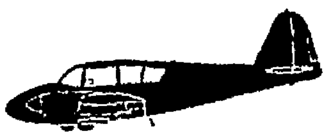
Advisory Circular

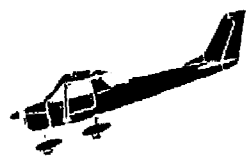
U.S. Department of Transportation
Federal Aviation Administration

AC NO: 23-8A

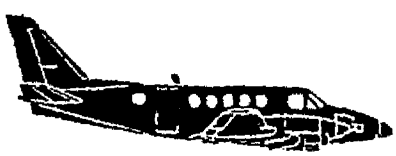
DATE: 2/9/89

FLIGHT TEST GUIDE FOR CERTIFICATION OF PART 23 AIRPLANES





DOT LIBRARY
10A SECTION
800 INDEPENDENCE AVE SW
WASHINGTON, DC 20591



U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: FLIGHT TEST GUIDE FOR CERTIFICATION OF PART 23 AIRPLANES
Date: 2/9/89
Initiated by: ACE-100
AC No: 23-8A
Change:

1. PURPOSE.

a. This advisory circular (AC) provides information and guidance concerning acceptable means, but not the only means, of showing compliance with Part 23 of the Federal Aviation Regulations (FAR) concerning flight tests and pilot judgments. Accordingly, this material 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 airplane certification.

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 Delegation Option Authorization (DOA), Designated Alteration Station Authorization (DAS), and Designated Engineering Representative (DER) personnel.

2. CANCELLATION. AC 23-8, Flight Test Guide for Certification of Normal, Utility, and Acrobatic Category Airplanes, dated October 20, 1987, is cancelled.

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

4. BACKGROUND. 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.

5. APPLICABILITY.

a. These methods and procedures are promulgated, in the interest of standardization, for use during all normal, utility, acrobatic, and commuter category airplane flight test certification activities. This material is not to be construed as having any legal status and must be treated accordingly. The procedures set forth herein are one acceptable means of compliance with applicable sections of Part 23.

Like all AC material, these guidelines are not mandatory and do not constitute regulations. They are derived from previous FAA experience in finding compliance with the airworthiness requirements and represent the methods and procedures found to be 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.

b. This AC covers the latest Part 23 amendments through amendment 23-34 which includes commuter category airplanes. 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).

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

6. RELATED PUBLICATIONS. Certification personnel should be familiar with FAA Order 8110.4, "Type Certification," and FAA Order 8100.5, "Aircraft Certification Directorate Procedures." In this AC, reference is made to other FAA AC's which give guidance on various aspects of type certification and supplemental type certification.

7. HOW TO OBTAIN. Copies of AC 23-8A may be ordered from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 or from any of the Government Printing Office bookstores located in major cities throughout the United States.

BARRY D. CLEMENTS
Manager, Small Airplane Directorate
Aircraft Certification Service

CONTENTS

ILLUSTRATIONS

The first block of digits in the figure number denotes the associated paragraph number. The second block of digits denotes the figure number within the paragraph.

ADVISORY CIRCULARS

ADVISORY CIRCULARS (continued)

Advisory Circular Number	Title	Paragraph Number	Page Number
23.807-3	Emergency Exits Openable From Outside for Small Airplanes	165	97
23.841-1	Cabin Pressurization Systems in Small Airplanes	176	98
23.909-1	Installation of Turbochargers in Small Airplanes with Reciprocating Engines	192	102
23.959-1	Unusable Fuel Test Procedures for Small Airplanes	207	105
23.961-1	Procedures for Conducting Fuel System Hot Weather Operation Tests	208	105
20-124	Water Ingestion Testing for Turbine Powered Airplanes	255	114
20-67B	Airborne VHF Communications Equipment Installations	287b(1)	121
90-45A	Approval of Area Navigation Systems for Use in the U.S. National Airspace System	287b(11)(i)	130
25-4	Inertial Navigation Systems (INS)	287b(12)(i)	130
121-13	Self-Contained Navigation Systems (Long Range)	287b(12)(i) 287b(13)(i)	130 131
20-101B	Omega and Omega/VLF Navigation Systems Approvals for Use in the Conterminous United States and Alaska	287b(16)	131
90-79	Recommended Practices and Procedures for the Use of Electronic Long-Range Navigation Equipment	287b(16)	131
120-31A	Operational and Airworthiness Approval of Airborne Omega Radio Navigation Systems as a Means of Updating Self-Contained Navigation Systems	287b(16)	131
120-37	Operational and Airworthiness Approval of Airborne Omega Radio Navigational Systems as a Sole Means of Long Range Navigation Outside the United States	287b(16)	131
20-121	Airworthiness Approval of Airborne Loran-C Systems for Use in the U.S. National Airspace System	287b(17)	131
23.1305-1	Installation of Fuel Flowmeters in Small Airplanes with Continuous-Flow, Fuel-Injection, Reciprocating Engines	290c	133

ADVISORY CIRCULARS (continued)

CHAPTER 1. GENERAL

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

a. Explanation.

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

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

b. Procedures. None.

2.-5. RESERVED.

CHAPTER 2. FLIGHT

Section 1. GENERAL

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

a. Explanation.

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

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

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

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

(5) Following are additional tolerances that are acceptable:

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

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

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

b. Procedures.

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

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

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

SAMPLE PORTION OF AIRSPEED INDICATOR CALIBRATION

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

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

A/S Ind. KNOTS

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

(3) Use of Ballast.

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

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

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

a. Explanation.

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

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

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

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

(i) The limits selected by the applicant;

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

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

b. Procedures. None.

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

a. Explanation.

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

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

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

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

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

b. Procedures. None.

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

a. Explanation.

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

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

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

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

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

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

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

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

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

(1) Fixed Pitch Propellers.

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

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

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

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

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

(2) Controllable Pitch Propellers Without Constant Speed Controls.

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

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

(3) Controllable Pitch Propellers With Constant Speed Controls.

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

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

(iii) Safe Operation Under Normal Operating Conditions.

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

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

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

12.-15. RESERVED.

Section 2. PERFORMANCE

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

a. Explanation.

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

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

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

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

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

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

(5) Humidity Correction. See appendix 1.

b. Procedures. See appendix 1.

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

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

a. Explanation.

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

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

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

(i) Uncontrollable downward pitching motion; or

(ii) the control reaches the stop.

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

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

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

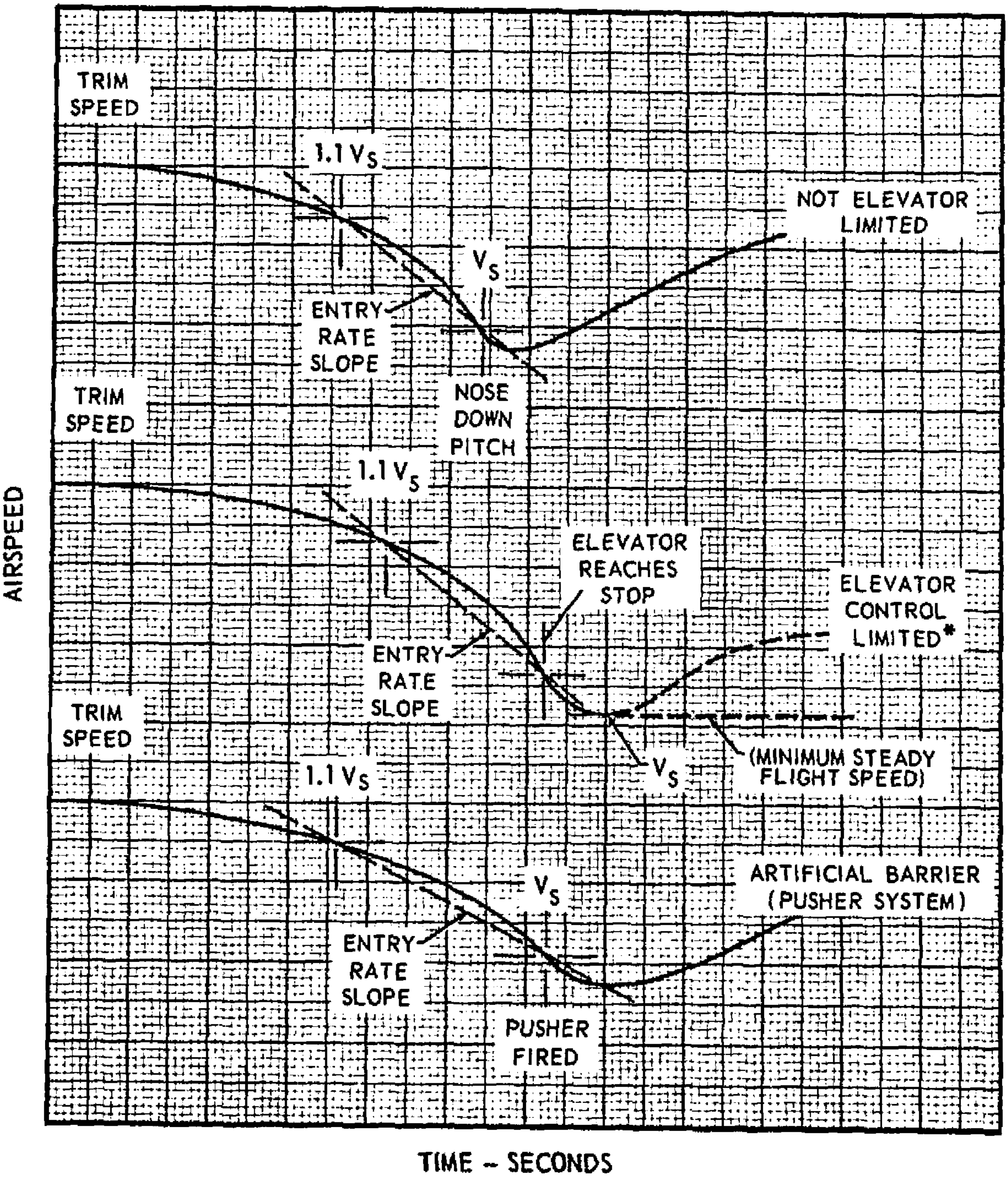
(i) Zero-thrust r.p.m. can be calculated by using the propeller manufacturer's propeller coefficient curves. The thrust will be zero when the propeller thrust coefficient is zero for the particular propeller blade angle. Using the propeller coefficient curves, obtain or construct a chart like figure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

Where C_T = thrust coefficient

C_P = power coefficient

β = blade angle setting

J = advance ratio



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

Figure 17-1 - STALL SPEED

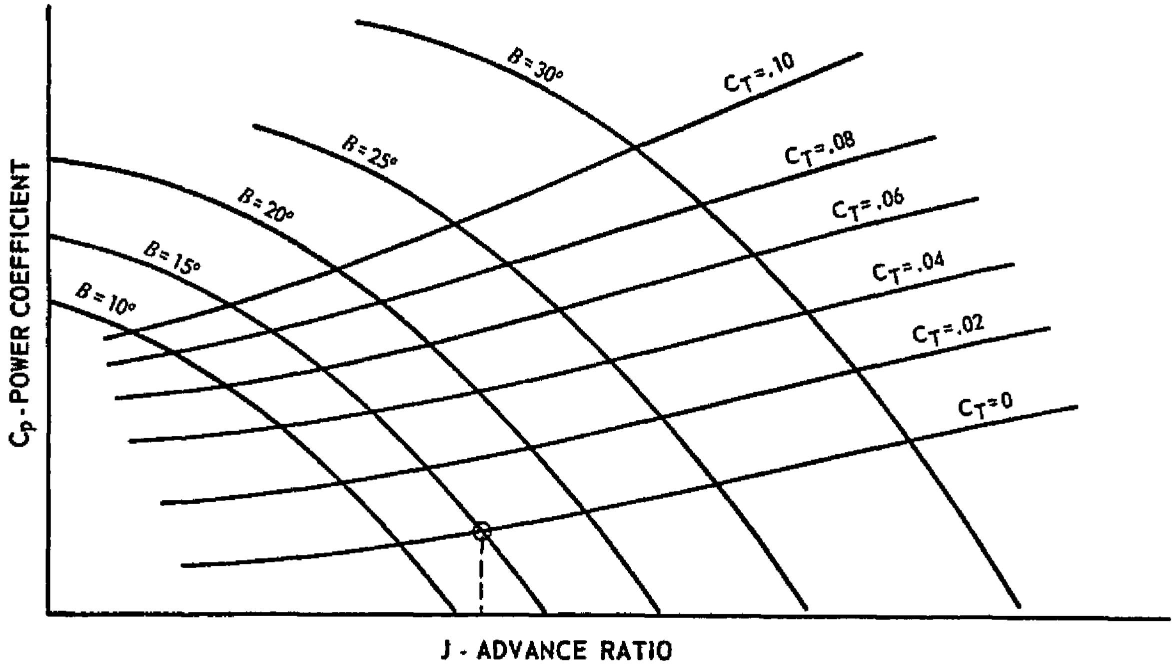


Figure 17-2 - PROPELLER COEFFICIENTS

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

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

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

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

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

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

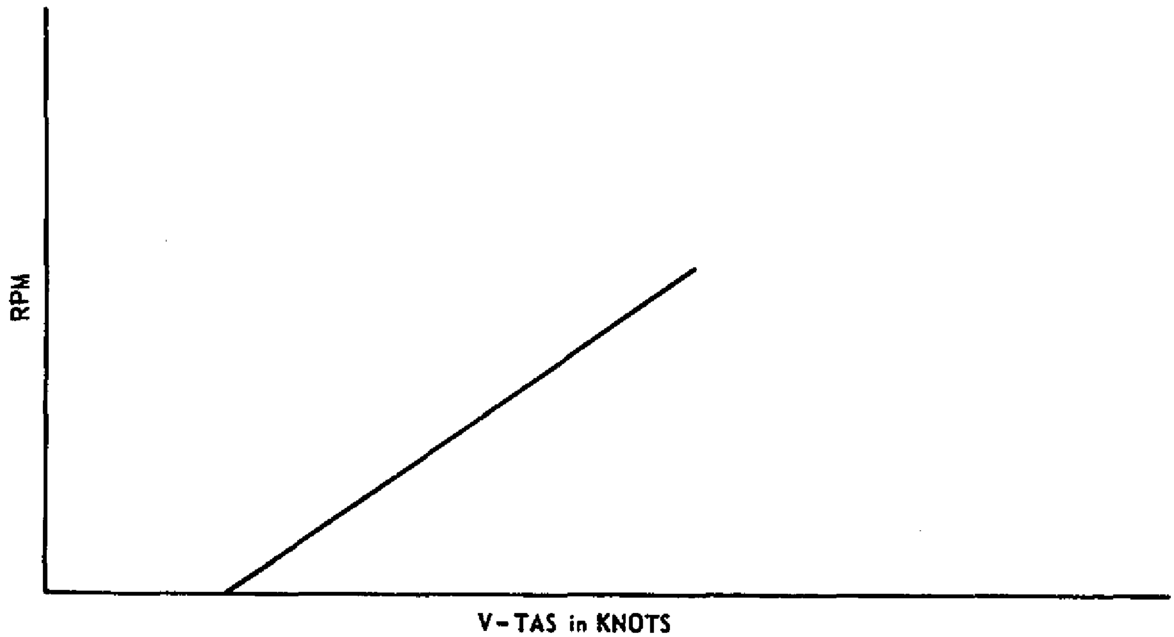


Figure 17-3 - ZERO THRUST

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

b. Procedures.

(1) Instrumentation.

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

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

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

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

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

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

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

(2) Test.

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

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

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

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

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

(3) Data Reduction. The correction involves:

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

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

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

Where V_S = Stall speed (CAS)

V_{st} = Test stall speed (CAS)

W_s = Standard weight (lbs.)

W_t = Test weight (lbs.)

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

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

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

a. Explanation.

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

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

(i) 1.1 V_{MC}, or

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

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

(i) 1.3 V_{S1}, or

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

(4) Takeoff Speed Investigations - General.

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

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

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

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

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

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

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

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

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

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

b. Procedures.

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

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

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

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

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

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

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

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

V_w = wind velocity (feet/second)

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

+ is used for headwind and - for tailwind

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

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

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

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

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

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

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

+ for upslope and - for downslope

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

b. Commuter Category Airplanes.

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

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

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

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

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

(v) <u>Section 23.53(c)(4) - Rotation Speed (V_R).</u>

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

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

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

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

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

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

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

(C) All-engines-operating abuse tests.

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

(i) An abuse on rotation speed, and

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

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

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

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

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

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

b. Procedures.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

(i) Heavy to light weight as required.

(ii) Most critical c.g. position.

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

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

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

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

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

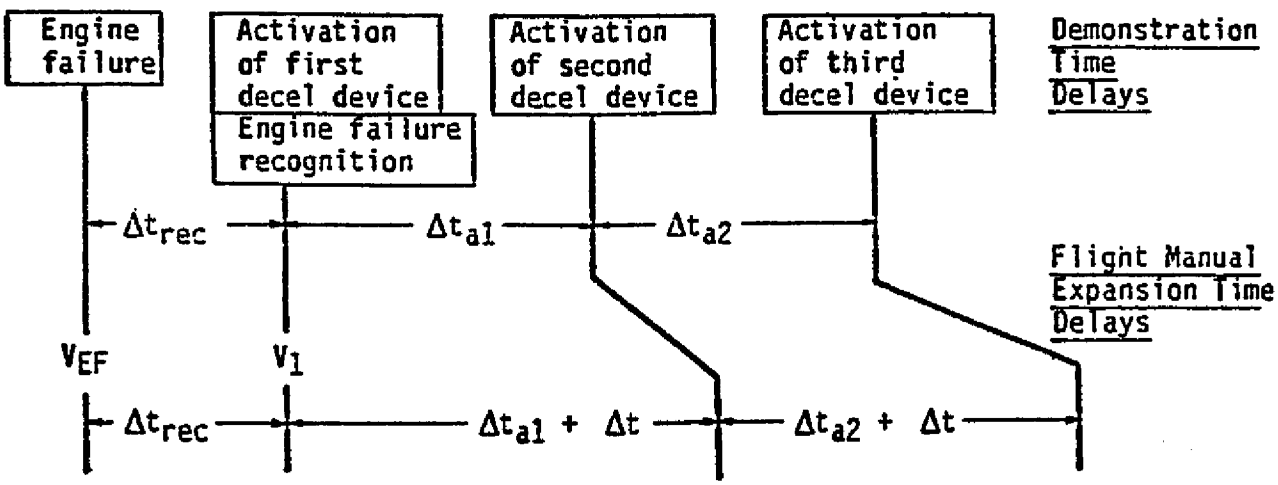


Figure 21-1 - ACCELERATE-STOP TIME DELAYS

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

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

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

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

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

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

22. <u>SECTION 23.57 (as added by amendment 23-34) TAKEOFF PATH</u>.

a. <u>Section 23.57(a)</u>.

(1) <u>Explanation</u>.

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

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

(2) <u>Procedures</u>.

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

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

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

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

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

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

(2) Procedures.

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

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

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

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

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

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

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

(B) Release brakes.

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

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

(A) Release brakes.

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

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

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

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

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

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

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

(2) Procedures.

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

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

Given:

- o Takeoff surface pressure altitude (Hp) = 2000 feet
- o Airport std. temp. abs. (T_S) = $11^oC+273.2 = 284.2^ok$
- o Airport ambient temp. abs. (T_{AM}) = $-20^oC+273.2 = 253.2^ok$
- o ΔGeometric height required (Δh) = 1500 feet above the takeoff surface

Find:

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

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

(1) Explanation.

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

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

(2) Procedures. None.

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

(1) Explanation.

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

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

(2) Procedures.

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

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

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

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

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

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

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

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

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

(ii) The actual performance variation during the segment.

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

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

(2) Procedures. None.

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

(1) Explanation. None.

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

k. Turboprop Reduced Power Takeoffs.

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

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

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

(ii) The reduced takeoff power setting

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

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

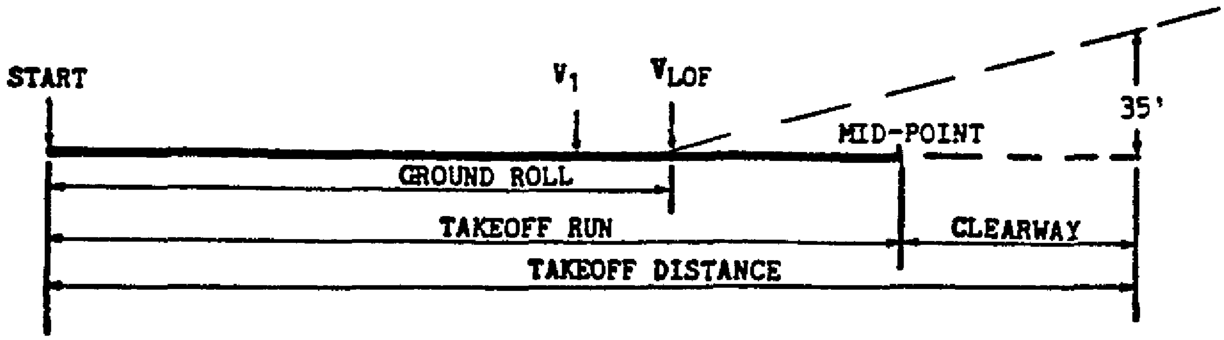


Figure 23-3 - TAKEOFF RUN
Critical Engine Failure Recognized at V_1

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

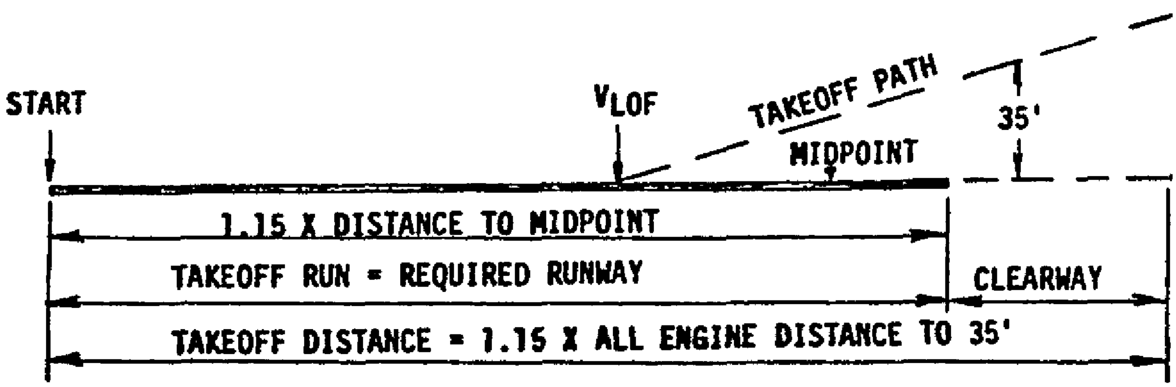


Figure 23-4 - TAKEOFF RUN
All Engines Operating

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

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

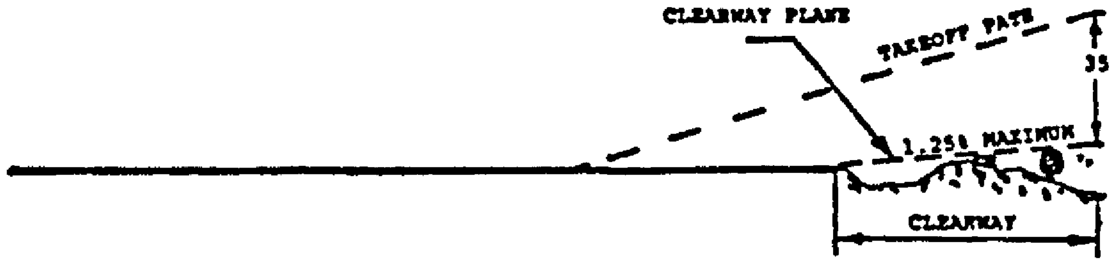


Figure 23-5 - CLEARWAY PROFILES

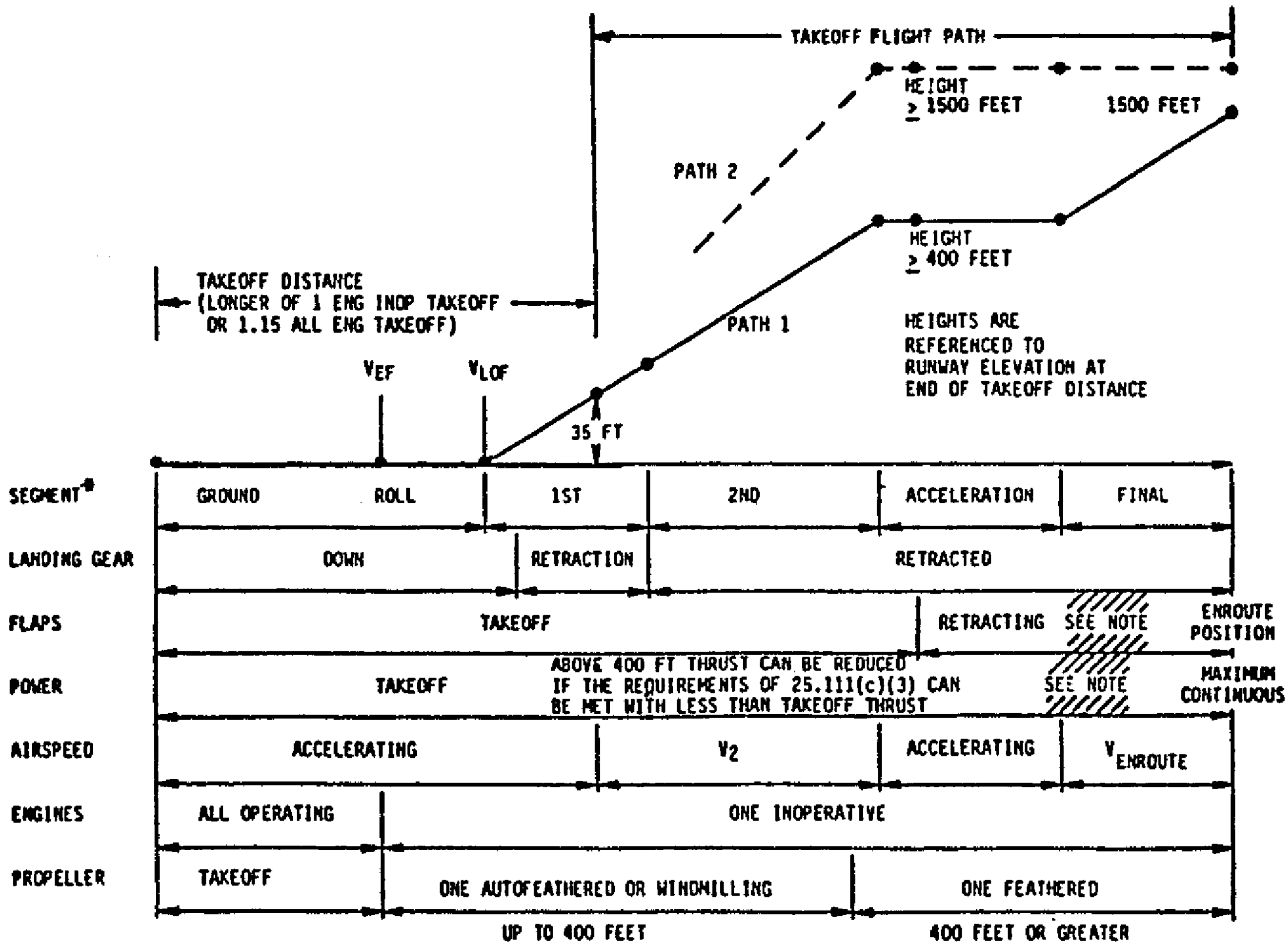
24. SECTION 23.61 (as added by amendment 23-34) TAKEOFF FLIGHT PATH.

