, and the dynamic effects, such as lag, which may be caused by acceleration on the runway.

(2) *Trapped Static Source*. An airtight bottle with sufficient internal volume so as to be infinite when compared to an airspeed indicator's internal changes in volume while sensing various airspeeds. The bottle should be insulated to minimize internal bottle temperature changes as testing is in progress. For short periods of time, it can be assumed that the bottle will reflect true static ambient pressure to the test indicator.

(3) *Production Airspeed Indicator*. An airspeed indicator that conforms to the type certification design standards. The indicator should be installed in the approved instrument panel location since these tests involve the dynamic effects of the indicator that may result from acceleration.

(4) *Test Airspeed Indicator*. A mechanical airspeed indicator with known dynamic characteristics during acceleration or an electronic transducer that can provide airspeed information.

(5) *Test Reference Altimeter*. An altimeter that indicates the altitude of the air trapped in the bottle or local ambient static air if the valve is opened.

(6) *Ground Run Position Error*. Ground run position error is the static-pressure error of the production static source during ground runs with any ground effects included. Any contributions to error due to the total-pressure (pitot) are ignored.

(7) *Instrument Error*. See paragraph 302a(3)(b).

(8) *Dynamic Effects on Airspeed Indicator*. The dynamic effects on airspeed indicators occur as a result of acceleration and rapid change in airspeed during takeoff. This causes many airspeed indicators to indicate an airspeed lower than the actual airspeed.

Note: It is possible for electronic airspeed indicators driven by an air data computer to also have errors due to dynamic acceleration effects because of characteristics inherent in the basic design.

(9) *Distance Measuring Unit*. An instrumentation system normally used to record takeoff distance measurements. One output of these systems provides the ground speed versus time as the airplane accelerates during the accelerate-takeoff ground run. Ground speed may be converted into a corresponding CAS value by applying wind and air density corrections at intervals during acceleration where the ship's airspeed indications have been recorded.

b. Trapped Static Source Method. The trapped static source method consists of comparing instantaneous readings of airspeed, as indicated on a test airspeed indicator, with readings on a production airspeed indicator while accelerating on each other. Readings may be recorded by film or video cameras for mechanical airspeed indicators or by electronic means if a transducer type device is being utilized. See Figure A9-7 for system schematic.

(1) *Test Conditions.*

(a) *Air Quality*. The surface winds should be light with a minimum of gusting.

(b) *Weight and C.G.* Ground run calibrations are not sensitive to c.g. The dynamic effects of acceleration may be affected by weight. Test weight variations should be sufficient to account for any measurable effects due to weight.

(c) *Speed Range.* The speeds should range from 0.8 of the minimum V_1 to 1.2 times the maximum V_1, unless higher values up to V_R are required for expansion of takeoff data.

(d) *Configuration.* The airspeed system should be calibrated during the accelerate-takeoff ground run for each approved takeoff flap setting.

(2) *Test Procedures.*

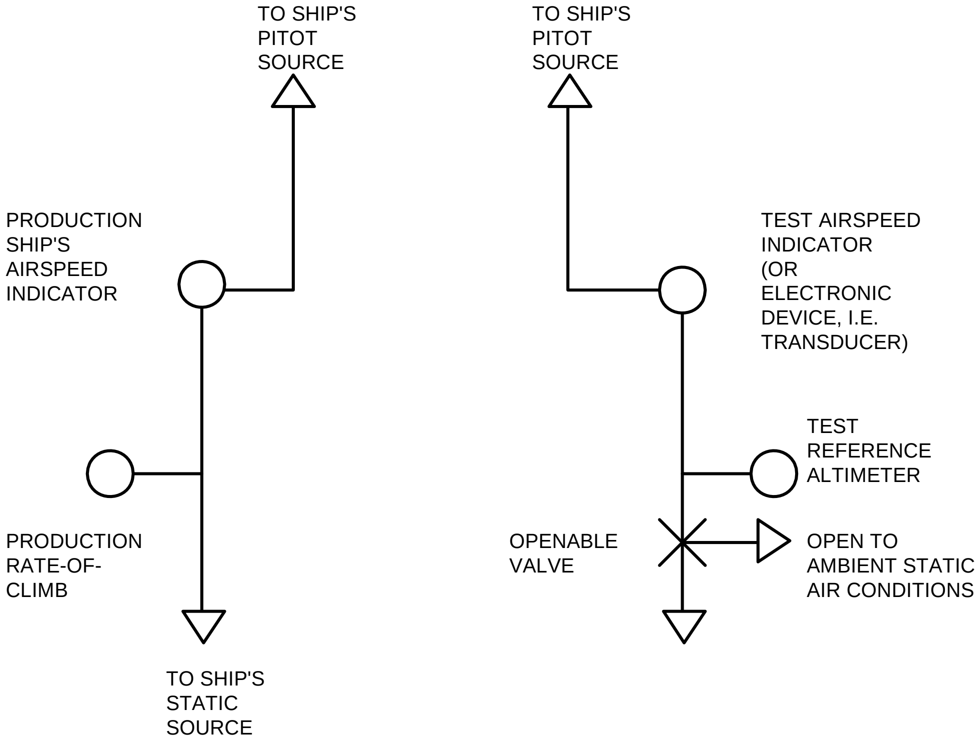
(a) Align the airplane with the runway.