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

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

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

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



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

*Segments as defined by § 23.67.

Figure 24-1 - TAKEOFF SEGMENTS AND NOMENCLATURE

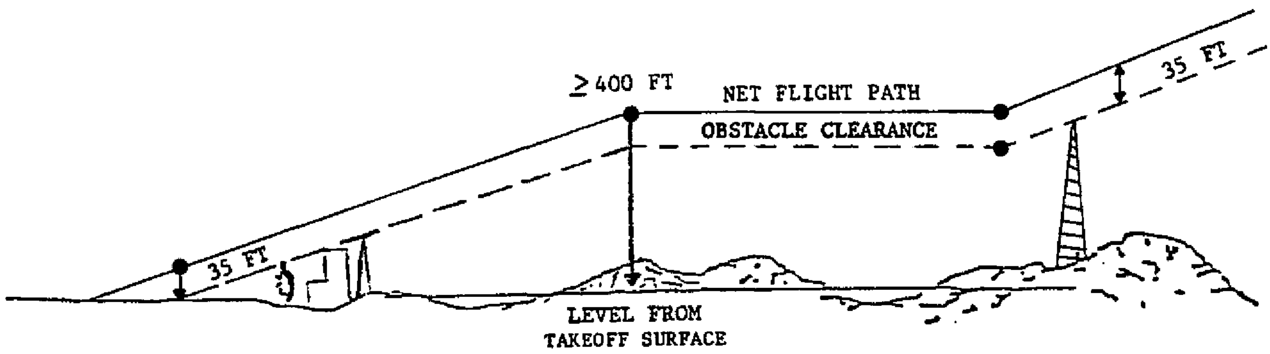


Figure 24-2 - NET TAKEOFF FLIGHT PATH

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

a. Explanation.

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

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

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

(i) As near sea level as practical.

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

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

b. Procedures - Sawtooth Climbs.

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

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

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

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

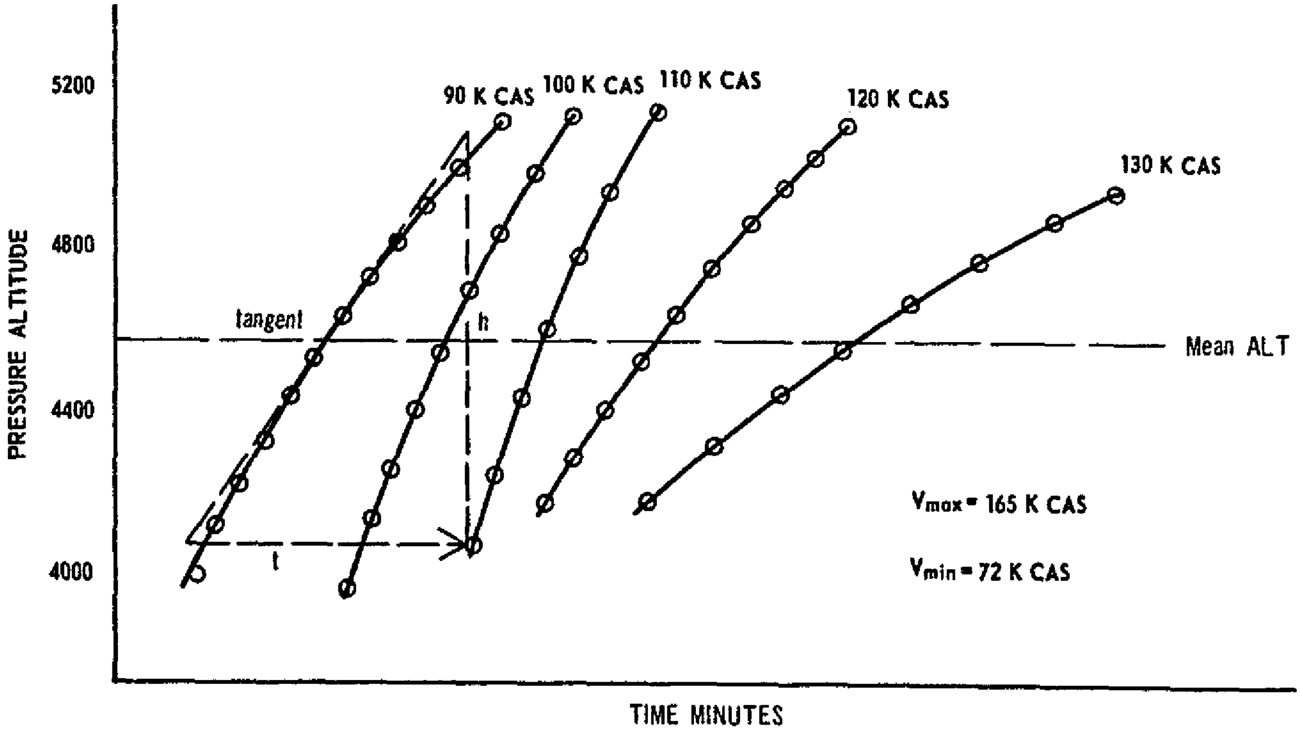


Figure 25-1 - OBSERVED DATA

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

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

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

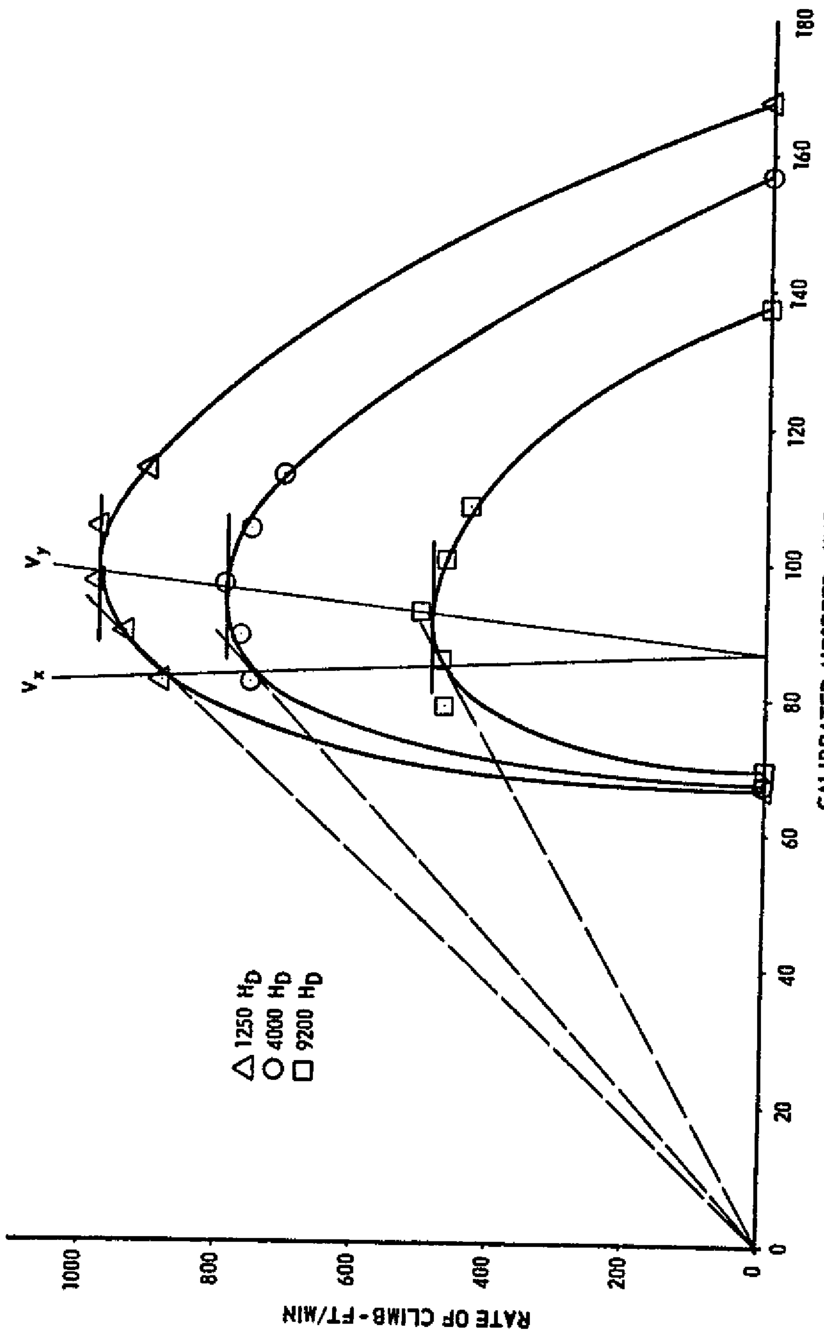


Figure 25-2 - RATE OF CLIMB VS. AIRSPEED

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

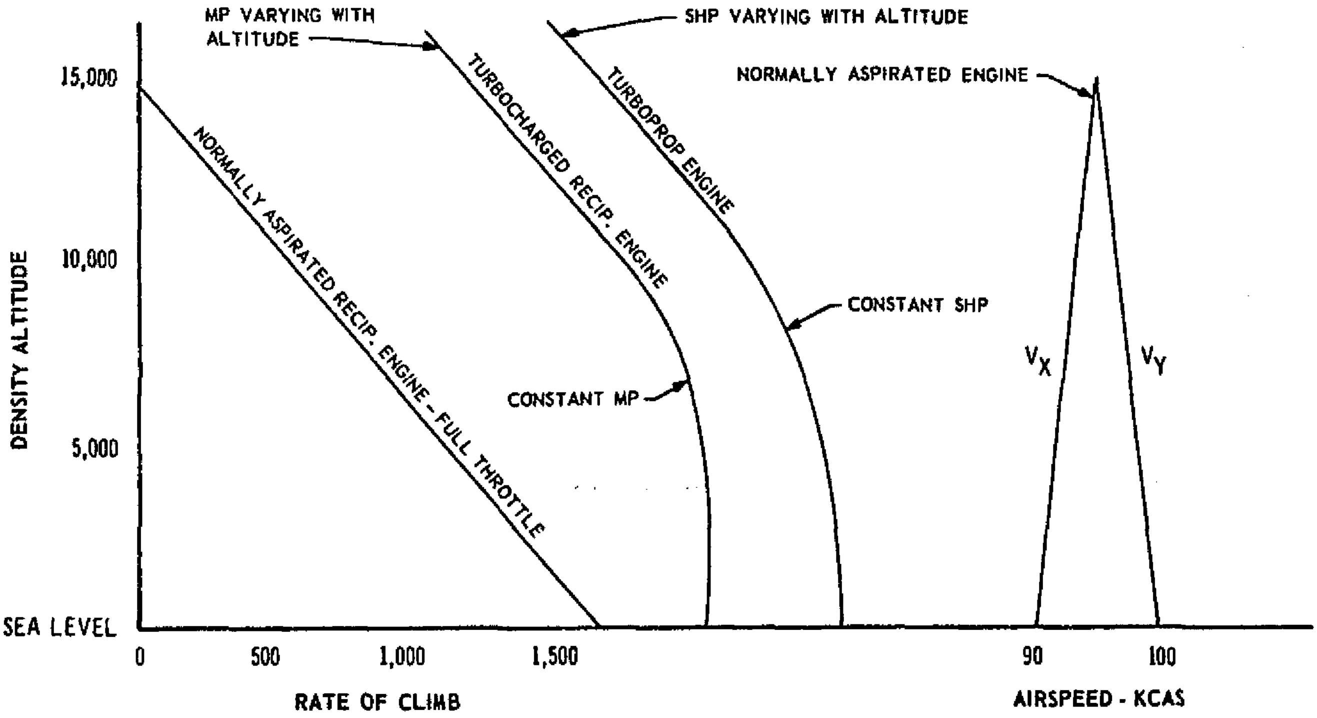


Figure 25-3 - RATE OF CLIMB AND SPEEDS

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

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

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

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

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

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

a. Normal, Utility, and Acrobatic Category Airplanes.

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

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

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

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

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

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

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

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

b. Procedure.

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

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

c. Commuter Category Airplanes.

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

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

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

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

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

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

(5) Power. See paragraph 22b.

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

a. Explanation.

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

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

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

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

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

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

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

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

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

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

(10) Commuter Category.

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

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

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

b. Procedures.

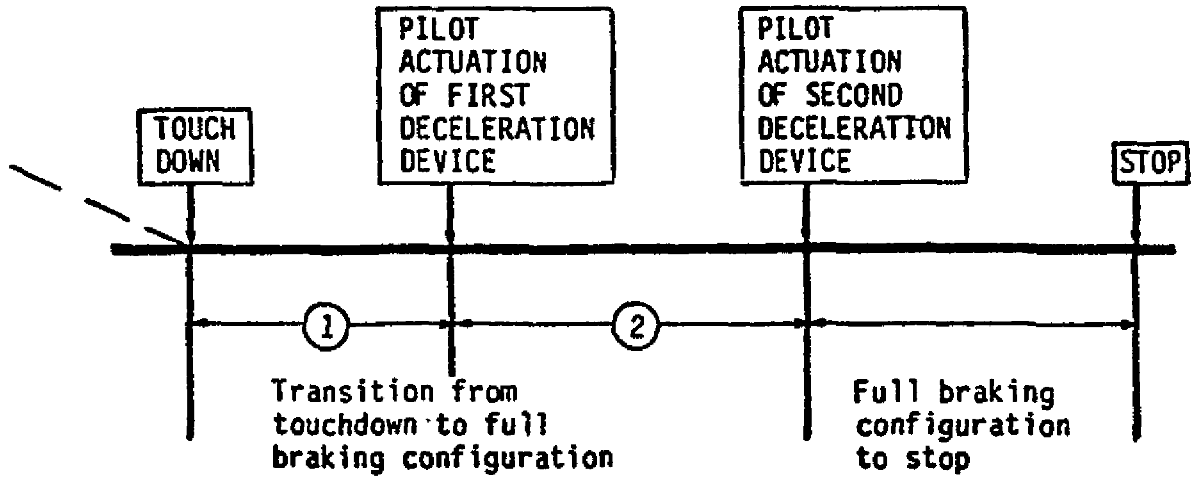
(1) Technique. The landing approach should be stabilized on target speed, power, and the airplane in the landing configuration prior to reaching the 50-foot height to assure stabilized conditions when the airplane passes through the reference height. The engine fuel control should be adjusted to the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

(2) Commuter Category Time Delays.

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

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

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



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

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

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

Figure 27-1 - LANDING TIME DELAYS

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

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

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

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

c. Data Acquisition.

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

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

(ii) Pressure altitude.

(iii) Ambient air temperature.

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

(v) Engine power or thrust data.

(vi) Cowl flap position.

(vii) Wing flap position.

(viii) Runway slope.

(ix) Direction of landing run.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

d. Procedures (Commuter Category).

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

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

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

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

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

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

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

29.-38. RESERVED.

Section 3. FLIGHT CHARACTERISTICS

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

a. Explanation.

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

of the fundamental nature of the airplane which 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 judgment by the 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 which requires rapid recognition and reaction to be coped with successfully.

(3) Stall Speed Multipliers. All flying qualities and trim speeds may be based on the forward c.g. stall speeds.

b. Procedures. None.

40.-44. RESERVED.

Section 4. CONTROLLABILITY AND MANEUVERABILITY

45. SECTION 23.143 (as amended by amendment 23-17) GENERAL.

a. Explanation.

(1) Temporary Control Forces. Temporary application, as specified in the table, 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 maximum pitch force less than 75 pounds is required for safety. For example, if a pilot is trying to overpower a nose-up malfunction during climb and reduce power at the same time, a maximum safe force may be less than 75 pounds. 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.

(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 directional 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, it is necessary that the airplane be controllable, since a change about one of the axis is necessary in order to change a direction of flight. It should also be noted that 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 purely 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.

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 Unbalance. Lateral fuel imbalance flight evaluations should be conducted on all airplanes where the wing fuel tanks are configured such that lateral trim and controllability may be affected by unbalanced fuel loadings. 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) En Route - All engine, one-engine-inoperative (multiengine airplanes), and autopilot coupled operations.

(iii) Approach and Landing - All engine, one engine inoperative (multiengine airplanes), crosswind, and autopilot coupled operations.

As a result of flight tests, appropriate lateral fuel 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.

46. SECTION 23.145 (as amended by amendment 23-17) 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) Amendment 23-21 Revision Errors. Amendment 23-21 revised § 23.161 and deleted § 23.161(c)(4), among other changes. Sections 23.145(a)(2), 23.145(b)(4), 23.145(b)(6) and 23.145(d) were not updated to pick up the proper § 23.161 reference paragraphs. Sections 23.145(a)(2), 23.145(b)(4), 23.145(b)(6) and 23.145(d) should refer to § 23.161(c)(2), the approach condition.

(4) One Hand Control Force. The "exertion of more control force than can readily be applied with one hand for a short period of time," mentioned in § 23.145(b), is synonymous with the temporary application discussed in paragraph 45a(1) of this AC.

(5) 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. Reference to § 23.677(b) makes it clear that § 23.145(e) is the flight test to demonstrate compliance with the requirement of § 23.677(b) which specifies a failure of the primary control system.

(6) 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. A low altitude and an altitude near the maximum altitude capability of the airplane. A high altitude may not be needed for normally aspirated engine airplanes.

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

(3) C.G. Section 23.145(a), most aft c.g. and most aft c.g. approved for any weight; § 23.145(b) 1 through 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 10-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.

47. SECTION 23.147 (original issue) DIRECTIONAL AND LATERAL CONTROL.

a. Explanation.

(1) Engine Failure. Section 23.147(a) established a minimum maneuvering capability for an airplane that has sustained an engine failure after takeoff at a point in the climb-out path where the airplane has reached a speed of 1.4 V_{S1}, or V_Y (applicant's option). This test assures enough aileron and rudder control to prevent loss of control during mild maneuvering which may be operationally necessary during climb-out after takeoff.

(2) Yawed Flight. Section 23.147(b) 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 15° of heading

change or the 150-pound force limit providing there are no dangerous characteristics. The control stop serves more effectively than the 150-pound force to limit the pilot's ability to induce a yaw beyond that which has been demonstrated acceptable.

b. Procedures. The airplane configurations to be tested are:

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

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

(3) The rearmost allowable center of gravity.

(4) The landing gear:

(i) retracted; and

(ii) extended.

(5) The flaps in the most favorable climb position.

(6) Maximum weight.

(7) Airplane trimmed, if possible.

c. Data Acquisition. Data should be recorded as necessary to substantiate compliance. Forces may be estimated unless they are considered marginal.

48. SECTION 23.149 (as amended by amendment 23-21) MINIMUM CONTROL SPEED.

a. Background. Section 23.149 requires the minimum control speed to be determined. Section 23.1545 requires the airspeed indicator to be marked with a red radial line. Section 23.1583 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 Reciprocating 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 without requiring pilot action.

(3) Propeller of the Inoperative Turbine Engine. Section 23.149c(5) requires the airplane to be in the most critical configuration when determining V_{MC}. The critical propeller configuration is usually windmilling. Many turbine-powered airplanes have automatically feathered (or otherwise driven to a minimum drag position) propellers which do not require pilot action.

(4) 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 aileron travel. For these reasons, V_{MC} tests should be conducted with rudder and aileron (if applicable) controls set at minimum travel. In addition, rudder and aileron control cable tensions 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.

(5) 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 and 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.

(6) Fuel Loading. The maximum allowable fuel unbalance 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 which generally requires maximum rudder and/or near maximum aileron deflection (unless limited by temporary control forces) 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 5° of bank toward the operating engine. Since 5° of bank allows the airplane to attain (or be closer to) zero sideslip, the 5° of bank is generally used as the option in certification.

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

(5) Deicer Boots. The installation of deicer boots, antennas, and other external gear could change the V_{MC} speed significantly. Reevaluation of the V_{MC} speed should be considered when these installations are made. See AC 23.1419-1 if a "flight into icing" approval is being sought.

(6) Variable V_{MC}. For commuter category airplanes, a V_{MC} which 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 anytime 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.

All annunciations should be evaluated to verify that they can be easily and quickly recognized. For critical systems, the AFM limitations should require a satisfactory preflight check and that the autofeather be armed 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, etc., 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. See subparagraph c(6) for a further explanation of extrapolation methods. If tests are conducted at less than approximately 3000 feet density altitude, no corrections to V_{MC} are normally necessary. If tests are conducted above 3000 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) Flap Settings. An applicant may want to specify more than one takeoff flap setting which would require V_{MC} investigation at each flap setting.

(4) 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.

(5) 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 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. Set the flaps to the takeoff setting being investigated. The landing gear should be in the retracted position.

(ii) Trim. The airplane should be trimmed to the settings associated with normal symmetrical power takeoff.

(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 5° bank option will be used (see paragraph 48b(3)) to maintain straight flight. A yaw string may be used to assist the test pilot in attaining zero sideslip (or minimum sideslip). The approximate ball deflection should be noted for inclusion in the AFM.

(v) Critical Engine. Repeat steps (i) thru (iv) 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 (i) thru (iv) with the critical engine inoperative and with the propeller windmilling.

(6) 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. Appendix 3 shows one method for extrapolating V_{MC} from test conditions to sea level standard day.

(7) 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 cut-off control) dynamically while gradually working speed back toward the static V_{MC} 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 be more than 20° 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 due to the fact that the inoperative engine, during spooldown, may provide net thrust or that control force peaks exceed limit values for a short period and go undetected or that due to high yaw and pitch angles and rates, the indicated airspeed values are errroneous. 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.

(8) Repeatability. Once determined, the dynamic V_{MC} should be verified by running a series of tests to determine the speed is repeatable. The dynamic V_{MC} speed is the minimum control speed for the airplane. This speed may not exceed 1.2 V_{S1} at maximum gross weight and the most unfavorable c.g. for stall speeds.

(9) AFM Minimum Control Speed Value. V_{MC} is usually observed at several different power settings and/or altitudes. 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 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.

49. SECTION 23.151 (original issue) 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 which 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.

(4) Maximum r.p.m.

50. SECTION 23.153 (as amended by amendment 23-14) CONTROL DURING LANDINGS.

a. Explanation.

(1) Purpose. The purpose of this requirement is to ensure that airplanes over 6000 pounds gross weight do not encounter excessive control forces when approaching at a speed of 5 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.

51. SECTION 23.155 (as added by amendment 23-14) 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 overstressing 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 should 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 should be investigated in the cruise configuration; that is, flaps up and gear up (if retractable):

Condition	Power	Level Flight Trim Speed	Altitude
1	75% Maximum Continuous Power (reciprocating engine) or Maximum Cruise Power (turbine)	Trimmed (but not to exceed V_{NE} or V_{MO}/M_{MO})	Low
2	75% Maximum Continuous Power (reciprocating engine) or Maximum Cruise Power (turbine)	Trimmed	Altitude for highest dynamic pressure (q)
3	75% Maximum Continuous Power (reciprocating engine) or Maximum Cruise Power (turbine)	V_A	Low
4	75% Maximum Continuous Power (reciprocating engine) or Maximum Cruise Power (turbine)	V_A	Highest attainable approved altitude

Compliance may be demonstrated by measuring the normal acceleration achieved with the limiting stick force 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. Nonlinear 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) Wt./c.g.

(2) Pressure altitude.

(3) Outside air temperature (OAT).

(4) Engine power parameters.

(5) Trim setting.

(6) Elevator force.

(7) Normal acceleration at c.g.

(8) Gear/flap position.

The test data should be presented in stick force versus g plots. Figure 51-1 shows a sample plot. Test results should be compared to the requirements of § 23.155(a).

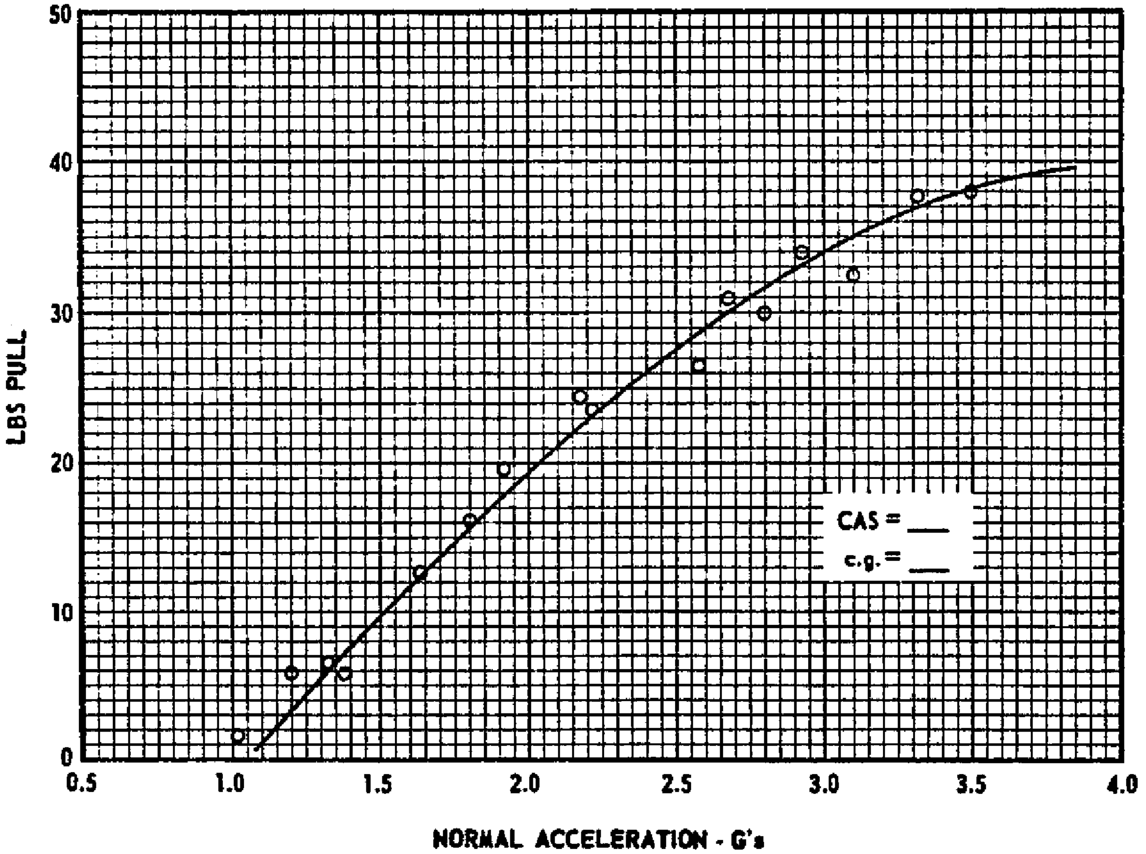


Figure 51-1 - Stick Force Per G

52. SECTION 23.157 (as added by amendment 23-14) 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° bank and rolled through an angle of 60°. For example, with the airplane in a steady 30° left bank, roll through a 30° 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 weight.

c. Commuter Category Airplanes. The original intent of § 23.157 did not extend the formulas in the rule to a weight above 12,500 lbs. Extending the formulas above 12,500 lbs. would result in excessive roll times. Roll times for commuter category airplanes should not exceed the roll times allowed for airplanes weighing 12,500 lbs.

53.-62. RESERVED.

Section 5. TRIM

63. SECTION 23.161 (as amended by amendment 23-34) 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 and thus, ground adjustable tabs are acceptable. For lateral-directional testing, the tabs may be adjusted for the test trim airspeed and readjusted for subsequent tests. For multiengine airplanes, directional trim is required for a range of speeds. Lateral baggage loading and fuel asymmetry should be considered in this evaluation, if appropriate.

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.

64.-69. RESERVED.

Section 6. STABILITY

70. SECTION 23.171 (original issue) 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 at any speed between the trim speed and those specified in § 23.175, rapidly enough for any substantial change in speed, through a change in the control forces, to be easily perceptible by the pilot. There shall be no reversal (that is, require forward push) in the control forces at any speed below the speeds specified in § 23.175 until the stalling speed is reached, that is, the control force shall in no case fall below zero before the stall is reached when trimmed as specified in § 23.175.

b. Procedures. None required for this section.

71. SECTION 23.173 (as amended by amendment 23-34) 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.

(3) Stable Slope. Section 23.173(c) is an extremely general requirement which requires the test pilot's best judgment as to whether or not 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.

b. Procedures. Refer to paragraph 72.

72. SECTION 23.175 (as amended by amendment 23-34) DEMONSTRATION OF STATIC LONGITUDINAL STABILITY.

a. Explanation. Section 23.175(b)(3) requires a power setting that will produce a speed for the trim point that is midway between the trim point used in testing high speed cruise and 1.3 V_{S1}, which usually necessitates testing at the high speed cruise condition first.

b. Procedures.

(1) Section 23.175(a) Climb.

(i) Pull. 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.

After observing trim speed, apply a light 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 very 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% (7.5% for commuter category airplanes in cruise) of the trim speed.

(ii) Push. 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% of the trim speed and the same determination should be made.

(2) Other Stability Test Procedures. The balance of the stability requirements is flown using the same flight techniques described for climb stability, but using the configurations, trim points, and speed ranges being tested as described in each subparagraph.

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. See figure 72-1 for an example of the data plot. Section 23.179 allows for qualitatively determining that the stability requirements are met, but in most programs, force measurements are taken to substantiate longitudinal stability. Collect test data within a reasonable altitude band of the trim point altitude, such as ±2000 feet.

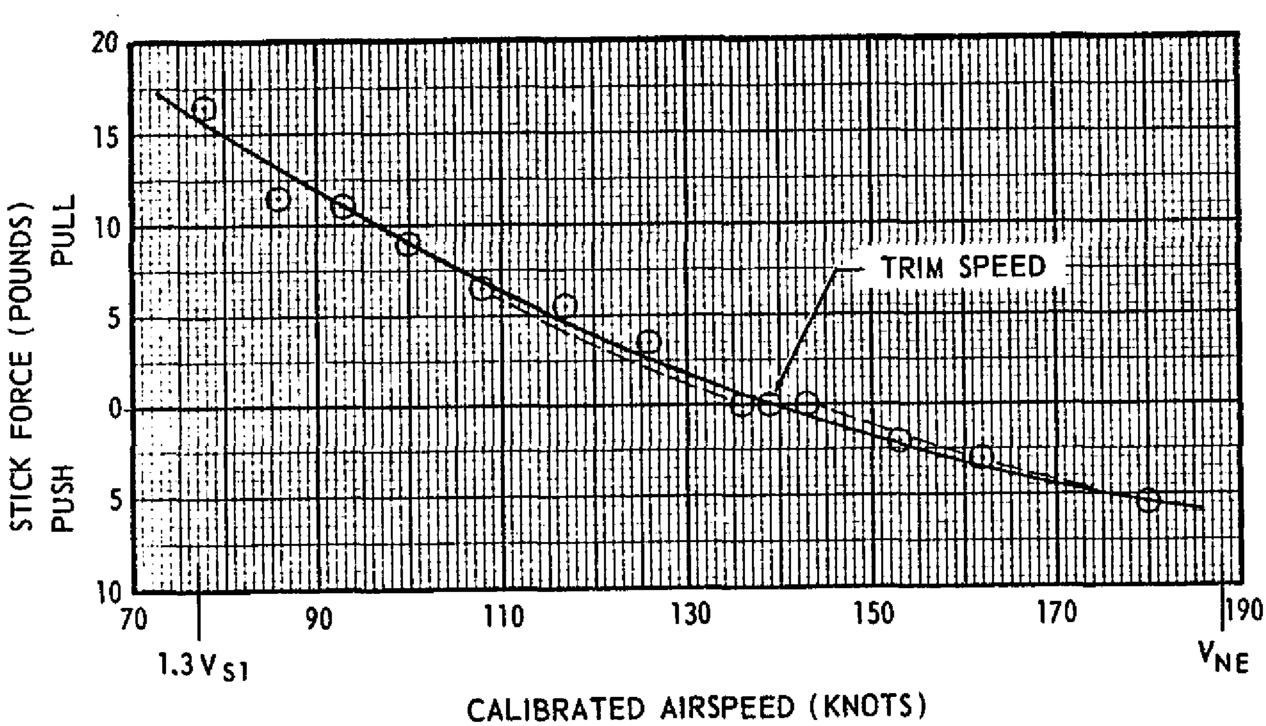


Figure 72-1 - STATIC LONGITUDINAL STABILITY PLOT (CRUISE CONDITION)

73. SECTION 23.177 (as amended by amendment 23-21) STATIC DIRECTIONAL AND LATERAL STABILITY.

a. Explanation.

(1) Purpose. The purpose of this section is to require positive directional and lateral stability for two- and three-control airplanes, and to verify the absence of rudder lock tendencies in three-control airplanes.

(2) Directional Stability. In § 23.177(a)(1), the determination of "appropriate" skid angles will depend on sound judgment in considering such things as airplane size, maneuverability, control harmony, and forces to determine the magnitude of skid angles 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(a)(2)) take a similar approach in that the basic requirement must be met at the 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}.

(4) Forces. The requirement of § 23.177(a)(3) is to be tested at a speed of 1.2 V_{S1} and larger than "appropriate" sideslip angles. At angles up to those which require full rudder or aileron control, or until the rudder or aileron force limits specified in the table in § 23.143 are reached, the rudder force may lighten but may not reverse.

(5) Two-Control Airplanes. For two-control airplanes, § 23.177(b)(1) is essentially a check of the adverse yaw characteristics with aileron input. A rapid roll from 45° of bank on one side to 45° on the other should not produce dangerous skid conditions.

(6) Spiral Stability. Section 23.177(b)(2) is a check of spiral stability. A dangerous attitude is construed to be 60° or more of bank, 30° or more of pitch, while a dangerous speed is V_{NE} or V_S.

(7) 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.

b. Procedures.

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

(2) Fuel Loading. The maximum allowable fuel unbalance should be maintained and both low fuel and full fuel loadings should be evaluated.

(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. See paragraph 63a for discussion of 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. See paragraph 63a for discussion of ground adjustable tabs. Section 23.177(a)(2) requires the slip angle to be appropriate to the type of airplane and the bank angle to be at least 10°. Some airplanes cannot maintain a heading in a slip with a 10° bank angle. In those cases, the slip should be performed with no less than a 10° bank and full opposite rudder and the heading allowed to vary. When the ailerons are released, the low wing should tend to return to level. The pilot should not assist the ailerons during this evaluation. The pilot should hold full rudder during the evaluation. The stability may be neutral at 1.2 V_{S1}.

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

74. SECTION 23.179 (original issue) INSTRUMENTED STICK FORCE MEASUREMENTS.

a. Explanation. None required.

75. SECTION 23.181 (as amended by amendment 23-21) DYNAMIC STABILITY.

a. Explanation - Longitudinal.

(1) Short Period. The short period oscillation is a qualitative evaluation and is the first oscillation the pilot sees after disturbing the airplane from its trim condition with the elevator control, as opposed to the long period oscillation (phugoid) which is sometimes excited along with the short period.

(2) Heavily Damped. For qualitative evaluations of longitudinal oscillations, the motion damping should appear "deadbeat;" that is, no residual oscillations that are perceptible to the pilot. If the damping is not "deadbeat," then an instrumented flight should be conducted and the airplane should be damped within two cycles after initial input. For lateral-directional oscillations (except Dutch roll), usually a qualitative evaluation will suffice, and the motion should be damped within two cycles.

b. Procedures - Longitudinal.

(1) General. The test for longitudinal dynamic stability is accomplished by a movement or 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. 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 deviations 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. The influence of control system springs/bob-weights can be significant.

(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) Dynamic Longitudinal Stability. Dynamic longitudinal stability should be checked under all the conditions and configurations that 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. Explanation - Lateral/Directional. Section 23.181(b) only requires investigation of the "Dutch roll" mode of the various lateral/directional couplings. Since the airplane responds in yaw through the Dutch roll mode every time it is disturbed in yaw, either by lateral gusts or by pilot inputs, the Dutch roll will be excited. The damping of the Dutch roll motion is probably the most important Dutch roll characteristic to be considered.

d. 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 which 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 very 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, full rudder, or a comfortable rudder force input. 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.

e. 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 which 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.

f. 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 7 cycles.

76.-85. RESERVED.

Section 7. STALLS

86. SECTION 23.201 (as amended by amendment 23-14) WINGS LEVEL STALL.

a. Explanation.

(1) Stall. Section 23.201(c) defines when the airplane can be considered stalled, for airplane certification purposes. When either of two conditions occurs, whichever occurs first, the airplane is stalled. The conditions are:

(i) Uncontrollable downward pitching motion; or

(ii) the control reaches the stop.

Additionally, for airplanes with a stall barrier system, stick pusher operation has been considered as the stall speed. The term "uncontrollable downward pitching motion" is the point at which the pitching motion can no longer be arrested by application of nose-up elevator and not necessarily the first indication of nose-down pitch. Figure 17-1 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 for airplanes with independent roll and directional controls, 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.

(4) Power. The propeller condition for the "power-off" tests prescribed by § 23.201(f)(6) 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 propeller thrust does not apply to stall characteristics demonstrations.

(5) Altitude Loss. Altitude loss in excess of 100 feet and nose-down pitch in excess of 30° will be entered in the performance information section of the AFM in accordance with § 23.1587(a)(1) for the wings level stalls. 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.

(6) Configurations. Stall characteristics should be evaluated:

(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 fuel unbalance.

(iv) At or near maximum approved altitude.

Also, 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. The FAA test pilot should carefully review the applicant's flight test report on stall and recovery characteristics. 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% power, but high enough to accomplish a safe recovery. The 75% power requirement means 75% 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% power.

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

(i) That the stick force curve remains positive up to the stall (that is, a pull force is required) (reference § 23.173(a)) 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 altitude loss.

(iv) The pitch attitude below level.

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

(vi) For two-control airplanes with interconnected lateral and directional controls, that it is possible to produce and correct roll up to the stall without producing what, in the opinion of the test pilot, is considered as "excessive yaw."

(4) Speed Reduction Rate. Section 23.201(c) 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. (See figure 17-1, stall speed determination.)

d. Stick Pusher.

(1) Background. Stick pushers have been installed in some airplanes which 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:

(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 15° 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° 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 3 knots or 5% 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 5 knots. For other airplanes with known and less hazardous aerodynamic stall characteristics, the speed margin may be reduced to not less than 2 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.

87. SECTION 23.203 (as amended by amendment 23-14) TURNING FLIGHT AND ACCELERATED STALLS.

a. Explanation.

(1) Explanations 86a(2) and (4) for wings level stalls also apply to turning flight and accelerated stalls.

(2) The only differences between the investigation required for turning flight and accelerated stalls are in the speed reduction rate and wing flap configurations.

b. Procedures.

(1) Procedure 86b(1) for wings level stalls applies to turning flight and accelerated stalls.

(2) During the maneuver, the test pilot should determine:

(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 pitchup.

(iv) That there are no uncontrollable spinning tendencies; i.e., 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 did not exceed 60° incremental in either direction.

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

(3) Section 23.203(a) requires the rate of speed reduction for a turning flight stall not exceed one knot per second; for an acclerated stall, 3 to 5 knots per second with steadily increasing normal acceleration.

c. Data Acquisition. Same as for wings level stalls.

88. SECTION 23.205 (as amended by amendment 23-14) CRITICAL ENGINE INOPERATIVE STALLS.

a. Explanation.

(1) Undue Spinning. In addition to the other stall requirements, for multiengine airplanes, § 23.205(a) requires that there be no undue tendency to spin when stalled from an unaccelerated wings level entry with the critical engine

inoperative. An "undue spinning" tendency would be considered to exist when other than normal use of the controls or exceptional skill, strength, or alertness were required to prevent spinning. In this case, reduction of power on the operating engine(s) during recovery, would be considered normal use of the controls.

(2) Power. Section 23.205(b)(4) states, ". . . the remaining engine(s) at 75% maximum continuous power or thrust, or the power or thrust at which the use of maximum control travel just holds the wings laterally level in the approach to stall . . . ." This section states that if use of maximum rudder or aileron control cannot maintain a wings level attitude prior to the stall, the power may be reduced from 75% MCP to a point where maximum control travel just maintains wings level approaching the stall. The intent of this section is to check one-engine-inoperative stall characteristics, not engine-out lateral directional control capability which is covered under tests for V_{MC}.

(3) Propeller. If propeller feathering is available (manual or automatic), the propeller on the inoperative engine should be feathered.

b. Procedures. With the airplane trimmed longitudinally as specified in § 23.205(b)(6), with the critical engine inoperative, gear and flaps up, and 75% MCP on the operating engine, conduct a wings level stall by reducing the airspeed with the elevator control at a rate not greater than 1 knot per second. Keep the wings level and heading constant up to the stall. If there is insufficient control to do so, discontinue the maneuver and start over with reduced power on the operating engine. The power reduction should be just enough to allow keeping wings level and heading constant with full control travel. The operating engine(s) may be throttled back during the recovery, but care should be exercised to reduce previous control inputs as the power is reduced. Record the altitude loss incurred during the stall in compliance with § 23.1587(c)(1). The stalls should be accomplished in smooth air.

c. Data Acquisition. Same as for other wings level stalls of § 23.201.

89. SECTION 23.207 (as amended by amendment 23-7) 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.

(4) Margin. The stall warning margin between 5 knots and the greater of 10 knots or 15% of the stalling speed, is applicable when the speed is reduced at the rate of one knot per second. Stall warning margin at greater deceleration rates should not be less than 5 knots above the stall or above a speed at which warning would become objectionable in the normal operating range.

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

c. Data Acquisition and Reduction. The speed at which stall warning is obtained should be recorded. This speed should be compared to the corresponding stall speed for the required stall warning margin of between 5 and the greater of 10 knots or 15% of the stalling speed above the corresponding stalling speed.

90.-99. RESERVED.

Section 8. SPINNING

100. SECTION 23.221 (as amended by amendment 23-7) SPINNING.

a. Explanation.

(1) Spin. A spin is a sustained auto rotation 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 four situations:

(i) Normal category spins.

(ii) Utility category spins.

(iii) Acrobatic category spins.

(iv) Airplanes characteristically incapable of spinning.

(3) Incapable of Spinning. If an airplane cannot be induced to spin, it may be considered "characteristically incapable of spinning." Section 23.221(d) gives the conditions of the test for this type of airplane.

(4) Utility Category Spins. Utility category airplanes must meet the spin requirements of either the normal or acrobatic category. Thus, the spin requirements reduce to either normal or acrobatic category requirements, each with its own objectives and tests.

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

(1) Weight and C.G. Envelope. See paragraph 7a of this AC for discussion of weight and c.g. envelope exploration.

(2) Control Deflections. Control surface deflections should be set to the critical side of the allowable tolerances, for example, if the rudder deflection is $20^{\circ} \pm 2^{\circ}$ left and right, it should be rigged at 18° left and right for the testing if the recovery phase is critical or 22° left and right if the entry phase is critical.

(3) 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)).

(4) Chutes and Ballast. A spin chute that has been structurally and functionally tested is recommended. NASA Technical Paper 1076, "Spin-Tunnel Investigation of the Spinning Characteristics of Typical Single-Engine General Aviation Airplane Designs," dated November 1977, may be of assistance in sizing the spin chute. In the past, rapidly movable jettisonable ballasts have been suggested but this may not effect recovery in practical use. 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 on spin characteristics.

(5) 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. See subparagraph 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.

(6) 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. Refer to paragraphs 100c and 100d for further discussion of spin entries.

(7) 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, unless the manufacturer determines the need for another procedure.

(8) Trimmable Stabilizer. For airplanes that trim with the horizontal stabilizer, the critical positions should be investigated.

(9) Altitude Engines. For airplanes with high-altitude engines, 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, etc.

c. Discussion 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 unrecoverable within one turn 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. Intentional, inadvertent, normal, and accelerated stalls should be considered.

(2) Uncontrollable Spins. Uncontrollable spins for normal category airplanes are defined as spins that persist after normal recovery control application is completed and one additional turn has passed. For example, if you are spinning left with right aileron (abnormal controls), recover by reducing power to idle, neutralize the ailerons, apply full right rudder followed by forward elevator. At this point, start the count (heading, ground reference, etc.) for one turn. If the manufacturer's recommended spin recovery procedure has a contingency step, such as, "apply forward elevator after rotation stops," then the count should start after the rotation stopping control is applied.

(3) Abnormal Control. The "abnormal" use of controls should not cause the airplane to become uncontrollable. "Pro-spin" is used to describe the use of the controls in the direction of the spin and is considered normal use of the controls; i.e., spinning left with left aileron, full back elevator, full left rudder and power on. "Anti-spin," "aileron against," and "abnormal use of controls" is control usage that is opposite the normal usage of controls. These conditions of control position would be expected to reduce the tendency to spin but, in fact, may aggravate or make the spin worse. The intent of all 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. 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.

(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. Flaps may be retracted after rotation ceases and the dive and pull-out are entered.

(6) Power. For power on normal category spins, the throttle can be reduced to idle after one turn.

(7) Back Pressure. Excessive back pressure is cause for noncompliance. Excessive back pressure is a judgment item and is defined as excessive force required to pitch the airplane down in recovery. Back pressure should not interfere with prompt and normal recovery.

d. Discussion 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:

(i) The controls are used abnormally (as well as normally) during the entry and/or during the spin;

(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) Uncontrollable Spins. Uncontrollable spins are defined as spins that persist after the normal recovery technique is applied and 1 1/2 additional turns have passed. The discussion of "abnormal" use of controls in paragraph 100c(3) also applies to acrobatic category spins.

(4) 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 100-1. 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.

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.	Slow Elevator Releases
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 from left and right turning flight.														
Tests with Abnormal Spin Controls	7	X			X		X		X		X	X	X	X
Left Spin Aileron Against 7 Thru 12	8		X			X	X		X		X	X	X	X
	9			X		X	X		X		X	X	X	X
	10	X			X			X		X	X	X	X	X
	11		X			X		X		X	X	X	X	X
	12			X		X		X		X	X	X	X	X
Repeat 7 Through 12 From a Right Spin														
Left Spin Aileron with 13 Thru 18	13	X			X		X		X		X	X	X	X
	14		X			X	X		X		X	X	X	X
	15			X		X	X		X		X	X	X	X
	16	X			X			X		X	X	X	X	X
	17		X			X		X		X	X	X	X	X
	18			X		X		X		X	X	X	X	X
Repeat 13 Through 18 From a Right Spin Repeat 7 Through 18 From Left & Right Turning Flight														

Figure 100-1 - SPIN EVALUATION CONFIGURATION MATRIX

(5) Spiral Characteristics. The acrobatic spin requirement stipulates that for the flap retracted six-turn spin, the spin may be discontinued after 3 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.

(6) Power. For power on acrobatic spins, the throttle can be reduced to idle after one turn.

(7) Recovery Placard. Section 23.1583(e)(3) 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.

101.-105. RESERVED.

Section 9. GROUND AND WATER HANDLING CHARACTERISTICS

106. SECTION 23.231 (original issue) LONGITUDINAL STABILITY AND CONTROL.

a. Explanation.

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

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

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

b. Procedures.

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

c. Procedures - Multiengine Airplanes. Evaluate all of the considerations contained in paragraph 106b, 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.

107. SECTION 23.233 (original issue) 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° crosswind component tested satisfactorily should be put in the AFM as performance information.

(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 23.333(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.

(i) 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.

(ii) 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.

(i) 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.

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

(3) Taxi Controllability.

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

(ii) 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 (multi-engine 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 that accepted techniques using one or more of the above must allow controllable taxiing.

(iii) 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° crosswind component has been tested.

108. SECTION 23.235 (original issue) TAXIING CONDITION.

a. Explanation. This requirement says 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.

109. SECTION 23.239 (original issue) SPRAY CHARACTERISTICS.

a. Explanation. This rule is intended to ensure that any spray produced during floatplane operation does not excessively interfere with the pilot's visibility nor damage beyond "normal wear-and-tear" the airplane itself.

b. Procedures.

(i) 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 contract areas on the airplane. These areas should be monitored to assure compliance with the rule.

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

110.-119. RESERVED.

Section 10. MISCELLANEOUS FLIGHT REQUIREMENTS

120. SECTION 23.251 (original issue) VIBRATION AND BUFFETING.

a. Explanation.

(1) Flutter. The test required under this section should not be confused with flutter tests which are required under § 23.629. No attempt is made to excite flutter, but this does not guarantee against encountering it. Therefore, the test 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. 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 calibrated airspeed 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 No.-calibrated airspeed graph may be found in the Air Force "Flight Test Engineering Handbook" (see 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. Also see paragraph 45 of this AC.

(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 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 above.

121. SECTION 23.253 (as amended by amendment 23-26) 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. It should be realized that 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) 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 multiaxis 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 mistrim 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 6 knots, or M_{MO} plus 0.01M.

(ix) Speed control during application of devices (power, speed brakes, high speed spoilers, etc.).

(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:

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

(ii) Increment allowance for penetration of jet stream or cold front (0.015M).

(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 (0.01M), 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, and the minimum acceptable combined value should not be less than 0.05M 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:

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

$$\text{or } M_{MO} = M_D - .05M$$

(vi) Altitudes where 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 3 and 6 knots, respectively, unless larger differences or errors are found to exist.

(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:

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

or for V_{NO} airplanes:

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

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. Unless otherwise stated, the airplane characteristics should be investigated at any likely speed up to and including V_{NO}/V_{MO} or M_{MO}; and the recovery procedures used should be those selected by the applicant, except that the normal acceleration during recovery should be 1.5g (total).