(b) With idle engine power, and with the cabin door open, open the valve to expose the bottle to static ambient conditions, then close the valve. Record the test altimeter reading.

(c) Close the cabin door.

(d) Conduct a takeoff acceleration using normal takeoff procedures. The camera should be recording speeds from the two airspeed indicators in increments sufficient to cover the required airspeed range.

Figure A9-7 - Trapped Static Source Schematic



(e) The takeoff run should be continued, if possible, until beyond the maximum required speed then aborted. When at rest with engines idling, open valve again and observe the test altimeter. Any significant jumps or changes in indicated altitude may indicate a system leak, too much runway gradient or other factors WHICH WILL INVALIDATE THE RESULTS OF THE RUN.

(f) Repeat steps (a) through (e) of this paragraph until there are sufficient runs to provide adequate calibration curves for the required configurations.

(3) *Data Acquisition and Reduction.* Read the recorded data (film or video) at increments of airspeed arbitrarily selected within the required range. See Table A9-2 for a sample data reduction. Record and perform the following:

Table A9-2 - Trapped Static (TS) Data Reduction

TIME		TRAPPED STATIC (TS) IAS (KNOTS)	(1) TS AIRSPEED INSTRUMENT CORRECTION	CORRECTED TS IAS	SHIP'S IAS (KNOTS)	(1) SHIP'S AIRSPEED INSTRUMENT CORRECTION	CORRECTED SHIP'S IAS	(2) AIRSPEED ERROR
7:41	:45	50.7	0	50.7	49	0	49	1.7
	:46	56.1	│	56.1	54	│	54	+2.1
	:47	61.4	│	61.4	61	│	61	+0.4
	:48	66.9	│	66.9	66	│	66	+0.9
	:49	71.9	│	71.9	72	│	72	-0.1
	:50	76.7	│	76.7	77	│	77	-0.3
	:51	82.1	│	82.1	83	│	83	-0.9
	:52	86.8	│	86.8	88	│	88	-1.2
	:53	91.5	│	91.5	91	│	91	+0.5
	:54	96.5	│	96.5	99	│	99	-2.5
	:55	100.9	│	100.9	102	│	102	-1.1
	:56	105.2	│	105.2	107	│	107	-1.8
	:57	110.1	│	110.1	113	│	113	-2.9
	:58	114.4	│	114.4	119	│	119	-4.6
	:59	118.2	│	118.2	123	│	123	-4.8
7:42	:00	122.9	∇	122.9	128	∇	128	-5.1

NOTES: 1. Obtain from instrument calibration.
Corrected trapped static IAS minus corrected ship's IAS.
2. Corrections are added.
3.