(1) Center-of-Gravity Shift. The airplane should be upset by the center-of-gravity 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 3 seconds after the overspeed indication or 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 5 seconds, after which recovery should be effected at not more than 1.5g (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 of the 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°, need not be greater than 60°, 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 3 seconds after V_{MO}/M_{MO} or 10 seconds, whichever occurs first.

(ii) Longitudinal Upset. Perform a longitudinal upset from normal cruise by displacing the attitude of the airplane (nose down from the trimmed attitude) in the range between 6-12°, 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. The airplane should be permitted to accelerate until 3 seconds after V_{MO}/M_{MO}.

(iii) Two-Axis Upset. Perform a 2-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° 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 3 seconds after V_{MO}/M_{MO}.

(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 1.5g (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 1.5g (total). The maneuver should be completed without exceeding V_D.

122.-131. RESERVED.

CHAPTER 3. DESIGN AND CONSTRUCTION

Section 1. GENERAL

132. SECTION 23.629 (as amended by amendment 23-31) FLUTTER. This subject is covered in AC 23.629-1A.

133.-137. RESERVED.

Section 2. CONTROL SYSTEMS

138. SECTION 23.671 GENERAL. (RESERVED).

139. SECTION 23.677 (as amended by amendment 23-34) 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 a 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 Backup 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 backup 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 other failures are considered to constitute a single failure for purposes of fault analysis; that is, 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. An aural or flashing visual warning signal (in clear view of the pilot), actuated by a trim-in-motion system, is considered to give the pilot clear warning. Consequently, pilot recognition time is considered negligible with a trim-in-motion system. The following time delays after pilot recognition are considered appropriate:

(i) Takeoff, approach, landing - 1 second.

(ii) Climb, cruise, descent - 3 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 is located within immediate reach and readily accessible to the pilot, which has the primary purpose of stopping all movement of the electric trim system. A circuit breaker is not considered to be a disconnect switch.

(2) Quick-Disconnect/Interrupt Switch. A switch or device that momentarily interrupts all movement of the electric trim system, which is located on the control wheel on the side opposite the throttles, or on the stick control, that 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, disconnect may be initiated after the delay times given in paragraph 139c(4).

(2) Disconnect Switch. With a disconnect switch, the time delays given in paragraph 139c(4) should be applied prior to corrective action by use of primary controls. In addition to these time delays, an appropriate reaction time to disconnect the systems should be added. When there are other switches in the immediate area of the quick-disconnect, a time increment should be added to account for identifying the 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, see paragraph 45 of this AC.

140. SECTION 23.679 (original issue) CONTROL SYSTEM LOCKS. This subject is covered in AC 23.679-1.

141. SECTION 23.697 WING FLAP CONTROLS. (RESERVED).

142. SECTION 23.699 WING FLAP POSITION INDICATOR. (RESERVED).

143. SECTION 23.701 FLAP INTERCONNECTION. (RESERVED).

144.-153. RESERVED.

Section 3. LANDING GEAR

154. SECTION 23.729 (as amended by amendment 23-26) LANDING GEAR EXTENSION AND RETRACTION SYSTEM. This subject is covered in AC 23.729-1.

155. SECTION 23.735 BRAKES. (RESERVED).

156.-160. RESERVED.

Section 4. PERSONNEL AND CARGO ACCOMMODATIONS

161. SECTION 23.771 PILOT COMPARTMENT. (RESERVED).

162. SECTION 23.773 PILOT COMPARTMENT VIEW. (RESERVED).

163. SECTION 23.777 COCKPIT CONTROLS. (RESERVED).

164. SECTION 23.803 (as added by amendment 23-34) EMERGENCY EVACUATION. This subject is covered in AC 20-118A.

165. SECTION 23.807 (as amended by amendment 23-34) EMERGENCY EXITS. AC's 23.807-2 and 23.807-3 address this subject.

166. SECTION 23.831 VENTILATION. (RESERVED).

167.-175. RESERVED.

Section 5. PRESSURIZATION

176. SECTION 23.841 (as amended by amendment 23-17) PRESSURIZED CABINS. AC 23.841-1 addresses this subject.

177. SECTION 23.843 PRESSURIZATION TESTS. (RESERVED).

178.-188. RESERVED.

CHAPTER 4. POWERPLANT
Section 1. GENERAL

189. SECTION 23.901 INSTALLATION. (RESERVED).

190. SECTION 23.903 (as amended by amendment 23-34) ENGINES.

a. Explanation:

(1) Automatic Propeller Feathering Systems. All parts of the feathering device which 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 normal 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:

(A) Momentary loss of power.

(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 engine 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 see §§ 23.67 and 23.1501.)

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

(viii) Most 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 to demonstrate nonrotation at one engine inoperative climb airspeed. The configuration should be:

(A) Critical engine inoperative.

(B) Wing flaps retracted.

(C) Landing gear retracted.

(D) Cowl flaps closed.

(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 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 or 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 an engine controlling this system will:

(A) Cause the allowable engine overspeed for this condition to be exceeded at any time.

(B) Cause a loss of thrust which 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 5 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.

(4) Intermixing of Engines.

(i) Explanation. Engines of different ratings and/or cowls may be intermixed on airplanes provided the proper performance associated with the engine combination is used. In general, for four-, three- or two-engine airplanes, the performance combination is as follows:

(A) When one lower thrust engine is installed, the normal AFM performance level is reduced by an increment appropriate to the decrease in thrust resulting from the intermix.

(B) When more than one lower thrust engine is installed, the performance should be based on the thrust of the lower/lowest rated engine.

(C) The V_{MC} should be based on the highest thrust engine(s).

(ii) Procedures.

(A) The operating procedures should be provided for all engines installed, that is, relight altitude/airspeed, flight idle lights, etc. Differences in operating methods should be limited to the equivalent of having a maximum of two different engines on the airplane.

(B) Air conditioning packs and bleed configurations for takeoff should be such that no more than two thrust parameters are to be monitored.

(C) Only one odd engine or odd operation of the same engines is permitted. A placard should be installed notifying the pilot of the odd case. However, two engines of each kind may be intermixed, but all engine limits and markings should be appropriate to the engine installed.

(D) The number of thrust gauges operative for takeoff should be considered for each individual case.

(E) Temperature and r.p.m. limits for the engine installed or the rating at which it will be operated, should be properly presented to the pilot in accordance with §§ 23.1541 through 23.1543.

c. Restart Envelope. For turbine engine-powered airplanes, the applicant should propose an airstart envelope wherein satisfactory inflight engine restarts may be accomplished. 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, etc., are obtained for inclusion in the Type Inspection Report. The airstart envelope should be included in the limitations sections of the AFM. The procedures used to restart the engine(s) should be contained in the emergency or abnormal procedures section of the AFM.

191. SECTION 23.905 (as amended by amendment 23-29) PROPELLERS. Included in § 23.903 material. See paragraph 190 of this AC.

192. SECTION 23.909 (as amended by amendment 23-7) TURBOSUPERCHARGERS. AC 23.909-1 addresses this subject.

193. SECTION 23.929 (as amended by amendment 23-14) 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, etc., function satisfactorily and operate properly without appreciable loss of power when the applicant requests approval for flight in icing conditions. See § 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.

194. SECTION 23.933 (as amended by amendment 23-34) REVERSING SYSTEMS.

a. Explanation. Self-explanatory.

b. Procedures. Reverse thrust propeller installations may be approved provided the following is acceptable:

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

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

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

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

(5) 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) 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) 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) 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) 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) The engine cooling characteristics should be satisfactory in any likely operating condition.

(11) 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 27a(7) of this AC).

195. SECTION 23.939 (as amended by amendment 23-18) 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. 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.

196. SECTION 23.943 (as amended by amendment 23-18) 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 levels of fuel and oil.

(2) Flight Envelope. 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 of -0.2g for 5 seconds, -0.3g for 4 seconds, -0.4g for 3 seconds, and -0.5g for 2 seconds should reveal any existing hazardous malfunctioning of the engine. Alternately, -0.5g for 5 seconds may be used. 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.

197.-206. RESERVED.

Section 2. FUEL SYSTEM

207. SECTION 23.959 (as amended by amendment 23-18) UNUSABLE FUEL SUPPLY. This subject is covered in AC 23.959-1.

208. SECTION 23.961 (original issue) FUEL SYSTEM HOT WEATHER OPERATION. This subject is covered in AC 23.961-1.

209.-220. RESERVED.

Section 3. FUEL SYSTEM COMPONENTS

221. SECTION 23.1001 (as added by amendment 23-7) 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 that 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 which 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 which 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.

222.-237. RESERVED.

Section 4. OIL SYSTEM

238. SECTION 23.1027 (as amended by amendment 23-14) PROPELLER FEATHERING SYSTEM. Included in § 23.903 material. See paragraph 190 of this AC.

239.-244. RESERVED.

Section 5. COOLING

245. SECTION 23.1041 (as amended by amendment 23-7) GENERAL. See paragraphs 246, 247, and 248 of this AC.

246. SECTION 23.1043 (as amended by amendment 23-21) COOLING TESTS.

a. Explanation. Paragraphs 247 and 248 of this AC provide details on reciprocating engine and turbine engine cooling tests. Additional procedures for certification of winterization equipment are given below.

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

(1) Other Than a 100-Degree Farenheit Day. Cooling test results for winterization installations may be corrected to any temperature desired by the applicant rather than the conventional 100°F hot-day. For example, an applicant may choose to demonstrate cooling to comply with requirements for a 50° or 60° 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 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, accompanied by instructions for its installation, manufacturers should provide suitable information regarding temperature limitations in the installation instructions.

247. SECTION 23.1045 (as amended by amendment 23-7) 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 any 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 §§ 23.65 and 23.67, which have 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 which 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 100°F at sea level must be used. Temperatures at higher altitudes assume a change at 3.6°F per 1000 feet of altitude, up to -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 3000 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) 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 airplane for approximately 1 mile to simulate normal taxi operations. Record cooling data at 1-minute intervals.

(3) 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 5 knots above the step speed for a minimum of 10 minutes continuous. Record cooling data at 1-minute intervals.

(4) Establish a pretakeoff holding condition on the taxiway (crosswind) for 20 minutes minimum or until temperatures stabilize. Record cooling data at 5-minute intervals.

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

(6) Takeoff as prescribed in § 23.51 and climb to pattern altitude. Record cooling data upon reaching pattern altitude or at 1-minute intervals if it takes more than 1-minute to reach pattern altitude.

(7) Retract flaps and continue climb with maximum continuous power at the speed selected to meet the requirements of § 23.65(c). Climb to the maximum approved altitude, recording cooling data at 1-minute intervals.

(8) Cruise at maximum continuous power (or V_{MO}/M_{MO}, if limiting) at maximum operating altitude until temperatures stabilize. Record cooling data at 1-minute intervals. For many components, this will be the critical temperature operating condition.

(9) Conduct a normal descent at V_{MO}/M_{MO} to holding altitude and hold until temperatures stabilize. Record cooling data at 1-minute intervals.

(10) Conduct a normal approach to landing. Record cooling data at 1-minute intervals.

(11) From not less than 200 feet above the ground, perform a balked landing go-around in accordance with § 23.77. Record cooling data at 1-minute intervals during a traffic pattern circuit.

(12) Climb to pattern altitude, perform a normal approach and landing in accordance with the applicable portion of § 23.75. Record cooling data at 1-minute intervals.

(13) Taxi back to ramp. Shut down engines. Allow engine to heat-soak. Record temperature data at 1-minute intervals until 5 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 1-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 5 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 semiautomatic 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.

(10) Pertinent nacelle and component temperatures.

f. Data Reduction.

(1) Limitations. A maximum anticipated temperature (hot-day conditions) of at least 100°F at sea level must be used. The assumed temperature lapse rate is 3.6°F (or 2°C) per 1000 feet altitude up to the altitude at which a temperature of -69.7°F is reached, above which altitude the temperature is constant at -69.7°F. On turbine engine-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: corrected temperature = true temperature + 1.0 [100 - 0.0036 (Hp) - true OAT].

Sample Calculation

True Temperature	300°F
True OAT	15°F
Hp	5000 ft.

The corrected temperature = 300 + 1.0 [100 - 0.0036 (5000) - 15] = 367°F.

The corrected temperature is then compared with the maximum permissible temperature to determine compliance with the cooling requirements.

248. SECTION 23.1047 (as amended by amendment 23-21) COOLING TEST PROCEDURES FOR RECIPROCATING ENGINE-POWERED AIRPLANES.

a. Procedures.

(1) Additional Procedures. The procedures of paragraph 247b(1) through 247b(6) of this AC also apply to reciprocating engines.

(2) Altitude. Engine cooling tests for reciprocating engine airplanes are normally initiated below 2000 feet pressure altitude. Service experience indicates that engine cooling tests started above 5000 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 2000 feet pressure altitude, the temperature margin should be increased by 30°F at 7000 feet for cylinder heads and 60°F for both engine oil and cylinder barrels with a straight line variation from sea level to 7000 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 10 minutes at 5 knots above the step speed, recording cooling data at 1-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 provide minimum slow-down time.

(6) Component Cooling. Accessories or components on the engine or in the engine compartment which have temperature limits should be tested and should be at their maximum anticipated operating conditions during the cooling tests; for example, generators should be at maximum anticipated loads.

(7) Superchargers. Superchargers and turbosuperchargers 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% maximum continuous power until temperatures stabilize. Record cooling data.

(ii) Increase engine power to takeoff rating and climb at a speed not greater than V_y except that a speed higher than V_y can be used under certain conditions. If a speed higher than V_y is chosen, § 23.1047(b) requires that the slope requirements of § 23.65 be met and a cylinder head temperature indicator is required, as specified in § 23.1305(f). Maintain takeoff power for 1 minute. Record cooling data.

(iii) At the end of 1 minute, reduce engine power to maximum continuous and continue climb for at least 5 minutes after temperatures peak or the maximum operating altitude is reached. Record cooling data at 1-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(a) or 23.67(b)(1) with the airplane in the configuration used in establishing critical one-engine-inoperative climb performance:

(i) At the lower altitude of 1000 feet below engine critical altitude or 1000 feet below the altitude at which the one-engine-inoperative rate of climb is $0.027\ V_{so}^2$, or at the lowest practical altitude (when applicable), stabilize temperatures of the test engine in level flight at not less than 75% 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(a) or 23.67(b)(1) is shown. If the speed exceeds V_{YSE}, § 23.1047(b)(2) requires a cylinder head temperature indicator be provided. With the test engine at maximum continuous power (or full throttle), continue climb until 5 minutes after temperatures peak or the maximum operating altitude is reached. Record cooling data at 1-minute intervals.

(10) Performance Limited Multiengine Airplanes. For multiengine airplanes that cannot meet the minimum one-engine-inoperative performance specified in §§ 23.67(a) or 23.67(b)(1):

(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% maximum continuous power and as near sea level as practicable or the minimum safe test altitude.

(iii) After temperatures stabilize, initiate climb at best rate-of-climb speed or minimum rate-of-descent speed, as applicable, with one engine inoperative and remaining engine(s) at maximum continuous power. Continue for at least 5 minutes after temperatures peak. Record cooling data at 1-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 semiautomatic 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.

(14) Temperatures of components or accessories which have established limits that may be affected by powerplant heat generation.

c. <u>To Correct Cylinder Barrel Temperature to Anticipated Hot-Day Conditions</u>.

(1) Corrected cylinder barrel temperature = true observed cylinder barrel temperature + 0.7 [100 - 0.0036 (pressure altitude) - true OAT].

(2) For example:

True observed maximum cylinder barrel temperature	244°F.
Pressure Altitude	8330 ft.
True OAT	$+55^{\circ}$F

(3) Corrected cylinder barrel temperature = 244 + 0.7 [100 - 0.0036 (8330) - 55] = 255°F.

(4) The corrected temperatures are then compared with the maximum permissible temperatures to determine compliance with cooling requirements.

d. <u>To Correct Cylinder Head or Other Temperatures to Anticipated Hot-Day Conditions</u>.

(1) Corrected temperature = true temperature + 1.0 [100 - 0.0036 (pressure altitude) - true outside air temperature].

(2) For example:

True maximum cylinder head temperature	406°F.
Pressure Altitude	8330 ft.
True OAT	+55°F

(3) Corrected cylinder head temperature = 406 + 1.0 [100 - 0.0036 (8330) - 55] = 421°F.

(4) The corrected temperatures are then compared with the maximum permissible temperatures to determine compliance with cooling requirements.

e. Liquid Cooled Engines. (RESERVED).

249.-254. RESERVED.

Section 6. INDUCTION SYSTEM

255. SECTION 23.1091 (as amended by amendment 23-7) AIR INDUCTION. AC 20-124 covers the turbine engine water ingestion aspects of this requirement.

256. SECTION 23.1093 (as amended by amendment 23-29) 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 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 90°F heat rise at 75% maximum continuous power at 30°F OAT.

(ii) Single-Engine Airplanes With a Carburetor Tending to Prevent Icing (Pressure Carburetor). Section 23.1093(a)(4) requires an alternate air source with a temperature equal to that of the air downstream of the cylinders.

(iii) Multiengine Airplane With Carburetors Tending to Prevent Icing (Pressure Carburetor). Section 23.1093(a)(5) requires a 90°F heat rise at 75% maximum continuous power at 30°F OAT.

(iv) Fuel Injection With Ram Air Tubes. A heat rise of 90°F at 75% 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 120°F heat rise at 75% maximum continuous power at 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% maximum continuous power at 30°F OAT or 40°F heat rise if an approved fluid deicing system is used.

(iii) Fuel Injection. Same as for sea level fuel injected engines.

(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 30°F. If the test cannot be conducted in an atmosphere with an ambient air temperature of 30°F, it will normally be flown at low, intermediate, and high altitudes. If a 30°F day exists at an altitude where 75% 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 temperature probe is placed at the carburetor deck; however, test data may be obtained with the pickup at other locations. A carburetor throat temperature pickup in lieu of carburetor air box temperature instrumentation will not suffice for accurate readings unless calibration data is made available to correlate carburetor throat temperatures to actual air inlet temperatures.

c. Test Procedures for Reciprocating Engine Airplanes.

(1) 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 carburetor heat and after condition stabilizes, record data.

(3) Reduce airspeed to 90% of that attained under item (1). With carburetor air heat control in the "cold" position and condition stabilized, record data.

(4) Apply carburetor heat and after condition stabilizes, record data.

(5) Reduce airspeed to 80% of that attained under item (1). With carburetor air heat control in the "cold" position and condition stabilized, record data.

(6) Apply carburetor heat and after condition stabilizes, record data.

(7) At the intermediate altitude, repeat steps (1) through (6).

(8) At high altitude, repeat steps (1) through (6). Data to be recorded.

(i) Altitude (feet).

(ii) Airspeed (IAS) (Knots).

(iii) Ambient air temperature ^{o}F.

(iv) Carburetor air temperature ^{o}F.

(v) Carburetor heat control position.

(vi) Engine r.p.m.

(vii) Engine manifold pressure (in Hg).

(viii) Throttle position.

d. Data Reduction. Figures 256-1 and 256-2 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

Figure 256-1 - CARBURETOR AIR HEAT RISE CALCULATIONS

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 Column #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 = $\sqrt{\dfrac{\text{std temp } (^{\circ}F) + 460}{\text{CAT } (^{\circ}F) + 460}}$

NOTE 2: Rated BHP = 140

NOTE 3: Circled numbers indicate data plotted on figure 256-2.

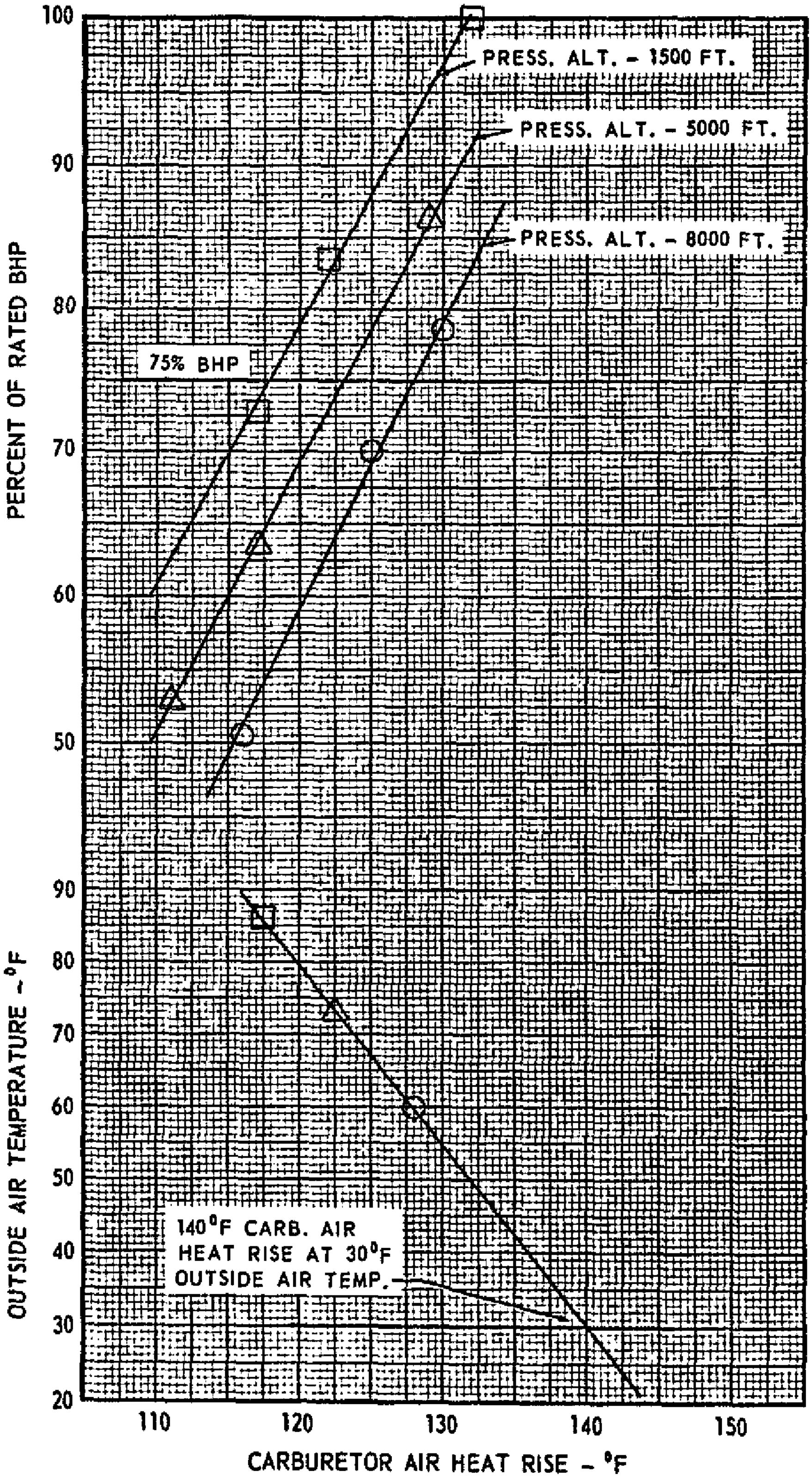


Figure 256-2 - CARBURETOR AIR HEAT RISE PLOTS should be conducted to encompass the icing conditions specified in Part 25, appendix C. Each airplane should be evaluated for compliance. Thermodynamic exercises and dry air tests alone are not usually adequate, and actual icing encounters or wind tunnel testing are necessary.

257.-265. RESERVED.

Section 7. POWERPLANT CONTROLS AND ACCESSORIES

266. SECTION 23.1141 (as amended by amendment 23-18) 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. (Also see § 23.777). Controls are required to maintain any position set by the pilot without tendency to creep due to vibration or control loads.

b. Procedures. None.

267. SECTION 23.1145 (as amended by amendment 23-18) IGNITION SWITCHES. (RESERVED).

268. SECTION 23.1153 (original issue) 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.

269.-278. RESERVED.

Section 8. POWERPLANT FIRE PROTECTION

279. SECTION 23.1189 (as amended by amendment 23-29) 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) and the location and clarity of any required indicators 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.

280.-285. RESERVED.

CHAPTER 5. EQUIPMENT
Section 1. GENERAL

286. SECTION 23.1301 (prior to amendment 23-20) FUNCTION AND INSTALLATION. A system that is not essential for safe operation, nor required by regulation, may be approved if it is not a hazard in normal operation or when it malfunctions or fails. It does not have to perform its intended function, but must be evaluated for hazards. An example of such a system is an engine fire extinguisher system. The operating information should include a placard and an entry in the AFM to the effect that the capability of the fire extinguisher system to perform its intended function has not been evaluated by the FAA.

287. SECTION 23.1301 (as amended by amendment 23-20) 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. All installations of this nature should be evaluated by the flight test pilot to verify that the equipment functions properly when installed.

b. Avionics Test.

(1) Very High Frequency (VHF) Communication Systems. See 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. Contact the nearest FAA Airway Facilities Sector Office to examine the order.

(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 (i.e., air data system, pressurization, etc.), 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, etc., 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 configurations used in flight; that is, flaps, landing gear, etc.). 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 Airman's 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 2°. 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 $\pm 6^\circ$. 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% 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 $20^\circ \pm 5^\circ$ (10° 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° right and 360° left turn at a bank angle of at least 10° at an altitude just above the lower 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.

(iv) High-Angle Reception. Repeat the turns described in (iii) above, but at 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% 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.

(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, subparagraph (3)(i).

(A) Signal Strength. The signal 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 Airman's Information Manual (AIM). This signal should be received for 360° of airplane heading at all bank angles up to 10° left or right at all normal pitch attitudes and at an altitude of approximately 2000 feet (see RTCA Document DO-102).

(B) Bank Angles. Satisfactory results should also be obtained at bank angles up to 30° when the airplane heading is within 60° of the inbound localizer course. Satisfactory results should result with bank angles up to 15° on headings from 60° to 90° of the localizer inbound course and up to 10° bank angle on headings from 90° to 180° 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°. 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 5 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.

(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 10 n.m. from the facility. This performance should be demonstrated at all airplane headings between 30° right and left of the localizer course (see RTCA Document DO-1010). The deviation indicator should properly direct the airplane back to path when the airplane is above or below path. Interference with the navigation operation, within 10 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 2000 to 3000 feet when flying at an altitude of 1000 feet AGL on the localizer centerline in all flap and gear configurations.

(B) An acceptable test to determine distances of 2000 to 3000 feet is to fly at a ground speed listed in table 1 and time the marker beacon light duration.

Table 1 - LIGHT DURATION

Altitude = 1000 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 tabled 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 5°, 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° 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 $180^{\circ} \pm 5^{\circ}$, the indicator should indicate the new bearing within $\pm 5^{\circ}$ in not more than 10 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°, 45°, 90°, 135°, 180°, 225°, 270°, and 315°. The indicated bearings to the station should correlate within 5°. 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 1000 to 2000 feet above ground level. Partial reversals which 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°. The indicator should indicate within $\pm 5^\circ$ of the bearing in not more than 10 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 tuned 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 10°.

(C) Climbing and descending at normal maximum climb and descent attitude.

(D) Orbiting a DME facility.

(E) Provide 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 10 n.m. from a DME facility and at an altitude of 2000 feet above the DME facility, fly the airplane on a heading so that the airplane will pass over the facility. At a distance of 5-10 n.m. beyond the DME facility, operate the airplane at its normal maximum climb attitude up to 90% of the maximum operating altitude, maintaining the airplane on a station radial (within 5°). 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° turns, one to the right and one to the left, at a bank angle of at least 10° at the maximum service volume distance of the DME facility and at an altitude of at least 90% 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% of the maximum operating altitude.

(vi) Penetration. From 90% 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 5000 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 2000 feet above the terrain, at holding pattern speeds appropriate for the type of airplane and with the landing gear extended, fly at least 15° 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 5 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 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 throughout the airspace within 160 n.m. of the radar station from radio line of sight to within 90% 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 to 10°.

(B) Climbing and descending at normal maximum climb and descent attitude.

(C) Orbiting a radar facility.

(iv) Climb and Distance Coverage.

(A) Beginning at a distance of at least 10 n.m. from and at an altitude of 2000 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% of the maximum altitude for which the airplane is certificated, maintaining the airplane at a heading within 5° 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° turns, one to the right and one to the left, at bank angles of at least 10° 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 (iv) above at a distance of 50 to 70 n.m. from the radar facility and at an altitude of at least 90% 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% 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 which 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 2000 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° turn right and left at a distance of approximately 10 n.m. from the ARSR facility. There should be no signal dropout (two or more sweeps).

(B) At an altitude of 2000 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° sectors of left and right 10 n.m. orbital patterns around a radar facility with gear and flaps extended. There should be no signal dropout (two or more sweeps).

(ix) 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 $\pm 10^{\circ}$ 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 which allow visual identification of a target, such as an island, a river, or a lake, at a range of approximately 80% 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 10° 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% of the maximum range.

(iii) Beam Tilting. The radar antenna should be installed so that its beam is adjustable to any position between 10° 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° above the point where ground return was eliminated. Roll right and left approximately 15°, then pitch down approximately 10° (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, etc. 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 (EMC). 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) Advisory Circular 90-45A. This AC is the basic criteria for evaluating an area navigation system, including acceptable means of compliance to the FAR.

(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. Advisory Circular 25-4 is the basic criteria for the engineering evaluation of an inertial navigation system (INS) and offers acceptable means of compliance with the applicable FAR. 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

10 hours, the radial error should not exceed 2 n.m. per hour of operation on a 95% statistical basis. For flights longer than 10 hours, the error should not exceed ±20 n.m. cross-track or ±25 n.m. along-track error. A 2 n.m. radial error is represented by a circle, having a radius of 2 n.m., centered on the selected destination point.

(ii) 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 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. This subject will be covered in a separate AC.

(16) VLF/Omega Navigation Systems. See AC's 20-101B, 90-79, 120-31A, and 120-37.

(17) LORAN C Navigation Systems. See AC 20-121.

(18) Microwave Landing Systems. (RESERVED).

288. SECTION 23.1303 (prior to amendment 23-17) FLIGHT AND NAVIGATION INSTRUMENTS.

a. Explanation. Section 23.1303, as amended by amendment 23-17, provides for a speed warning device for all turbine engine-powered airplanes. Section 23.1303(e) should not be applied to Amended Type Certificates or Supplemental Type Certificates (STCs) with a certification basis prior to amendment 23-17, where a reciprocating engine is replaced with a turbine engine under § 21.101(b), since it would normally increase the level of safety above that established by the regulations referenced on the original type certificate. An aural speed warning device may be required on such airplanes only if an unsafe condition would exist without one.

b. <u>Procedure</u>. The following procedure should be used to determine whether an unsafe condition exists when converting a reciprocating engine small airplane to turbine engine(s):

(1) Determine if there is any distinctive natural warning that becomes unmistakably evident if the limiting speed (V_{NO}, V_{MO}) is exceeded by 6 knots or the limiting Mach (M_{MO}) is exceeded by .01. Aerodynamic buffet by itself is not considered an adequate natural warning of an overspeed condition (see paragraph 121a(6)).

(2) The airplane should be evaluated for compliance with the high-speed characteristics of § 23.253. An acceptable means of demonstrating compliance is provided in this section.

(3) When evaluating the specific upset conditions for determining the need for an overspeed warning device, record the airspeed at the end of the specified delay times. If an overspeed warning system is not installed, or there is no natural warning, the time delays shall begin at the airspeed defined for overspeed warning, that is, V_{NO}/M_{MO} plus 6 knots or M_{MO} plus 0.01M. If the airplane will accelerate to more than the previous V_{NE} or to a speed more than half way between V_{MO}/M_{MO} and V_D/M_D, then an overspeed warning will be required.

(4) V_{MO}/M_{MO} is established by procedures defined in § 23.335(b) and an upset maneuver that is attitude, time, thrust, and drag sensitive. All established recognition and recovery procedures for determining the acceptability of a given V_{MO}/M_{MO} under §§ 23.251 and 23.253 are predicated upon the pilot receiving a clear and distinct warning slightly past the established V_{MO}/M_{MO}. Definite recognition establishes the beginning of time delay for 3 seconds prior to recovery initiation, thus providing an adequate normal operation margin for recovery. If an airplane accelerates rapidly enough during this time delay, to exceed the previously established V_{NE}, or half the distance between V_{MO}/M_{MO} and V_D/M_D, the time remaining to recover is considered inadequate to meet the criteria envisaged in the procedures prescribed in § 23.335(b). This would be considered as an unsafe feature under the provisions of § 21.21.

289. <u>SECTION 23.1303 (as amended by amendment 23-17) FLIGHT AND NAVIGATION INSTRUMENTS</u>.

a. <u>Free Air Temperature (FAT)</u>. Section 23.1303(d) requires that turbine engine-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 pickup 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 302 of this AC. The constant altitude and tower fly-by calibration methods are described in Air Force Technical Report No. 6273 (see appendix 2, paragraph f(2) of this AC).

b. <u>Remaining Flight and Navigation Instruments. (RESERVED)</u>.

290. SECTION 23.1305 (as amended by amendment 23-34) 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. Advisory Circular (AC) 23.1305-1 covers the installation of fuel flowmeters in airplanes with continuous-flow fuel injection reciprocating engines.

291. SECTION 23.1307 (as amended by amendment 23-23) MISCELLANEOUS EQUIPMENT.

a. Explanation. This subpart requires an approved seat for each occupant, a master switch arrangement, an adequate source of electrical energy and electrical protective devices.

b. Procedures. Verify the proper functioning of each required equipment item. Confirm that when approved production seats are in place, that the seats can be easily adjusted and will remain in a locked position. Confirm that the master switch arrangement is prominently located and marked. Where applicable, proper function of these items may be verified by ground tests.

292. SECTION 23.1309 EQUIPMENT, SYSTEMS, AND INSTALLATIONS. (RESERVED).

293.-299. RESERVED.

Section 2. INSTRUMENTS: INSTALLATION

300. SECTION 23.1321 ARRANGEMENT AND VISIBILITY. (RESERVED).

301. SECTION 23.1322 WARNING, CAUTION, AND ADVISORY LIGHTS. (RESERVED).

302. SECTION 23.1323 (as amended by amendment 23-34) 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.

(2) Air Data Computer Systems. (RESERVED).

(3) Definitions. Section 1.1 of Part 1 of the FAR defines indicated airspeed (IAS), calibrated airspeed (CAS), equivalent airspeed (EAS), true airspeed (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 pitot-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 (see subparagraph g) gives various design considerations. The static pressure error is more difficult to measure and can be quite large.

(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 which convert 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 as would be affected by 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 the FAR 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 f(2) 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 which is used in demonstrating compliance with other applicable regulations. The airspeed system may be calibrated using the speed course method, pacer airplane method, trailing bomb and/or airspeed boom method, tower flyby method, or trailing cone method. 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(c) 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 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. See appendix 9 for test procedures and a sample data reduction.

c. Trailing Bomb and/or Airspeed Boom Method. See appendix 9 for procedures, test conditions, and a sample data reduction.

d. Pace Airplane Method. See appendix 9 for test procedures.

e. Tower Flyby. See paragraph 303 for explanation.

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. See 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.

303. SECTION 23.1325 STATIC PRESSURE SYSTEM (as amended by amendment 23-34).

a. Definitions. Paragraph 302 defines several of the terms associated with the pitot-static systems. Others may need further explanation.

(1) Altimeter. An altimeter is a pressure gage 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 which 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 which 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 flyby method. Alternately, for properly designed pitot systems, the pitot has minimal effects 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:

$$dh = .08865\left(dV_c\right)\left\{1 + .2\left\{\frac{V_c}{661.5}\right\}^2\right\}^{2.5}\left\{\frac{V_c}{\sigma}\right\}, \text{ ft.}$$

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 Flyby. The tower flyby method is one of the methods which 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 Flyby.

(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 which 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.

(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.

(ii) 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 $\pm$ 30 feet at 100 knots or less, with linear variation of $\pm$ 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, § 23.1325(f) requires that the altimeter system calibration be shown in the AFM.

304. SECTION 23.1327 MAGNETIC DIRECTION INDICATOR. (RESERVED).

305. SECTION 23.1329 (as amended by amendment 23-23) AUTOMATIC PILOT SYSTEM. This subject will be covered in a separate AC.

306. SECTION 23.1331 INSTRUMENTS USING A POWER SUPPLY. (RESERVED).

307. SECTION 23.1335 FLIGHT DIRECTOR SYSTEMS. (RESERVED).

308. SECTION 23.1337 (as amended by amendment 23-18) POWERPLANT INSTRUMENTS.

a. Explanation.

(1) Fuel Quantity Indicator. The indicator should be legible and easily read without excessive head movement. The calibration units (pounds or gallons) 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, etc., 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.

309.-318. RESERVED.

Section 3. ELECTRICAL SYSTEMS AND EQUIPMENT

319. SECTION 23.1351 GENERAL. (RESERVED).

320. SECTION 23.1353 STORAGE BATTERY DESIGN AND INSTALLATION. (RESERVED).

321. SECTION 23.1357 CIRCUIT PROTECTIVE DEVICES. (RESERVED).

322. SECTION 23.1361 MASTER SWITCH ARRANGEMENT. (RESERVED).

323. SECTION 23.1367 SWITCHES. (RESERVED).

324.-328. RESERVED.

Section 4. LIGHTS

329. SECTION 23.1381 INSTRUMENT LIGHTS. (RESERVED).

330. SECTION 23.1383 LANDING LIGHTS. (RESERVED).

331.-335. RESERVED.

Section 5. SAFETY EQUIPMENT

336. SECTION 23.1411 GENERAL. (RESERVED).

337. SECTION 23.1415 DITCHING EQUIPMENT. (RESERVED).

338. SECTION 23.1416 (as added by amendment 23-23) PNEUMATIC DEICER BOOT SYSTEM. See AC 23.1419-1.

339. SECTION 23.1419 (as amended by amendment 23-14) ICE PROTECTION. See AC 23.1419-1.

340.-349. RESERVED.

Section 6. MISCELLANEOUS EQUIPMENT

350. SECTION 23.1431 ELECTRONIC EQUIPMENT. (RESERVED).

351. SECTION 23.1435 HYDRAULIC SYSTEMS. (RESERVED).

352. SECTION 23.1441 OXYGEN EQUIPMENT AND SUPPLY. (RESERVED).

353. SECTION 23.1447 EQUIPMENT STANDARDS FOR OXYGEN DISPENSING UNITS. (RESERVED).

354. SECTION 23.1449 MEANS FOR DETERMINING USE OF OXYGEN. (RESERVED).

355.-364. RESERVED.

CHAPTER 6. OPERATING LIMITATIONS AND INFORMATION

Section 1. GENERAL

365. SECTION 23.1501 (as amended by amendment 23-21) 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 thru 23.1527 prescribe the minimum limitations to be determined. Additional limitations may be required.

(3) Information Presentation. Sections 23.1541 thru 23.1589 prescribe how the information should be made available to the flight crew.

b. Procedures. None.

366. SECTION 23.1505 (as amended by amendment 23-7) AIRSPEED LIMITATIONS.

a. Explanation. This section establishes the operational speed limitations which establish 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.

367. SECTION 23.1507 (original issue) MANEUVERING SPEED. This regulation is self-explanatory.

368. SECTION 23.1511 (original issue) FLAP EXTENDED SPEED. This regulation is self-explanatory.

369. SECTION 23.1513 (original issue) MINIMUM CONTROL SPEED. This regulation is self-explanatory.

370. SECTION 23.1519 (original issue) WEIGHT AND CENTER OF GRAVITY. This regulation is self-explanatory.

371. SECTION 23.1521 POWERPLANT LIMITATIONS. (RESERVED).

372. SECTION 23.1523 (as amended by amendment 23-21) MINIMUM FLIGHT CREW. All configurations evaluated should be carefully documented.

373. SECTION 23.1523 (as amended by amendment 23-34) MINIMUM FLIGHT CREW.

a. Discussion. 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.

(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 to 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) For reciprocating-engine-powered airplanes, the complexity and difficulty of operation of the fuel system with particular consideration given to the required fuel management schedule necessitated by center of gravity, structural, or other airworthiness considerations. Additionally, the ability of each engine to operate continuously from a single tank or source which 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, deicing, and other systems while en route. Also, recording of engine readings, etc.

(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 systemtic 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 which a given manufacturer uses for determining crew workload may vary depending on flight deck configuration, availability of a suitable reference, original design or modification, etc.

(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 in 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 this evolutionary characteristic 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, if corroborated by a reasonable sample of qualified pilots over various assumed flight regimes, provide substantial evidence that workload is or is not reduced by the innovation.

(A) If an early subjective analysis by FAA flight test personnel shows that workload levels may be substantially increased, a more in-depth evaluation or 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 refererence design may have lessened value. Without a firm data base 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 the airplane has been flown by a panel of experienced pilots, trained and qualified in the airplane. The training should be essentially that required for a type rating. Where single pilot approval is sought by the applicant, 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 which 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 communiations 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 Air Traffic Control (ATC) services.

(B) Weather. The airplane should be test flown in a geographical area that is likely to provide some adverse weather such as a 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 incorportaed 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 aproaches, 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: Prior to 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 recordkeeping 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 373a 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 preestablished 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.

374. SECTION 23.1524 (as added by amendment 23-10) MAXIMUM PASSENGER SEATING CONFIGURATION. This regulation is self-explanatory.

375. SECTION 23.1525 (original issue) KINDS OF OPERATION.

a. Explanation.

(1) Required Equipment. See discussion under § 23.1583(h), paragraph 411 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).

376. SECTION 23.1527 (as added by amendment 23-7) MAXIMUM OPERATING ALTITUDE.

a. Explanation.

(1) Safe Operation. Section 23.1527 requires the establishment of a maximum operating altitude for all turbine, turbosupercharged, 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 unsatisfactory structures, propulsion, systems, and/or flight characteristics.

(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 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% maximum continuous.

(2) Stall warning, cruise configuration only (§ 23.207).

(3) Longitudinal stability, cruise configuration only (§§ 23.173 and 23.175).

(4) Lateral and directional stability, cruise configuration only (§§ 23.177 and 23.181).

(5) Upsets, if required (§ 23.253).

(6) Systems operation, including icing system, if installed.

(7) Propulsion operation, including stall, surge, and flameout tests throughout the speed range from near stall to maximum level flight speed.

377.-386. RESERVED.

Section 2. MARKINGS AND PLACARDS

387. SECTION 23.1541 (as amended by amendment 23-21) 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)(2) requires a placard for acrobatic category airplanes concerning spin recovery. A checklist is provided in appendix 4 which 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. Advisory Circular (AC) 20-88A provides additional guidance on the marking of powerplant instruments.

388. SECTION 23.1543 (original issue) INSTRUMENT MARKINGS: GENERAL. Advisory Circular (AC) 20-88A provides guidance on the marking of powerplant instruments.

389. SECTION 23.1545 (as amended by amendment 23-23) AIRSPEED INDICATOR. This regulation is self-explanatory.

390. SECTION 23.1547 (as amended by amendment 23-20) MAGNETIC DIRECTION INDICATOR. This regulation is self-explanatory.

391. SECTION 23.1549 POWERPLANT INSTRUMENTS. (RESERVED).

392. SECTION 23.1551 OIL QUANTITY INDICATOR. (RESERVED).

393. SECTION 23.1553 FUEL QUANTITY INDICATOR. (RESERVED).

394. SECTION 23.1555 CONTROL MARKINGS. (RESERVED).

395. SECTION 23.1557 MISCELLANEOUS MARKINGS AND PLACARDS. (RESERVED).

396. SECTION 23.1559 (as amended by amendment 23-21) OPERATING LIMITATIONS PLACARD. This regulation is self-explanatory.

397. SECTION 23.1561 (original issue) 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 thru 23.1419 cover the requirements for safety equipment.

398. SECTION 23.1563 (as amended by amendment 23-7) AIRSPEED PLACARDS. This regulation is self-explanatory.

399. SECTION 23.1567 (as amended by amendment 23-21) FLIGHT MANEUVER PLACARD. This regulation is self-explanatory.

400.-409. RESERVED.

Section 3. AIRPLANE FLIGHT MANUAL AND APPROVED MANUAL MATERIAL

410. SECTION 23.1581 (as amended by amendment 23-34) 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) which will fulfill the requirements of an AFM if the POH meets all of the requirements of §§ 23.1581 thru 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 an FAA-required AFM and is FAA approved.

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 Aircraft Certification Office Manager, or his 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."

The indication of approval for the approved section should be as discussed in the preceding paragraph. GAMA Specification No. 1 has been found to comply with the provisions of § 23.1581(b)(2).

c. Part 36 Noise Limitations and/or Procedures.

(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) 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 36.1581(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 have 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. Concerning 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.

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) Operation of strobe lights during flight through fog, clouds, or flying closely under an overcast.

(2) Use of carburetor heat.

(3) Restricted use of flaps during sideslips.

(4) Management of propeller pitch when Beta Range is provided.

(5) Procedures for the temporary use of sand screens and engine heater devices.

(6) Unusual feathering design where propeller will not feather with throttle closed.

(7) Scheduling for fuel flow by engine mixture leaning procedure.

(8) Unusual spin recovery techniques.

(9) Wheelbarrowing characteristics.

(10) Pilot-induced oscillations or oscillations caused by turbulence, particularly on swept-wing airplanes.

(11) Depressurization procedures prior to landing.

(12) Procedures for operation of automatic devices; that is, wing levelers, mach trim, yaw damper, etc.

411. SECTION 23.1583 (as amended by amendment 23-34) 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 of the FAR. 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.

Although there is no specific format required for the KOEL, we recommend, in the interest of standardization, that the KOEL be columned 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:

(1) The kinds of operation for which the airplane was type certificated (that is, day or night Visual Flight Rules (VFR), day or night Instrument Flight Rules (IFR), and icing conditions).

(2) 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:

(i) required under the basic airworthiness requirements,

(ii) required by the operating rules (FAR 91 requirements, as a minimum),

(iii) required by special conditions,

(iv) required to substantiate equivalent safety findings,

(v) required by airworthiness directives (AD), and

(vi) items of equipment and/or systems not specifically required under items (i) thru (v) of this paragraph but used by the applicant in order to show compliance with the regulations.

The KOEL should not:

(1) Contain those obvious components required for the airplane to be airworthy such as wings, empennage, engines, landing gear, brakes, etc.

(2) Contain an exceptions column.

d. Fuel Limitations. The fuel limitations discussion in GAMA Specification 1 may not be applicable depending on the airplane certification basis.

e. Commuter Category Airplanes. For those performance weight limits which 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.

412. SECTION 23.1585 (as amended by amendment 23-34) OPERATING PROCEDURES.

a. Explanation. See 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 of the FAR, and its predecessor, § 3.779 of the CAR. Section 23.1581 of the FAR/§ 3.777 of the CAR is also applicable for the manner and format of presentation. Many airplanes under Part 23 of the FAR/Part 3 of the CAR do not require, nor do they have, an approved AFM. Therefore, electronic checklist displays for these airplanes would continue to be unapproved.

(2) Display Content. For those airplanes with approved AFM's, 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 STCs 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 alteration. 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 cathode-ray tube (CRT) 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 FAA-approved AFM takes precedence in case of conflicting checklist information.

(6) Automatic Display. Automatic display of appropriate checklists during conditions of engine failure, generator failure, etc., will require a review based upon the specific application involved. Approval of the checklist content, malfunction prioritization, and operation is required.

413. SECTION 23.1587 (as amended by amendment 23-34) 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.

b. Normal, Utility, and Acrobatic Category Airplanes. See GAMA Specification 1.

c. 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 (e.g., anti-skid devices, automatic spoilers, etc.). This section should also include definitions of terms used in the Performance Section (e.g., IAS, CAS, ISA, configuration, net takeoff flight path, icing conditions, etc.), 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)(6) requires the speeds be given in CAS. Since the aircrew 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 which 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 (e.g., tire speed limitations, brake energy limitations, etc.).

(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 (e.g., procedures, speed schedules), should be presented for the configurations and flight path segments existing between the end of the presribed 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) Climb Limited Landing Weight. The climb limited landing weight which is the most limiting weight showing compliance with § 23.77.

(12) Landing Approach Speeds. The scheduled speeds associated with the approved landing distances should be presented together with associated conditions.

(13) 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. At the option of the applicant, FAR 135 landing field length and alternate landing field length may be presented.

414. SECTION 23.1589 (original issue) LOADING INFORMATION. See GAMA Specification 1.

415.-424. RESERVED.

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 which 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, etc. These charts nearly always assume a "best power" fuel to air ratio which can rarely be consistently used in service under normal operating conditions. Many installations, for example, intentionally use fuel to air ratios which are on the fuel-rich side of best power so that the engine will not overheat. Providing sufficient cooling air flow 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 no 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 which 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 horsepowers which 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 1/2%; +5%, -2%; or +5%, -0%. This means that with all the variables affecting power being held constant (i.e., 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 of 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% 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% 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 1/2%, test day sea level chart horsepower would be assumed to be 350 + .025 (350), or 358.8.