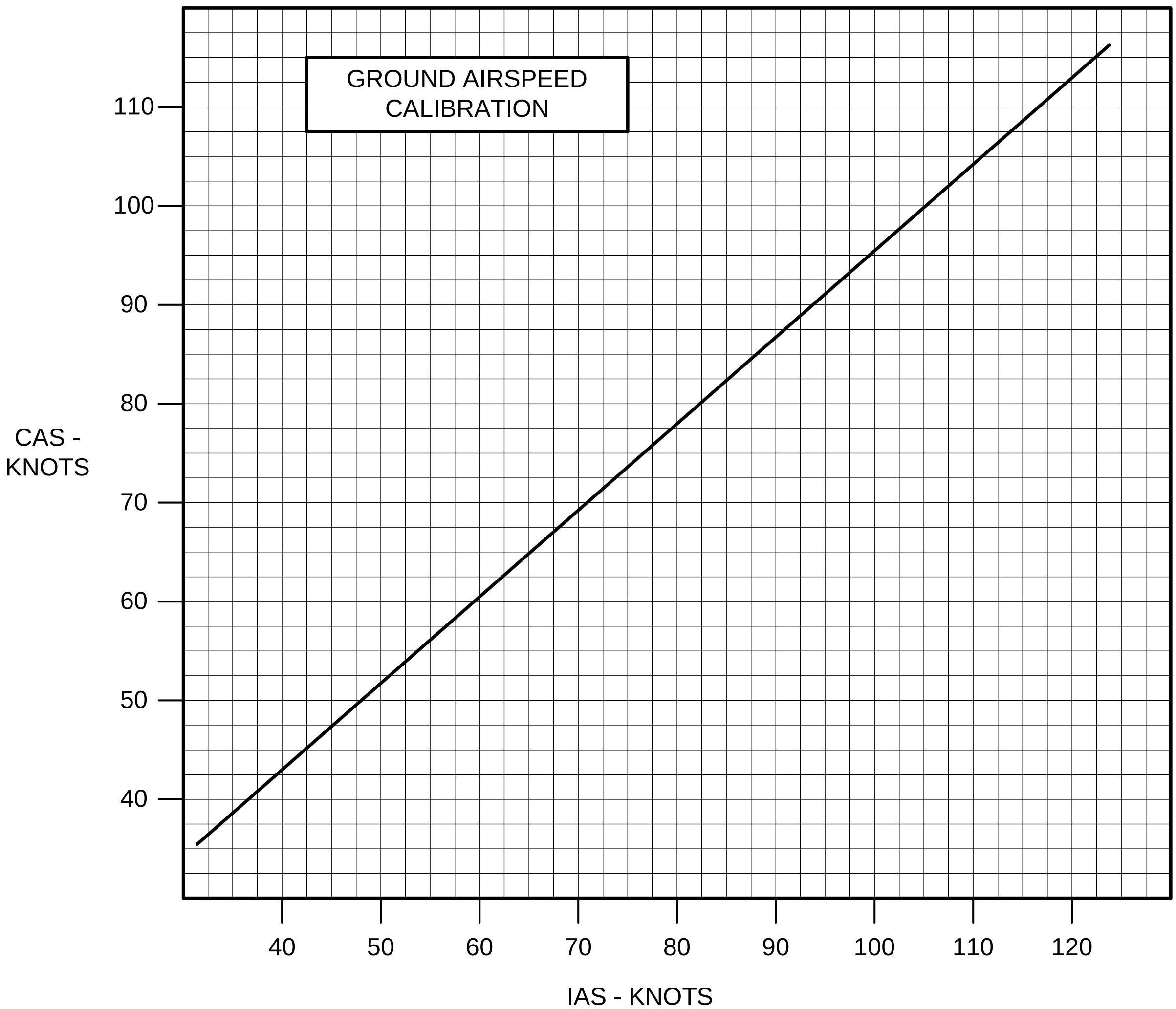
(a) Production indicated airspeed, test indicated airspeed, and configuration.

(b) Correct the test indicated airspeed for instrument error and, in the case of electronic devices, any known dynamic effects. Static pressure in the bottle is assumed to result in no position error. These corrected airspeed values may be assumed to be CAS.

(c) Calculate the amount of system error (difference between corrected trapped static indicated airspeed and production indicated airspeed).

(d) Plot IAS versus CAS within the required range of speeds. See Figure A9-8 for a sample plot.