(3) Humidity. Section 23.45(d) requires performance to be based on 80% relative humidity on a standard day. Experience has shown that conditions such as 80% 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% relative humidity correction should be applied if the engine manufacturer has an acceptable method and the correction is significant.

f. Variation 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 1. Figure 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 1):

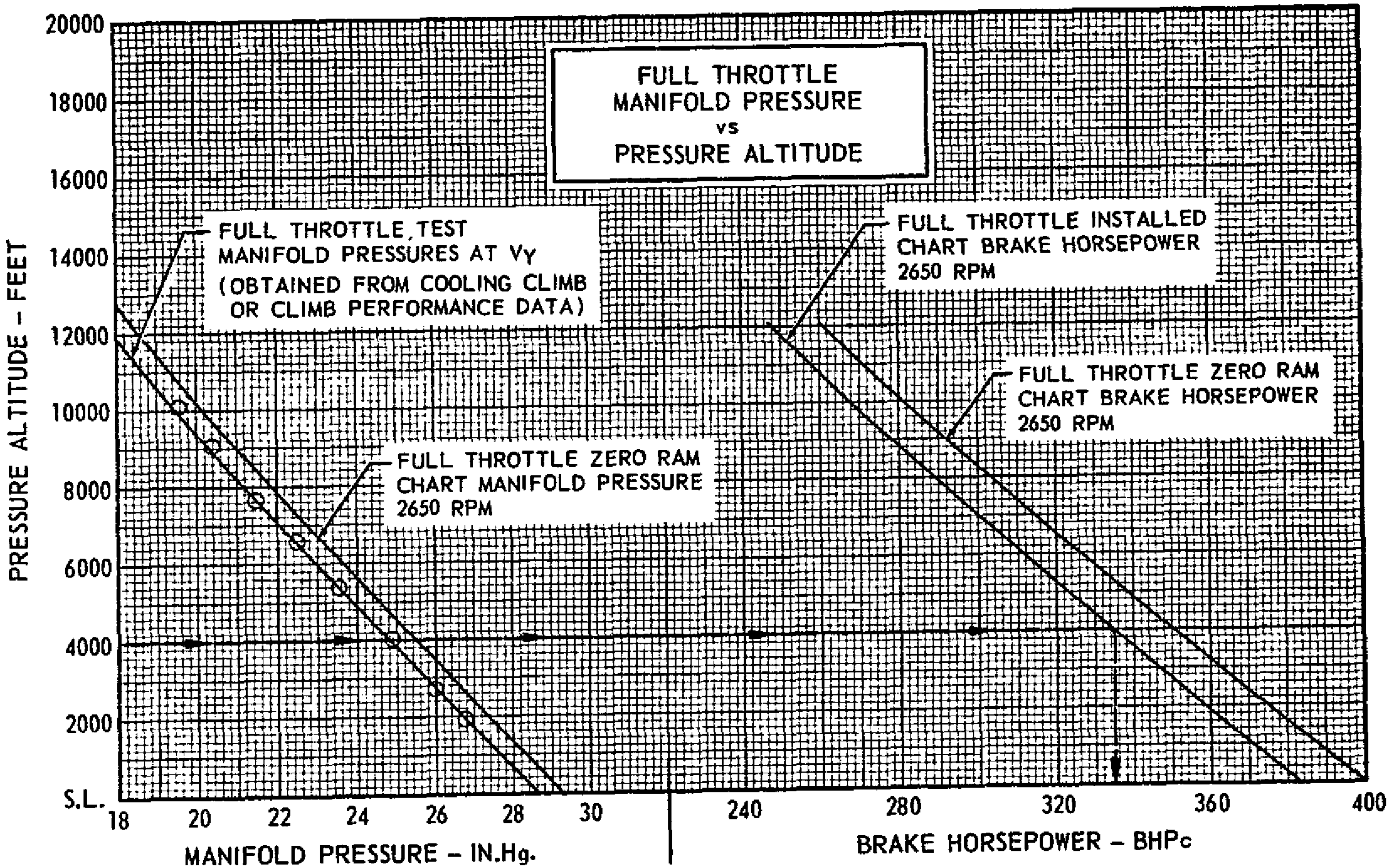


Figure 1 - BRAKE HORSEPOWER VERSUS PRESSURE ALTITUDE

Known:	Pressure Altitude	-	4,000 feet
	Manifold Pressure	-	24.9 in. Hg.
	Outside Air Temperature	-	+55°F
	Inlet Temperature	-	+63°F
	Engine Speed	-	2,650 R.P.M.
	Engine Calibration	-	-0.7%
	Engine Tolerance	-	±2 1/2%

Calculated Test Day BHP for a Calibrated Engine:

Standard Temperature @ 4,000 ft. - 44.7°F

Installed Chart Brake Horsepower (from figure 1) - 335 BHP

Engine Calibration Correction = (335)(-.007) - -2.3 BHP

Correcting for Inlet Temperature

$$\text{Test Day BHP} = (335-2.3)\sqrt{\frac{460+44.7}{460+63.0}}$$ - 326.8 BHP

Calculated Test Day BHP for an Uncalibrated Engine:

Standard Temperature at 4,000 ft. - 44.7°F

Installed Chart Brake Horsepower (from figure 1) - 335 BHP

$$\text{Test Day BHP} = [335 + .025(335)]\sqrt{\frac{460 + 44.7}{460 + 63}}$$ - 337.3

Calculated BHPc for Test Day Density Altitude (Hd):

Hd at 4,000 ft. and 55°F - 4,670 ft.

Installed BHPc (from figure 1) - 326 BHP

Standard Temperature at 4,670 ft. - 42°F

Correcting for Inlet Temperature Rise

$$\text{BHPc} = 326\sqrt{\frac{460 + 42}{460 + 42 + 8}}$$ - 323.4 BHP

Calculated BHPc for the AFM Expansion:

For the Same Conditions as Test Day,

BHP (from figure 1) - 335 BHP

Correcting for Inlet Temperature, expansion

$$\text{BHPc} = 335\sqrt{\frac{460+44.7}{460+63}}$$ - 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 horsepowers to be utilized in data expansion. For some installations, the manifold pressure and fuel flows are limited by the airplane manufacturer's designed 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 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 limits 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% decrease in power for each 6°F 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 2):

Known:	Pressure Altitude	-	9,500 feet
	Manifold Pressure	-	44.3 in. Hg.
	Outside Air Temperature	-	53.0°F
	Compressor Inlet Temperature	-	67°F
	Engine Speed	-	2,575 R.P.M.
	Engine Calibration	-	+1.7%
	Engine Tolerance	-	±2 1/2%

Calculated Test Day BHP for a Calibrated Engine:

Standard Temperature @ 9,500 ft.	-	25.1°F
Power Correction Due to Temperature at 1%/6°F (Temp. rise = 67°-25.1°F)	-	-6.98%
Installed Chart Brake Horsepower (from figure 2)	-	351 BHP
Engine Calibration Correction (351)(.017)	-	+5.97 BHP
Test BHP = (351 + 5.97) - (.0698)(356.97)	-	332.1 BHP

Calibrated Test Day BHP for an Uncalibrated Engine:

Standard Temperature at 9,500 ft.	-	25.1°F
Power Correction at 1%/6°F	-	-6.98%
Installed Chart Brake Horsepower (from figure 2)	-	351
Test BHP = 351 - (351)(.0698) + 351(.025)	-	335.3

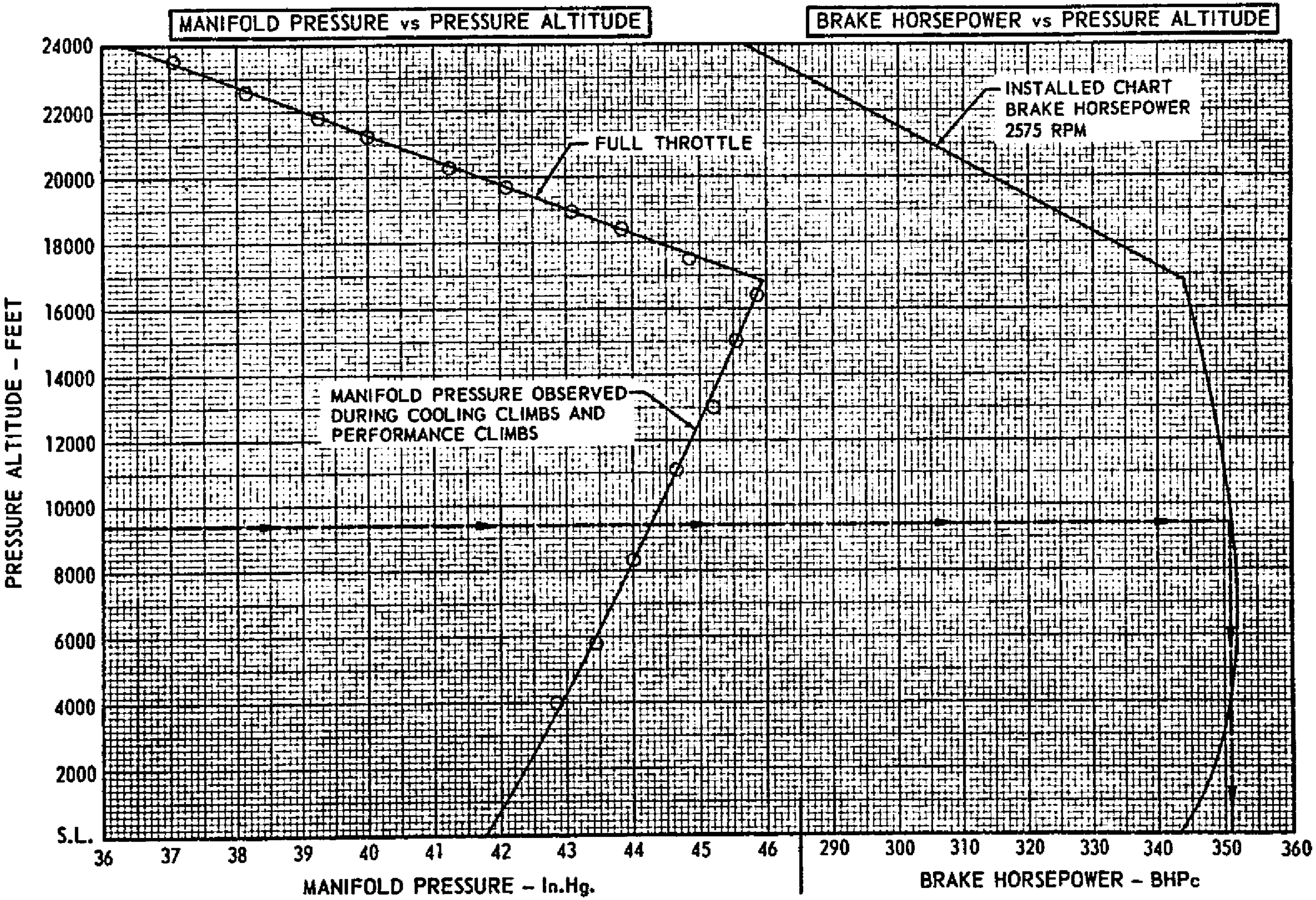


Figure 2 - TURBOCHARGED BRAKE HORSEPOWER VERSUS ALTITUDE

Calculated BHPc for Test Day Density Altitude (Hd):

Hd at 9,500 ft. and 53°F	-	11,280 ft.
Installed BHPc (from figure 2)	-	350 BHP
Power Correction Due to Inlet Temperature Rise at 1%/6°F (temp. rise = 14°F)	-	-2.33%
BHPc = 350-(350)(.0233)	-	341.8 BHP

Calculated BHPc for the AFM Expansion:

For the Same Conditions as Test Day, BHPc (from figure 2)	-	351 BHP
Temperature correction to BHPc = 351 - (.0698)(351)	-	326.5 BHP

5. NORMALLY ASPIRATED ENGINES WITH FIXED PITCH PROPELLERS. (RESERVED).

6. TURBOPROPELLER ENGINES.

a. Power Measurement. Turbopropeller engines are gas turbine engines which turn a propeller. Power output is a function of exhaust gas temperature or turbine interstage temperatures. Torque is measured by an integral torque measuring device which can be related directly to shaft horsepower output. Torque pressure is typically obtained by a slip ring or strain gauge arrangement which has been calibrated to indicate torque. Torque values with the associated propeller shaft r.p.m. are used to calculate shaft horsepower. Shaft horsepower differs from brake horsepower in that shaft implies the power being developed at the propeller shaft. The total thrust horsepower (sometimes called equivalent thrust horsepower) is a combination of propeller shaft horsepower times propeller efficiency plus the effect 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 which assumes climb speeds where the compressibility drag is negligible (usually Mach numbers below 0.6), climb angles of less than 15°, 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:

$$C_D = \left[BHP_T\,(\eta_p) - \frac{T_{AT}}{T_{AS}}\;\frac{(AF)(R/C_O\;\;W_T)}{33{,}000} \right] \left[\frac{96209\sqrt{\sigma}}{(V_e)^3\,S} \right]$$

$$C_L = \frac{295\,(W_T)\sqrt{1 - \left[\frac{\sqrt{\sigma}}{(101.27V_c)}\;\frac{T_{AT}}{T_{AS}}\;(AF)R/C_O \right]^2}}{(V_e)^2\,S}$$

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 - °Kelvin

T_{AS} = standard air temperature - °Kelvin

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)

$$AF = \frac{(1 + 0.2M^2)^{3.5} - 1}{(1 + 0.2M^2)^{2.5}} - 0.133M^2 + 1$$

Where: M = Mach number,
V_C is constant,
altitude below 36,089 feet

c. Data Plotting. Once C_D and C_L 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 that climb data is obtained.

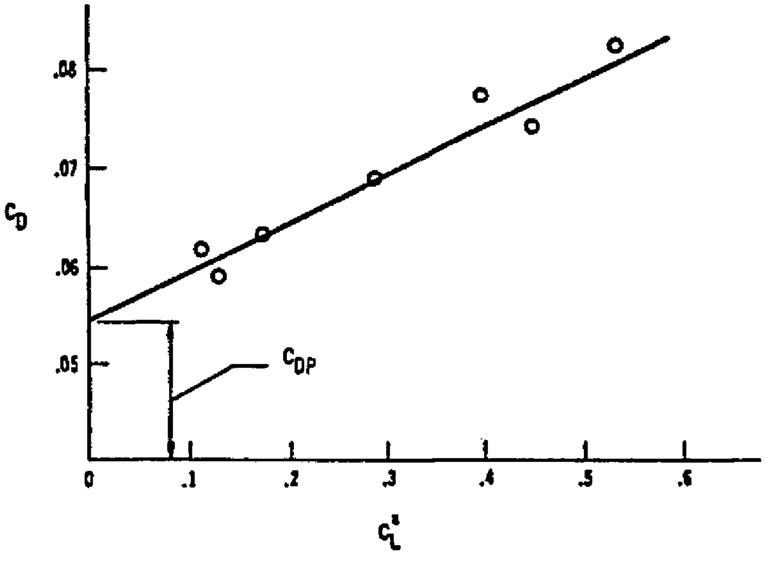


Figure 1 - COEFFICIENT OF DRAG VERSUS COEFFICIENT OF LIFT

From this plot the profile drag coefficient (C_{DP}) can be determined graphically and Oswald's efficiency factor (e) can be calculated.

$$e = \frac{C_L^{\,2}}{\left(C_D - C_{DP}\right) 3.1416 \left(\frac{b^2}{S}\right)} \quad \text{or} \quad e = \frac{\Delta C_L^{\,2} / \Delta C_D}{3.1416 \left(\frac{b^2}{S}\right)}$$

Where: b = wing span - feet
S = wing area - square feet

d. Standard Day Correction. Since the $C_L^{\,2}$ vs. 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)

$$THP_A = BHPc\ (\eta_p)$$

Where: BHPc = chart brake horsepower at test day density altitude (see appendix 1)

η_p = propeller efficiency

$$THP_R = \frac{\sigma (V_T)^3 \quad C_{DP} \quad S}{96209} + \frac{(0.2883) \quad (W_C)^2}{e\ \sigma\ b^2 \quad V_T}$$

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 Nonstandard 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°, 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 Russel M. 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)
P.O. Box 1553
Springfield, Virginia 22151

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. $Hd = 145539 \left[1-(\sqrt{\sigma})^{.4699}\right]$
5	Std. Temp. @ Hp (Ts) -- °F + 460
6	IAS -- knots
7	CAS -- knots
8	TAS = ⑦ / $\sqrt{③}$
9	Observed rate of climb -- ft./min.
10	T/Ts = (② + 460)/⑤

Item No.	Item
11	Actual R/C = ⑨ x ⑩
12	Test Weight, w -- lbs.
13	$\Delta R/C_{\Delta w}$ = ⑪ (1 - ⑫ /Wc)
	where Wc = aircraft weight to which correction is to be made
14	$q \pi e b^2$ = ⑦ $^2 \pi e b^2/295$
	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	ΔD_i = (Wc^2 - ⑫^2) / ⑭
16	$\Delta (R/C) \Delta D_i$ = 101.27 ⑮ ⑧ /Ws
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 Hp
21	BHPc corrected for temperature from appendix 1 at Hd
22	η_p -- propeller efficiency (obtain from propeller manufacturer or may be estimated)
23	ΔTHP = ㉒ (㉑ - ⑳)
24	$\Delta (R/C) \Delta_p$ = ㉓ x 33,000 /Wc
25	R/C_{std} = ⑪ - ⑬ - ⑯ + ㉔

Items 4, 7, and 25 are used to plot figure 25-2.

APPENDIX 3. 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 geometrical relationship between the yawing moment about the center of gravity 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. 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^{o} bank angle are ignored.

c. Do not use this method for fixed-pitch or windmilling propellers.

d. Any altitude effects which may result from windmilling propeller drag on the inoperative engine have been ignored.

e. Computing a V_{MC} value at sea level involves raising to the power of 1/3 (use .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 a two-engine turbopropeller airplane 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 1 presents five data points which were collected at various altitude and temperature conditions, and the resulting C_2 values which were calculated. For these tests, the inoperative propeller was feathered (auto-feather available).

Table 1 - FLIGHT TEST DATA

	OBSERVED					CALCULATED			
RUN	PRESSURE ALTITUDE (FEET)	O.A.T. (^oF)	TORQUE (FT-LB)	PROPELLER RPM	V_{MC} (KCAS)	$\sqrt{\sigma}$	SHAFT HORSE-POWER (1)	η_p (2)	C_2
1	3500	86.3	3219	1700	91.2	.9142439	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	.8915881	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	.8700833	1041.95	.570	1443.907

(1) Calculated from observed torque and propeller r.p.m.
(2) Obtained from propeller manufacturer.

The propeller efficiencies were obtained from a 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 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 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 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 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	698.25	99.1
105	1050	.688	722.4	100.2

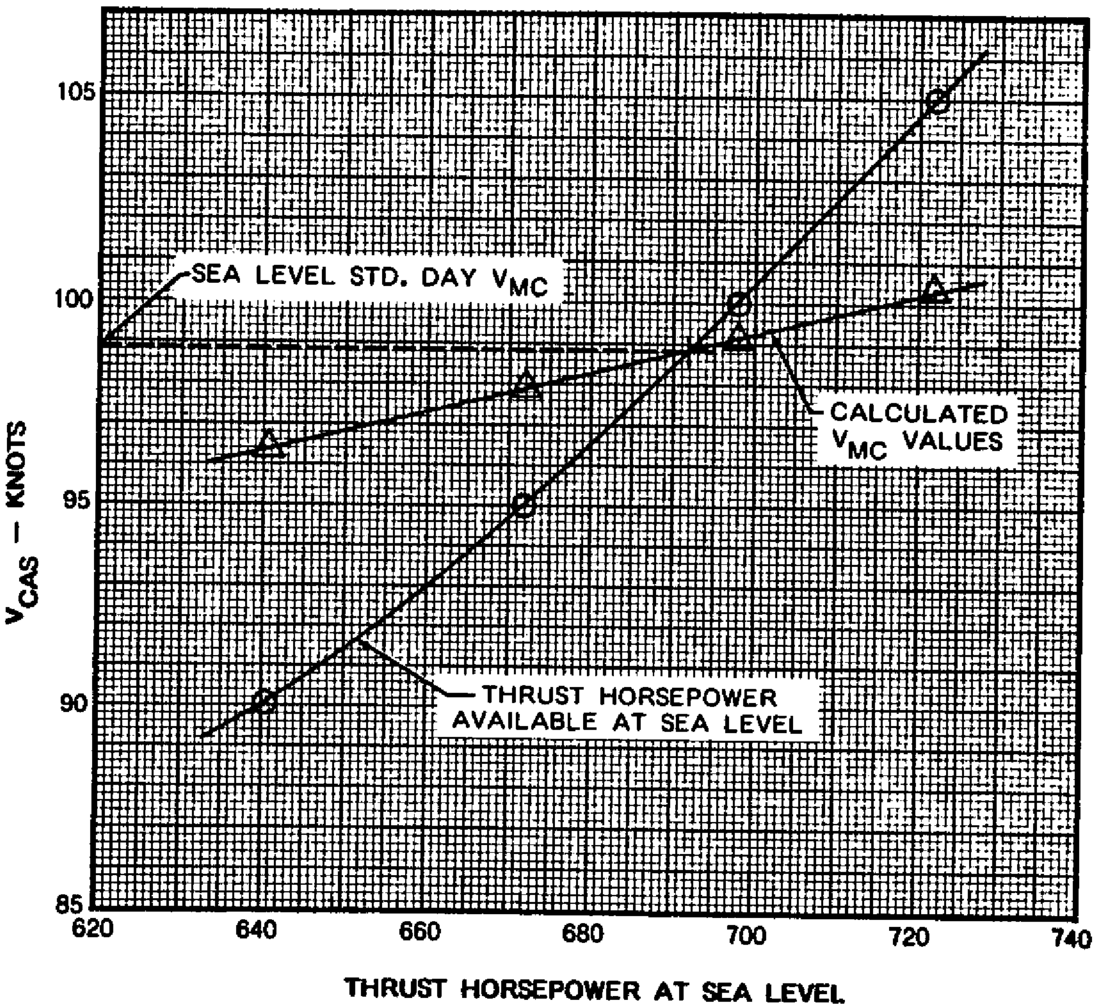


Figure 1 - THRUST HORSEPOWER AT SEA LEVEL

APPENDIX 4. FAR 23 MANUALS, MARKINGS & PLACARDS CHECKLIST

PRIMARY FAR	SUPPORT FAR	DESCRIPTION	MAN-UAL	MARK	PLA-CARD	AMENDMENT NO.
23.25(a)(2)	23.1557(b)	Occupant weight less than 170 lbs normal or 190 lbs. utility & acrobatic			X	21
23.31(b)	23.1557(a)	Placement of removable ballast Ballast-content and weight limitations	X	X	 X	13
23.221(c)(2)	23.1541(a)(2)	Prohibited spins with flaps extended			X	7
23.671(b)		Identify controls		X		Orig.
23.677(a)		Direction and position of trim device		X		7
23.685(d)		Marking of control system elements		X		17
23.733(b)		Marking of specially constructed tires		X		17
23.777(a)	23.1555(a)	Identify cockpit controls		X		7
23.785(d)		Seats in util. and acro. airplanes which won't accommodate parachute			X	23
23.807(b)(3)		Emergency exit location & operation		X		10
23.841(b)(7)		Warning-max. differential cabin pressure and landing loads exceed limit			X	17
23.853(c)		Smoking prohibited in personnel compartments if applicable			X	25
23.903(d)	23.1581(a)(2)	Piston engine start technique and limitations	X		X	26

FAR 23 MANUALS, MARKINGS & PLACARDS CHECKLIST

PRIMARY FAR	SUPPORT FAR	DESCRIPTION	MANUAL	MARK	PLACARD	AMENDMENT NO.
23.903(e)(1)	23.1581(a)(2)	Turbine engine start techniques and limitations	X		X	26
23.903(e)(3)	23.1581(a)(2)	Turbine engine inflight restart techniques and limitations	X		X	26
23.955(d)(2)	23.1555(c)(3)	Aux. fuel tank usage, if required			X	7
23.973(a)	23.1557(e)	Fuel tank filler		X		18
23.1001(g)		Adverse configurations for jettisoning fuel, if applicable			X	7
23.1013(c)	23.1557(c)	Oil tank filler connections		X		15
23.1061(c)	23.1557(c)	Coolant tank filler connection		X		Orig.
23.1141(a)	23.1555(a)	Powerplant control marking		X		18
23.1301(b)		Label equipment for identification, function or operating limitations		X		20
23.1325(b)(3)	23.1541(a)(2)	Alternate static correction card, if required		X		20
23.1327(b)	23.1547(e)	Magnetic indicator deviations of more than 10 degrees			X	20
23.1329(c)		Direction of motion for autopilot controls		X		23
23.1337(b)		Mark fuel quantity either pounds or gallons		X		18

FAR 23 MANUALS, MARKINGS & PLACARDS CHECKLIST

PRIMARY FAR	SUPPORT FAR	DESCRIPTION	MAN-UAL	MARK	PLA-CARD	AMENDMENT NO.
23.1357(d)		Identify essential circuit breakers or fuses		X		20
23.1367(d)		Label switches for operation and circuit controlled		X		Orig.
23.1419(a)	23.1585(a)	Ice Protection equipment operation	X			14
23.1450(c)		Oxygen flow, duration & heat warning			X	20
23.1541(a) and (b)	23.1545 thru 23.1567	Requires and specifies characteristics of markings and placards		X	X	21
23.1541(c)		For multicategory airplanes - requires one category basis for markings and placards and AFM	X	X	X	21
23.1543		Alignment and visibility of instrument markings		X		Orig.
23.1545(b)		Requires airspeed indicators marked for: (1) red radial line for V_{NE} (2) yellow arc for caution range (3) green arc for normal operating range (4) white arc for flap operating range (5) blue arc for V_y, one-engine inoperative (6) red radial line for V_{MC}		X		23
23.1545(c)		Means to indicate variation with altitude of V_{NE} or V_{NO}		X		23

FAR 23 MANUALS, MARKINGS & PLACARDS CHECKLIST

PRIMARY FAR	SUPPORT FAR	DESCRIPTION	MANUAL	MARK	PLACARD	AMENDMENT NO.
23.1545(d)		If applicable, show variation of V_{MO}/M_{MO} with altitude or compressibility limitations or red radial line for lowest V_{MO}/M_{MO} up to maximum altitude		X		23
23.1547	23.1327	Conditions for, and calibration of, magnetic direction ind.			X	20
23.1549		Powerplant instrument (1) red radial line-maximum & minimum operating limits (2) green arc - normal range (3) yellow arc - caution & takeoff (4) red arc - restricted range vibration		X		12
23.1551		Oil quantity indicator increments		X		Orig.
23.1553		Red arc for unusable, fuel, if applicable		X		Orig.
23.1555(a)		Cockpit controls for function and method of operation		X		21
23.1555(b)		Secondary controls marked		X		21
23.1555(c)(1)		Fuel selector position		X		21
23.1555(c)(2)		Fuel tank sequence		X		21
23.1555(c)(3)		Conditions for use of fuel from restricted usage tank			X	21
23.1555(c)(4)		Multiengine fuel selector position		X		21

FAR 23 MANUALS, MARKINGS & PLACARDS CHECKLIST

PRIMARY FAR	SUPPORT FAR	DESCRIPTION	MAN-UAL	MARK	PLA-CARD	AMENDMENT NO.
23.1555(d)(1)		Usable fuel marked at indicator, if applicable		X		21
23.1555(d)(2)		Usable fuel marked on selector, if applicable		X		21
23.1555(e)(1)		Landing gear position indicator marking		X		21
23.1555(e)(2)		All emergency controls must be red and method of operation marked		X		21
23.1557(a)		Baggage, cargo and ballast location placards for weight and content			X	23
23.1557(b)		Seats less than 170 lbs.			X	23
23.1557(c)		Fuel filler openings		X		23
23.1557(d)		Emergency exit placards and controls			X	23
23.1557(e)		External power plug markings		X		23
23.1557(f)		Unusable fuel placard by fuel quantity indicator			X	23
23.1559(a)(1)		Operating limitations - single category			X	21
23.1559(a)(2)		Operating limitations - multicategory			X	21
23.1559(b)		Kinds of operation			X	21
23.1561		Method of operation and stowage of safety equipment		X		Orig.

FAR 23 MANUALS, MARKINGS & PLACARDS CHECKLIST

PRIMARY FAR	SUPPORT FAR	DESCRIPTION	MANUAL	MARK	PLACARD	AMENDMENT NO.
23.1563		V_A and V_{LO} near airspeed indicator			X	7
23.1567		Flight maneuvers 1. Normal - prohibits acrobatics 2. Utility - lists approved acro. maneuvers & entry speeds <u>or</u> spins prohibited 3. Acrobatic - lists approved acro. maneuvers and entry speeds a. prohibits inverted if not approved			X	21
23.1581	23.1583 thru 23.1589	1. Requires AFM 2. Requires any other info necessary for safe operation	X			21
23.1583(a)	23.1545	Requires information for marking airspeed indicator per 23.1545 and V_A, V_{LE} and V_{LO} and their significance	X			23
23.1583(b)	23.1521 23.1549 thru 23.1553	Info explaining powerplant limitations and instrument markings	X			23
23.1583(c)		Maximum weight and maximum landing weight if less than maximum	X			23
23.1583(d)		Center of gravity limits	X			23
23.1583(e)(1)	23.221	Acrobatics prohibited. Statement "incapable of spinning" if applicable; otherwise placard against spins	X		X	23

FAR 23 MANUALS, MARKINGS & PLACARDS CHECKLIST

PRIMARY FAR	SUPPORT FAR	DESCRIPTION	MAN-UAL	MARK	PLA-CARD	AMENDMENT NO.
23.1583(e)(2)	23.221	Authorized maneuvers and entry speeds. Statement "Incapable of spinning" if applicable	X			23
23.1583(e)(3)		Authorized maneuvers and entry speeds. spin recovery placard	X		X	23
23.1583(f)		Positive limit load factor in g's	X			23
23.1583(g)		Number and function of minimum flight crew, if more than one	X			23
23.1583(h)		Kinds of operation and meteorological conditions and listing of installed equipment affecting limitations identified as to function	X			23
23.1583(k)	23.1527	Maximum operating altitude	X			23
23.1583(1)		Maximum passenger seating configuration	X			23
23.1585(a)		Information concerning: 1. Normal and emergency procedures 2. Demonstrated crosswind velocity 3. Operation in crosswind 4. Airspeeds, procedures and info pertinent to use of: a. Recommended climb speed & variation with altitude b. V_X and variation with altitude c. Approach speeds and speeds for transition to balked landing	X			23

FAR 23 MANUALS, MARKINGS & PLACARDS CHECKLIST

PRIMARY FAR	SUPPORT FAR	DESCRIPTION	MAN-UAL	MARK	PLA-CARD	AMENDMENT NO.
23.1585(c)	23.51	1. All engine takeoff procedures 2. Multiengine airplane info concerning one-engine-inoperative procedures for a. Maintaining or recovering control at speeds $\pm V_{MC}$ b. Landing & go-around, if safe, or warning against attempting go-around c. Obtaining best performance including effects of configuration	X			23
23.1585(d)	23.953	Multiengine info identifying operating conditions when fuel system independence is necessary for safety and instructions for placing fuel system in that configuration	X			23
23.1585(e)	23.1353	*Procedures for disconnecting battery* from charging source, if applicable	X			23
23.1585(f)		Unusable fuel if applicable	X			23
23.1585(g)		Usable fuel in each tank	X			23
23.1587(a)(1)	23.201(b)	Loss of altitude of more than 100 ft. or nose down pitch more than 30° during stall recovery	X			21
23.1587(a)(2)		*Condition for total usable* fuel	X			21
23.1587(a)(3)		V_{SO} at maximum weight	X			21
23.1587(a)(4)		V_{S1} gear & flaps up at bank angles up to 60°	X			21

PRIMARY FAR	SUPPORT FAR	DESCRIPTION	MAN-UAL	MARK	PLA-CARD	AMENDMENT NO.
23.1587(a)(5)	23.51	Takeoff distance; speed at 50' ht., configuration, kind of surface, use of cooling and flight path control devices & landing gear retraction usage	X			21
23.1587(a)(6)	23.75	Landing distance; configuration, kind of surface, and flight path control devices	X			21
23.1587(a)(7)	23.65 23.77	Steady rate or gradient of climb: Airspeed, power, configuration	X			21
23.1587(a)(8)		Calculated approximate effect on takeoff distance, landing distance and rate of climb, of variations in 1. altitude, S.L. to 8000' 2. temperature, S.L. to 8000', ISA, $-60^{\circ}+ 40^{\circ}$F	X			21
23.1587(a)(9)	23.1041 thru 23.1047	For recip. engines, max. temp. for cooling	X			21
23.1587(b)		Approximate degradation of climb performance with skis on fixed gear landplanes, not to be "critical" and not to exceed 30 to 50 feet per minute	X			21
23.1587(c)(1)	2.205	One-engine-inoperative stall altitude loss and pitch angle	X			21
23.1587(c)(2)	23.67	One-engine-inoperative best climb or minimum descent speed	X			21

FAR 23 MANUALS, MARKINGS & PLACARDS CHECKLIST

PRIMARY FAR	SUPPORT FAR	DESCRIPTION	MAN-UAL	MARK	PLA-CARD	AMENDMENT NO.
23.1587(c)(3)	23.1047	One-engine-inoperative cooling climb speed, if required	X			21
23.1587(c)(4)	23.67	One-engine-inoperative rate or gradient of climb: airspeed, power & configuration	X			21
23.1587(c)(5)	23.67	Calculated approximate effect on steady rate of climb of variation in 1. Altitude at sea level and 8000', ISA, cruise configuration 2. Temperature at sea level and 8000', ISA $-60^{\circ}$to + 40°F	X			21
23.1589(a)	23.25	Weight and location of each item of equipment installed	X			Orig.
23.1589(b)	23.25	Loading instructions for load conditions between minimum and maximum weight which could put c.g. out of limits selected by applicant, for structure, or for functional requirement compliance	X			Orig.
FAR 23 Appendix E (a)(2)		Increased weight allowed with standby power and Administrator's operating limitations (if nec.) and prohibition to operate at high weight when standby power stored too long or expended	X	X	X	2

APPENDIX 5. GUIDE FOR PREPARING AIRPLANE FLIGHT MANUAL AND PILOT'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 instructions 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, etc.

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. 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.

l. Type as shown on sample AFM Supplement leaving a blank space so date of approval can be added.

m. If the supplement requires more than one page, 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).

n. For those airplanes without flight manuals, and placards are not appropriate, the document should be labeled a Supplemental 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.

o. If applicant revises the AFM supplements, pertaining to one airplane model, a log of revisions may be added, as follows:

LOG OF REVISIONS

Revision No.	Pages Affected	Description	FAA-Approved	Date

p. 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 and performance information not contained in this supplement, consult the basic airplane flight manual.

I. LIMITATION: (h)

II. PROCEDURES: (i)

III. PERFORMANCE: (j)

FAA-Approved ____(k)____

Manager, Aircraft Certification Office
Federal Aviation Administration
City, State

DATE ______________________
(l)

Revised ______________________
(If applicable)

Page 1 of ______________________
(m)

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 Conditions
Flight Controls (ATA-27)					
1. 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
Instruments (ATA-31)					
1. Clock	0	0	1	1	1

	VFR Day	VFR Night	IFR Day	IFR Night	Icing Conditions
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.

	VFR Day	VFR Night	IFR Day	IFR Night	Icing 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
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
4. Propeller Reversing	2	2	2	2	2

	VFR Day	VFR Night	IFR Day	IFR Night	Icing Conditions
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 Presure 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 the equipment and/or system was 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: Equipment and/or systems in addition to those listed above may be required by the operating regulations.

U.S. STANDARD ATMOSPHERE (1962)

Geopotential Altitude h (ft)	(°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 1

U.S. STANDARD ATMOSPHERE (1962)

Geopotential Altitude h ft	Temp. T °F	°R	°C	Temp. Ratio θ	Press. p psi	Press. Ratio δ	Density ρ slug/ft^3	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 1 (continued)

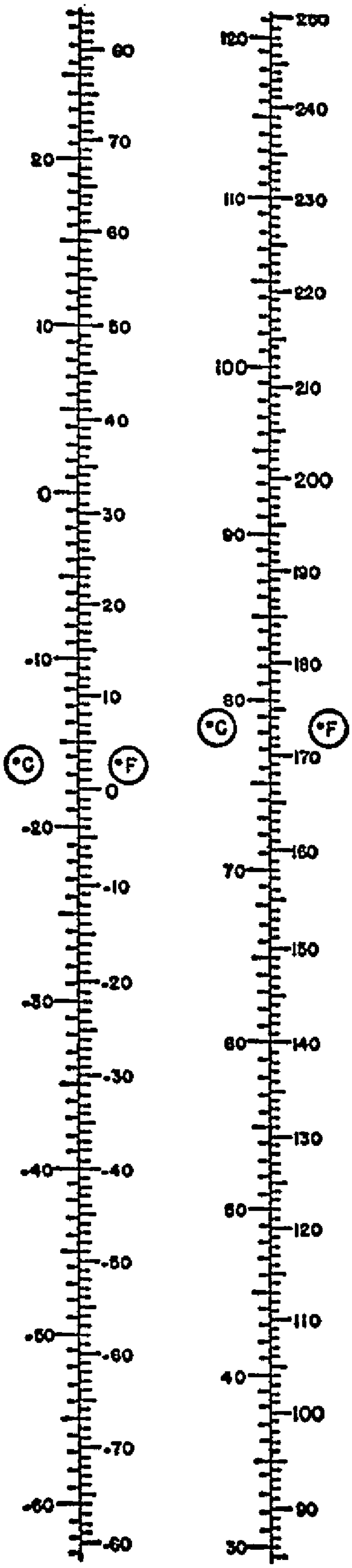


Figure 2 - TEMPERATURE CONVERSION CHART

DETERMINATION OF AIR TEMPERATURE IN RELATION TO INTERNATIONAL STANDARD ATMOSPHERE

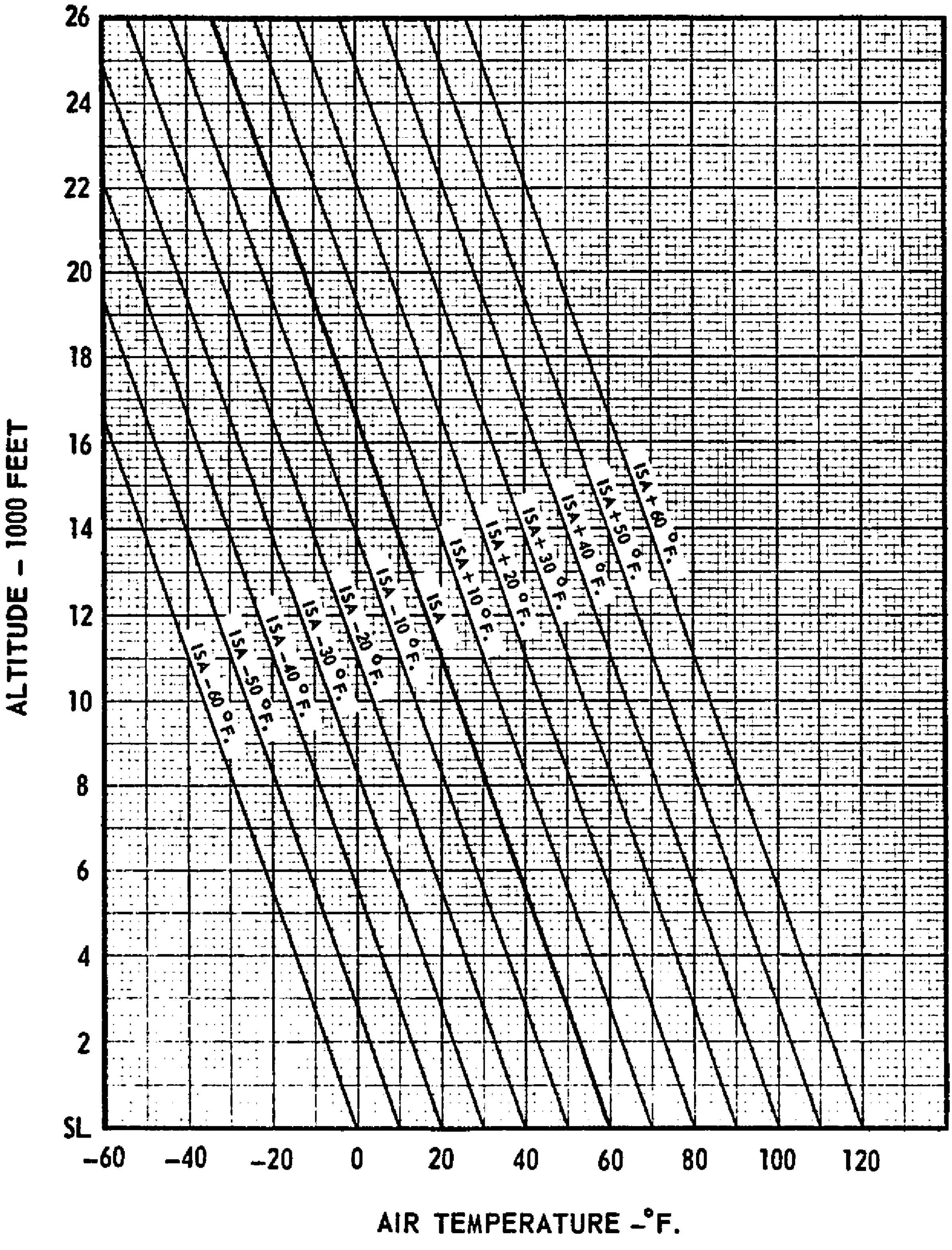


Figure 3

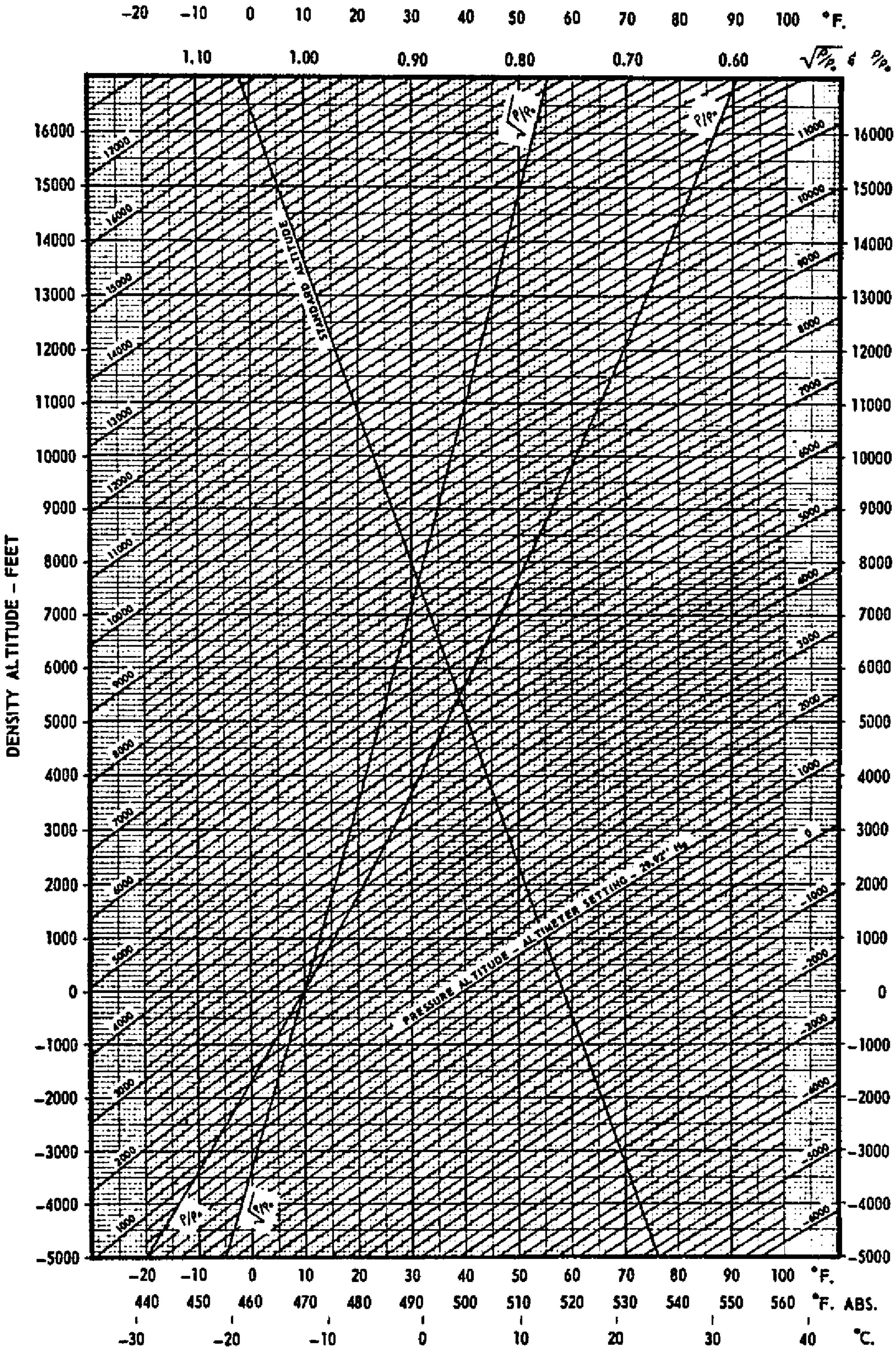


Figure 4 - DENSITY/PRESSURE ALTITUDE CONVERSION

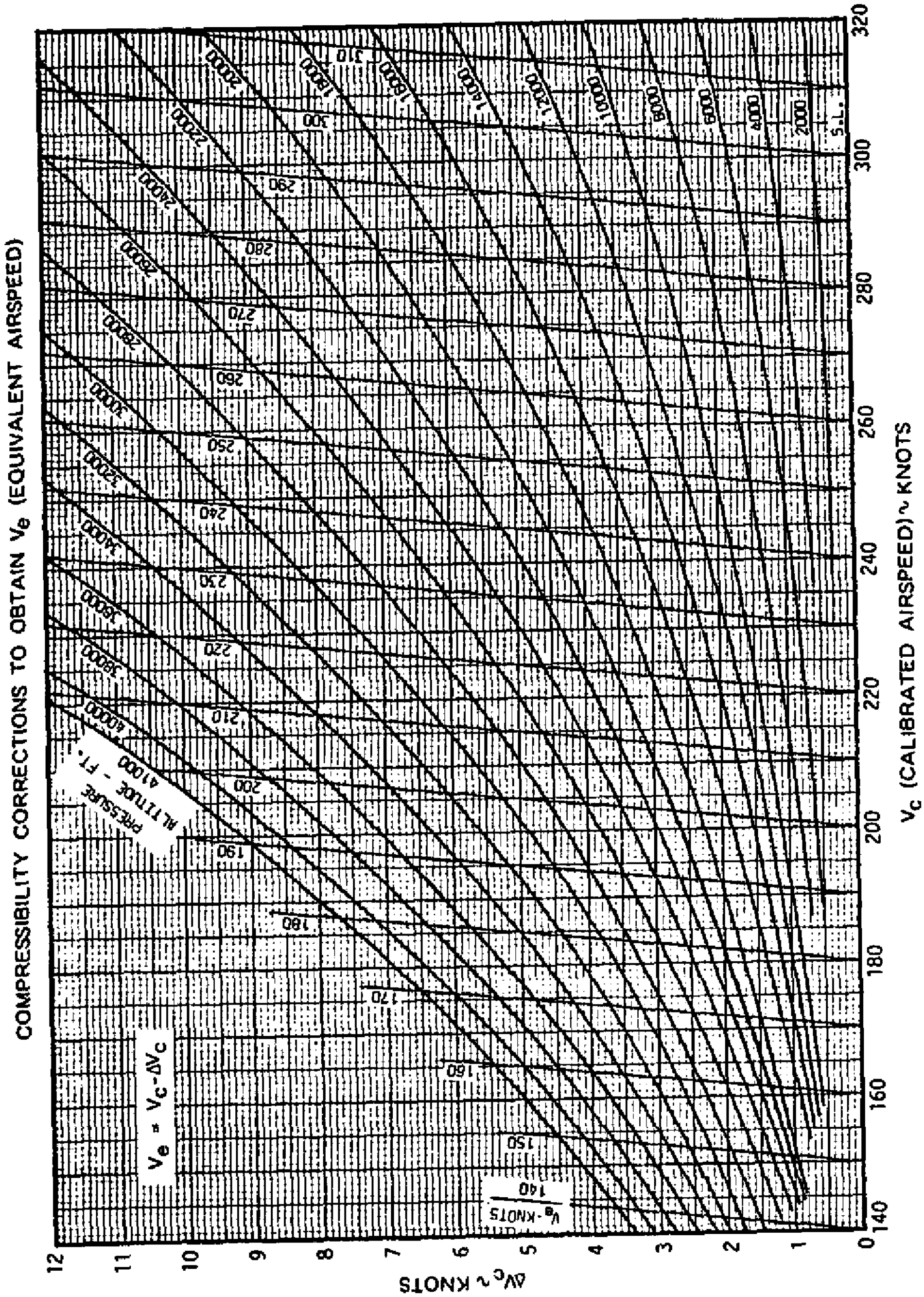


Figure 5 - COMPRESSIBILITY CORRECTION TO CAS

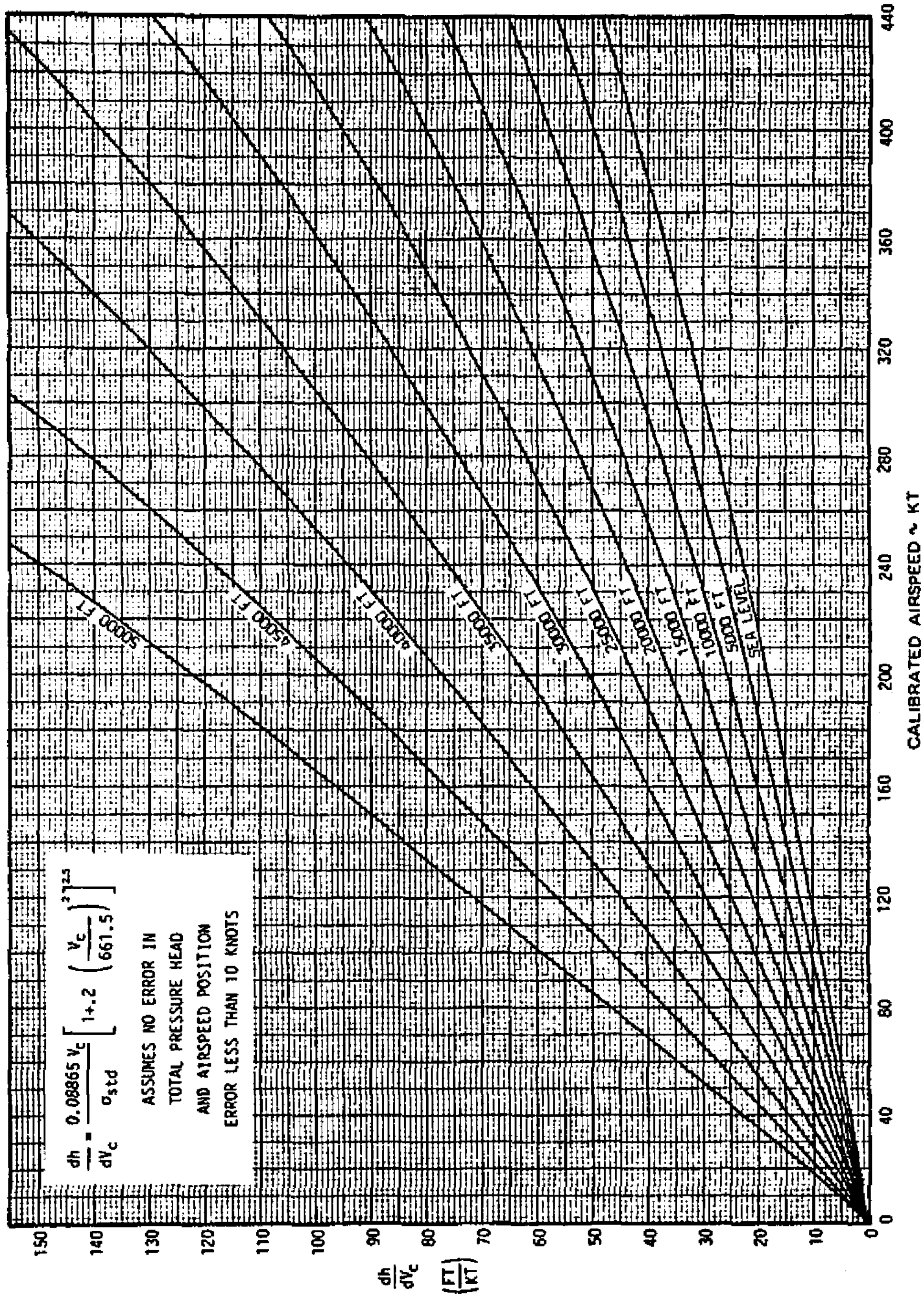


Figure 6 - ALTIMETER ERROR VS. CAS

$$\frac{\text{Indicated Temp. } (^{o}K)}{\text{Outside Air Temp. } (^{o}K)} = 1 + (\text{recovery factor}) \frac{\text{mach number}^2}{5}$$