Figure A9-8 - Ground Airspeed Calibration



c. Distance Measuring Unit Method. The distance measuring unit method consists of utilizing the readouts of ground speed to obtain CAS values within the required range of speeds. These values are compared with readings at the same instant on a production airspeed indicator. Airspeed indicator readings may be recorded by film or video cameras for mechanical airspeed indicators or by electronic means if a transducer type device is being utilized. There should be a method of correlating recorded airspeeds with the CAS values obtained from the distance measuring unit system.

(1) *Test Conditions*.

(a) *Air Quality*. The surface wind velocity should be steady, as low as possible, and not exceed 10 knots. The wind direction should be as near as possible to the runway heading.

(b) *Weight and C.G*. Same as for the trapped static source method.

(c) *Speed Range.* Same as for the trapped static source method.

(2) *Test Procedures*.

(a) Align the airplane with the runway.

(b) Conduct a takeoff acceleration using normal takeoff procedures. The distance measuring unit should be recording/determining the ground speeds. The camera should be recording speeds from the production airspeed indicator and the time or counting device utilized to correlate speeds.

(c) The takeoff may continue or be aborted when beyond the maximum required speed.

(d) Record surface wind velocity and direction; surface air temperature and runway pressure altitude for each run.

(e) Repeat steps (a) through (d) of this paragraph until there are sufficient runs to provide adequate calibration curves for the required configurations.

(3) *Data Acquisition and Reduction*. Read the recorded data (film or video) at increments of airspeed arbitrarily selected within the required range. For these same increments, determine the ground speeds from the distance measuring unit system. See Table A9-3 for a sample data reduction. Record and perform the following:

Table A9-3 - Sample Ground Airspeed Calibration Using a Distance Measuring Unit

	TIME	DMU GROUND SPEED (KNOTS)	WIND COMPONENT DOWN THE RUNWAY	TAS (KNOTS)	(1) CAS (KNOTS)	SHIP'S IAS (KNOTS)	(2) SHIP'S AIRSPEED INSTRUMENT CORRECTION	CORRECTED SHIP'S IAS	(3) GROUND AIRSPEED ERROR
07:00	:09	48.0	3	51.0	50.1	49	0	49	+1.1
	:10	52.8	|	55.8	54.8	54	|	54	+0.8
	:11	56.8	|	59.8	58.7	59	|	59	-0.3
	:12	61.0	|	64.0	62.8	63	|	63	-0.2
	:13	64.2	|	67.2	66.0	68	|	68	-2.0
	:14	67.3	|	70.3	69.0	71	|	71	-2.0
	:15	70.9	|	73.9	72.5	75	|	75	-2.5
	:16	74.0	|	77.0	75.6	78	|	78	-2.4
	:17	77.2	|	80.2	78.7	82	|	82	-3.3
	:18	80.7	|	83.7	82.2	83	|	83	-0.8
	:19	83.9	|	86.9	85.3	87	|	87	-1.7
	:20	87.0	|	90.0	88.3	89	|	89	-0.7
	:21	90.6	|	93.6	91.9	92	|	92	-0.1
	:22	93.8	|	96.8	95.1	95	|	95	+0.1
	:23	96.9	|	99.9	98.1	101	|	101	-2.9
	:24	100.3	|	103.3	101.4	103	|	103	-1.6
	:25	103.6	|	106.6	104.7	106	|	106	-1.3
	:26	106.6	∇	109.6	107.6	110	∇	110	-2.4

Test Conditions:

Pressure Altitude - 1240 ft.
Temperature - 52 °F
$\sqrt{\sigma}$ - 0.982
Runway - 1
Wind - 350/3

1. CAS = TAS$\left(\sqrt{\sigma}\right)$
2. Obtain from instrument calibration
3. CAS minimum corrected Ship's IAS
4. Corrections must be added

Notes:

(a) Production indicated airspeed, ground speed, surface air temperature, runway pressure altitude, wind velocity and wind direction with respect to runway heading.

(b) Compute a CAS value for each data point. This is accomplished by identifying the wind component parallel to the runway; computing the corresponding true airspeed; computing the air density ratio; then computing the calibrated airspeed.

(c) Calculate the amount of system error (difference between CAS and production indicated airspeed).

(d) Plot IAS versus CAS within the required range of speeds. See Figure A9-8 for a sample plot.

Appendix 10. Guide for Determining Climb Performance After STC Modifications

(not applicable to SFAR 23, SFAR 41, or to commuter category)

1. Introduction. Section 23.1587 requires certain performance information to be included in the AFM. These include the climb requirements and rate of climb information as specified by §§ 23.69, and 23.77. Additionally, some turbine-powered airplanes may have the maximum weight of § 23.1583(c) limited by climb performance. If an airplane is modified externally (and/or an engine change) and the changes are deemed significant enough to produce measurable effects, any appropriate requirements and information should be determined for inclusion in the AFM supplement.

2. General. Supplemental Type Certificates involve modifications to in-service airplanes that may, for one reason or other, not exactly match Type Design climb performance data that was determined and published in the AFM. These effects can be the result of engine power deteriorations, added antennae, exterior surfaces not polished or smooth, propeller nicks, or a variety of other reasons. In addition, it is difficult and costly to obtain calibrations of engine power output that may have been available during the original certification process. The extent of performance degradation observed after incorporating external modifications could be partially due to deficiencies present in the airplane prior to modification. In other instances, the results of performance measurements indicate that there is little or no effect from the modification, and the test airplane closely matches the values contained in the basic AFM even though analysis indicates some degradation. For either of these situations, the actual loss in performance could be skewed or masked by these other variables. For these reasons, any climb performance measurements conducted as part of an STC modification should be conducted such that the actual effects of the modification are identified. One effective means of accomplishing this is to measure the performance of the unmodified airplane then repeat the same tests with the external modifications incorporated. Any variations from the basic performance predictions due to engine power or other variables will be minimized or eliminated.

3. Procedure for Extending Climb Performance to Additional Airplanes. The conditions to be evaluated should be identified from a review of the applicable regulations and related to the modifications to be incorporated. The instruments that are to be involved in the flight tests should have recent calibrations. The airspeed system should be verified to be in agreement with the basic airplane calibrations.

Prior to modifications, conduct a series of climbs utilizing the general procedures and information presented in paragraphs 25, 26, and 28 of this Flight Test Guide. Test speeds and other conditions may be abbreviated to those that are presented in the AFM. The AFM can also be utilized as a guide to identify how climb performance is predicated to vary with altitude and other conditions. Results should be corrected to some standard in accordance with Appendix 2, or some other acceptable method. The before and after tests should be conducted, as nearly as possible, at the same airplane weight.

After the modification, the series of climbs conducted above should be repeated. Apply the same procedures and corrections as before. Corrected results of climbs before and after the modification should be compared by plotting the combined results. The performance in the AFM is useful in identifying how climb performance was predicated to change with altitude and temperature. It is likely that there will be some scatter and variations in the final results. With a limited amount of testing, the effects of the modification should be determined conservatively and identified in a manner suitable for presentation in the AFM supplement.

4. "One Only" Airplane. Often, there are circumstances where the full range of performance tests before and after the STC modification are not warranted. These might include:

a. A limited effectivity such as a one-only modification.

b. An excessively conservative reduction in published climb performance, which would not limit normal operations of the airplane and limitations are not affected.

The conditions to be evaluated should be identified from a review of the applicable regulations and related to the modifications to be incorporated. The instruments that are to be involved in the flight tests should have recent calibrations. The airspeed system should be verified to be in agreement with the basic airplane calibrations.

If the reduction in climb performance is not limiting, then it may be acceptable to conduct tests of the modified airplane only and provide analysis that could be used to support and compare with the tests. Values of climb degradation should be selected that are sufficiently conservative to overcome any variations or discrepancies that may have been present. This should not involve any requirements of § 23.1583. The information required by § 23.1587, however, could be excessively conservative without degrading normal operations of the airplane in service.

For example, analysis predicts that a particular modification will reduce the one-engine-inoperative climb performance by 50 feet-per-minute, and limited testing shows a reduction of 30 feet-per-minute. In order to overcome the introductory considerations and variables, a degradation in climb performance should be obviously conservative. The higher of the two rate of climb degradation values could be doubled to achieve this objective. For this example, the AFM supplement would reflect a degradation in one-engine-inoperative climb performance of 100 feet-per-minute.