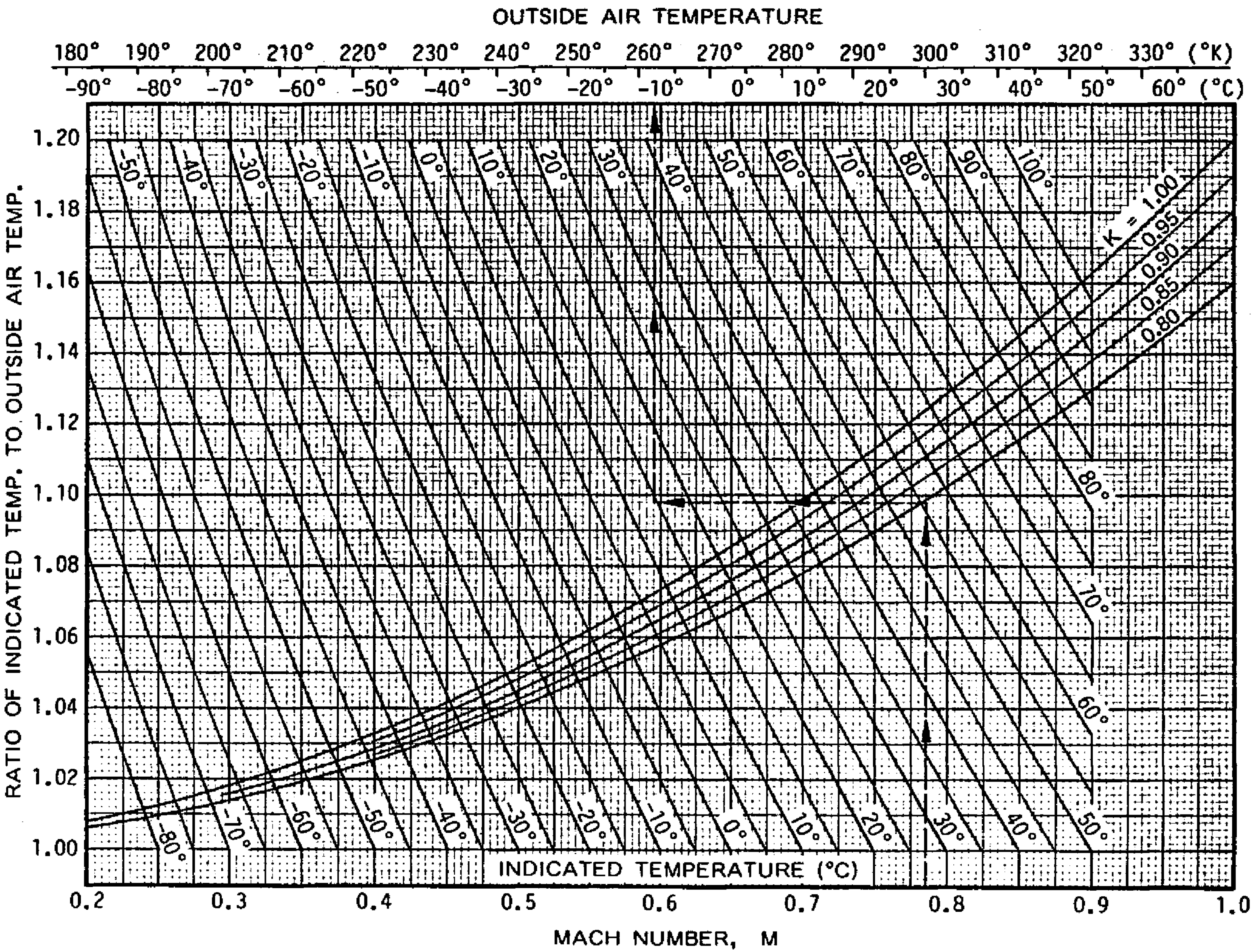


Figure 7 - TEMPERATURE RAM RISE

STALLING SPEED AS A FUNCTION OF ANGLE OF BANK - Ø

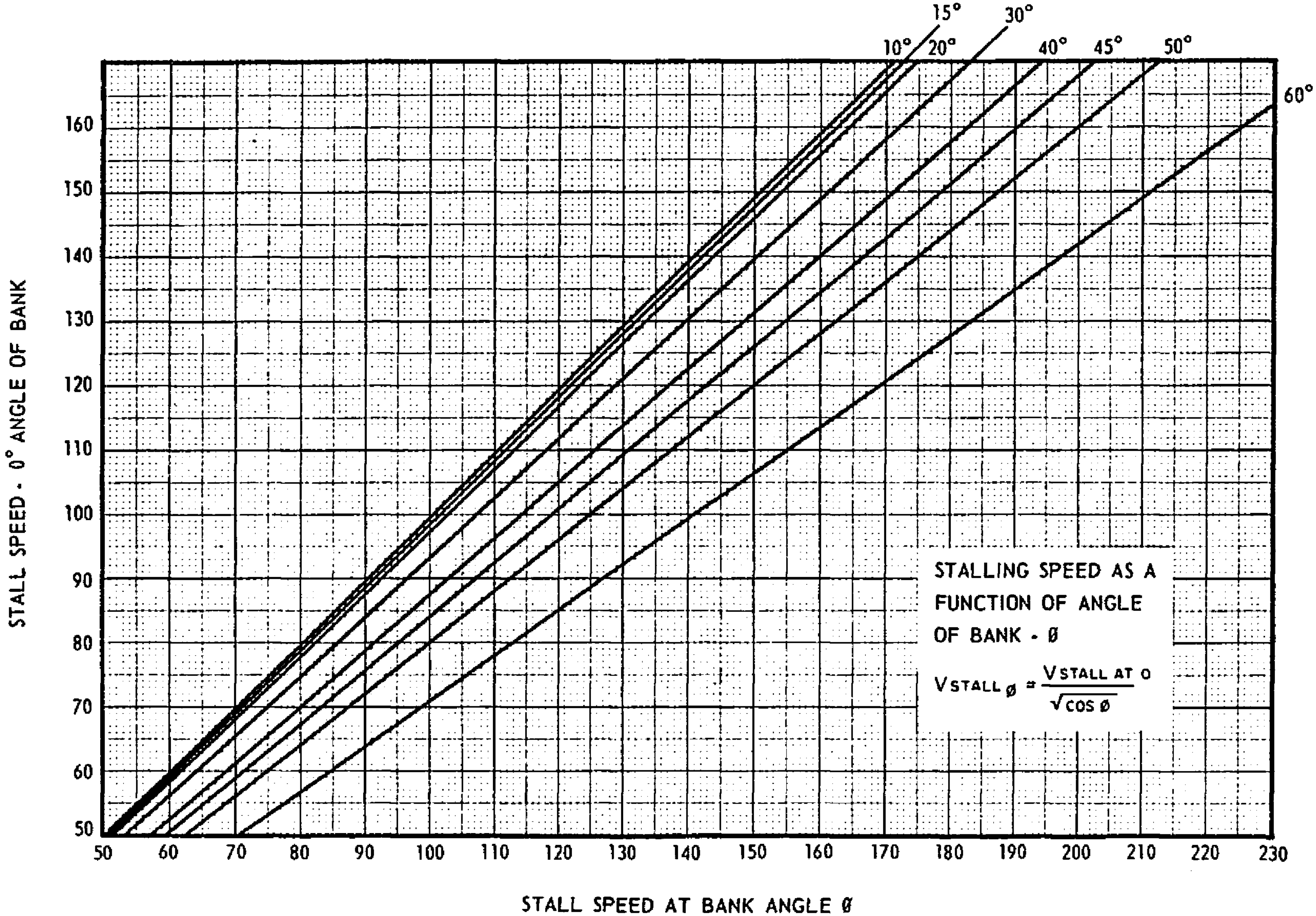
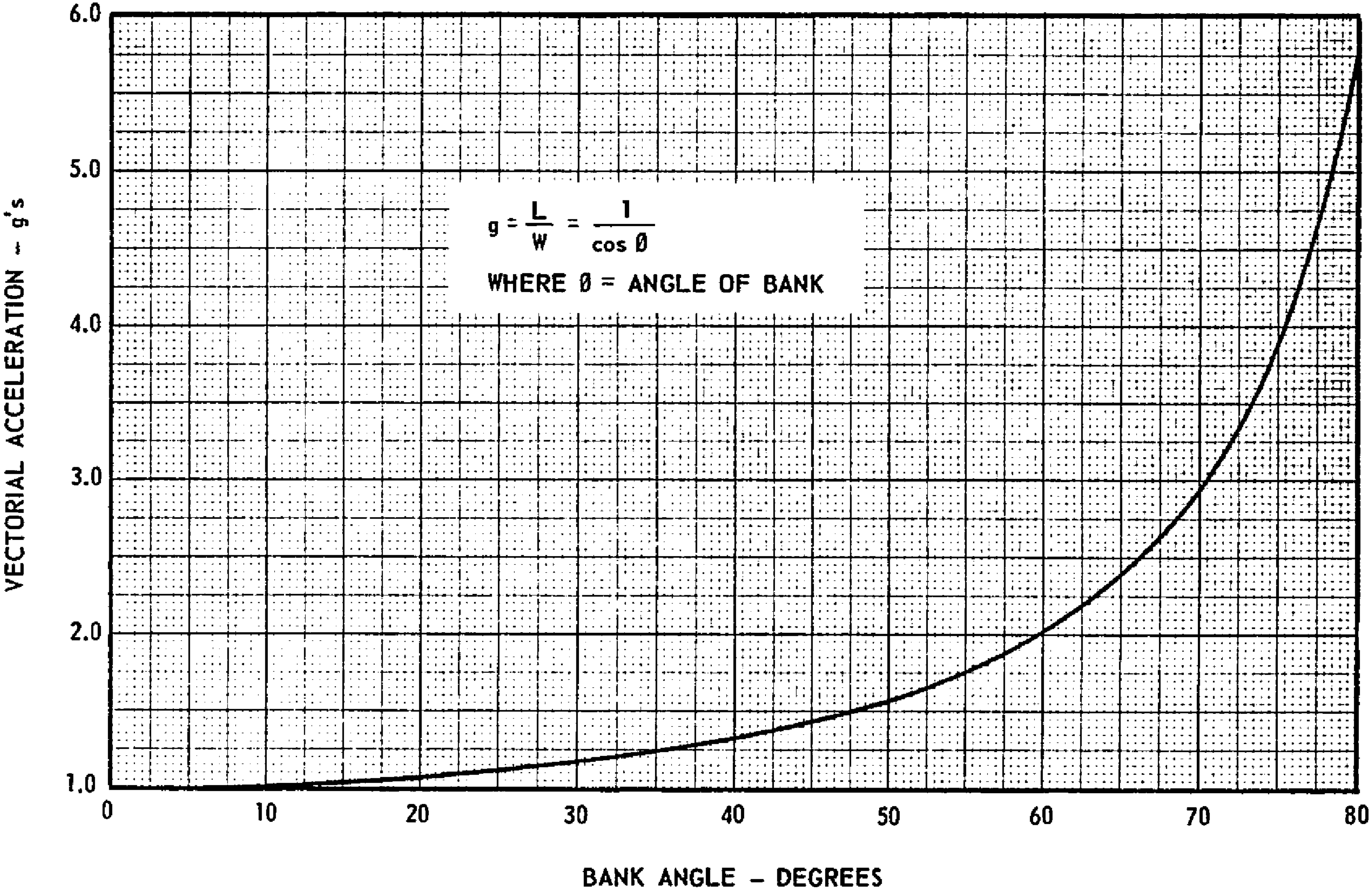


Figure 8

Figure 9

VECTORIAL ACCELERATION VERSUS ANGLE OF BANK



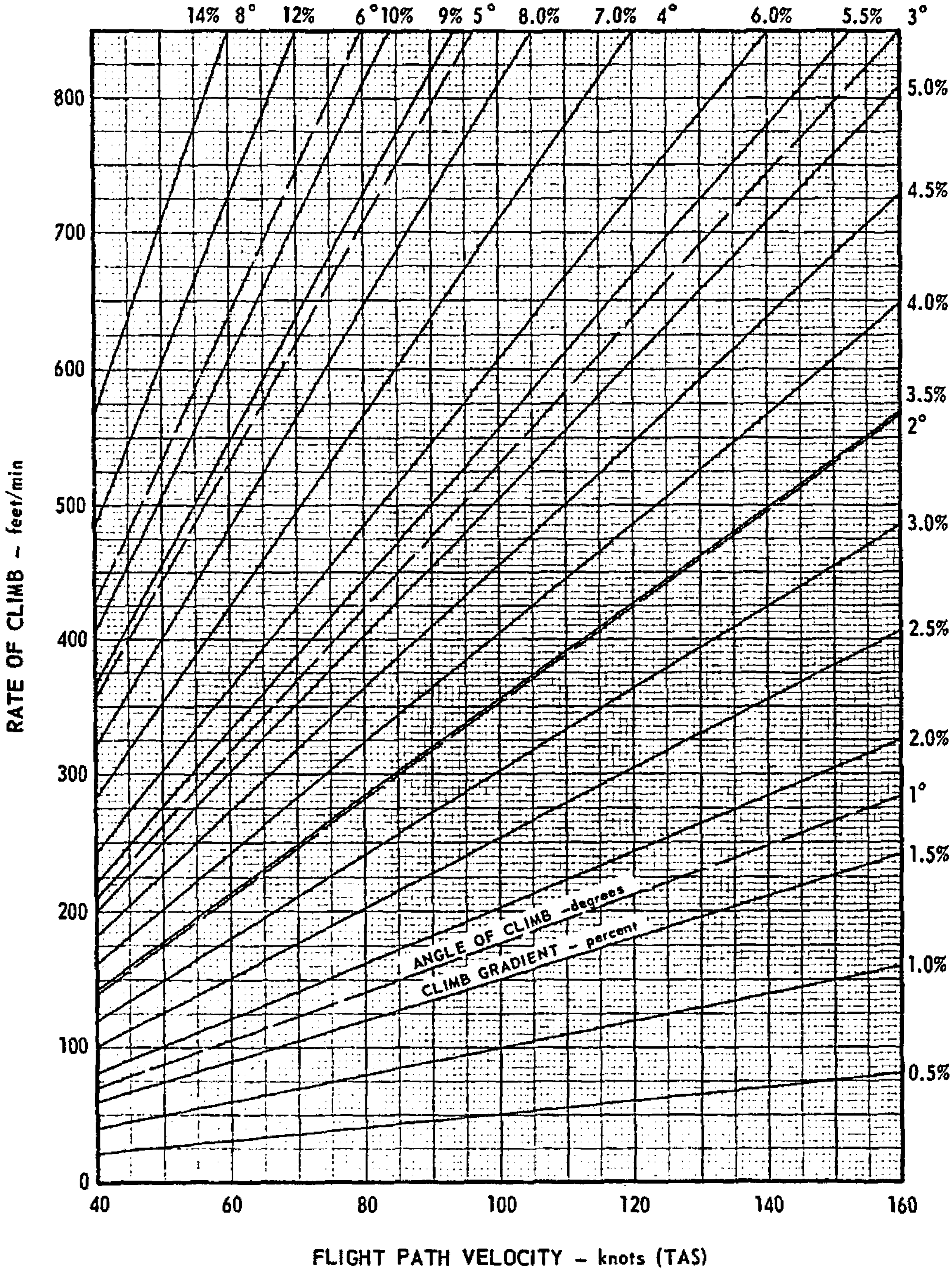

14%
8°
12%
6°
10%
9%
5°
8.0%
7.0%
4°
6.0%
5.5%
3°
5.0%
4.5%
4.0%
3.5%
2°
3.0%
2.5%
2.0%
1°
1.5%
1.0%
0.5%
ANGLE OF CLIMB -degrees
CLIMB GRADIENT - percent
RATE OF CLIMB - feet/min
0
100
200
300
400
500
600
700
800
40
60
80
100
120
140
160
FLIGHT PATH VELOCITY - knots (TAS)

Figure 10

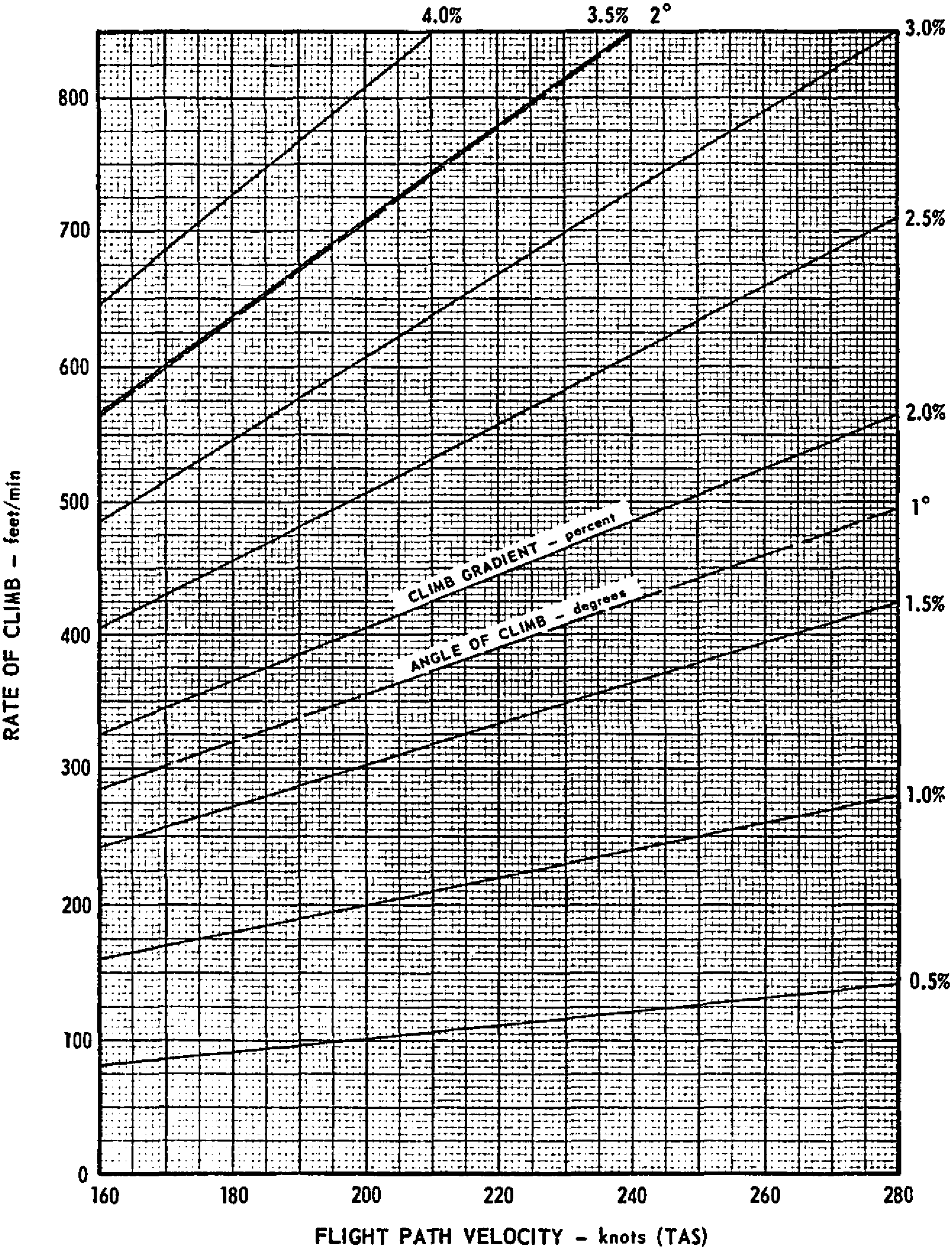


Figure 10 (continued)

TAKEOFF AND LANDING CROSSWIND COMPONENT

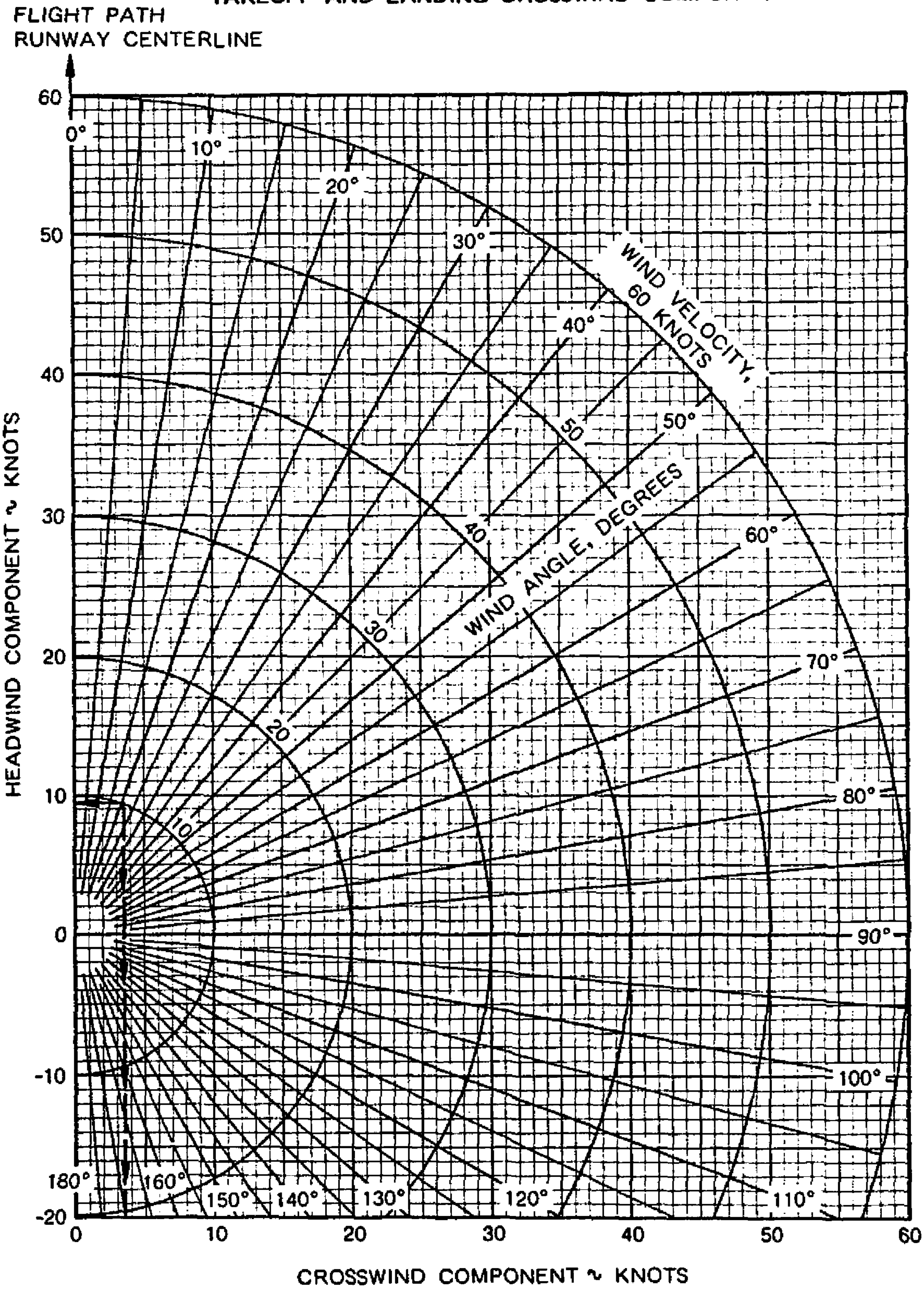


Figure 11

APPENDIX 8. CONVERSION FACTORS TABLE

LENGTH

Multiply	By	To Obtain
Centimeters	0.3937	Inches
	0.03281	Feet
	.01	Meters
Kilometers	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 Centimeters	10^{-3}	Liters
	0.0610	Cubic Inches

VOLUME (continued)

Multiply	By	To Obtain
Cubic Feet	28317	Cubic Centimeters
	1728	Cubic Inches
	0.03704	Cubic Yards
	7.4805	Gallons (U.S.)
	28.32	Liters
Cubic Inches	4.329×10^{-3}	Gallons (U.S.)
	0.01732	Quarts (U.S.)
	0.0164	Liters
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	Liters
Gallons, U.S.	231	Cubic Inches
	0.1337	Cubic Feet
	3.785	Liters
	0.8327	Imperial Gallons
	128	Fluid Ounces
Fluid Ounces	29.59	Cubic Centimeters
	1.805	Cubic Inches
Liters	61.02	Cubic Inches
	0.2642	Gallons (U.S.)
	1.057	Quarts (U.S.)

AREA

Multiply	By	To Obtain
Square Centimeters	0.1550	Square Inches
	0.001076	Square Feet
Square Feet	144	Square Inches
	0.1111	Square Yards
Square Inches	645.16	Square Millimeters
Square Kilometers	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 (at 4°C)	0.00246	Atmospheres
	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

1. 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, etc.) should be long enough to allow for drift and accurate sighting of end line passage. 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 span 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 thru 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) thru (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.

(7) Direction of run.

d. Sample Speed Course Data reduction (Refer to figure 1).

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

$$1\ \text{Knot} = \frac{6076.1}{3600}\ \frac{\text{feet/nautical mile}}{\text{second/hour}} = 1.6878\ \text{feet/second}$$

$$GS = \frac{10560}{(1.6878)(47.1)} = \frac{.5925\ (10560)}{47.1} = 132.8\ \text{knots}$$

$$GS_{AVE}\ (TAS) = \frac{132.8 + 125.6}{2} = 129.2\ \text{knots}$$

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 29.92")

Flap Position Degrees	Gear Position (Up or Down)	Observed Data				Ground Speed* Knots	Average Ground Speed, Knots	Factor**	Calibrated Air Speed Knots	Average I.A.S. Knots	Error Knots		
		Time Seconds	I.A.S. (Knots)	Pressure Altitude Ft.	SAT. °F						Airspeed System	Instrument	Position
	Fixed	47.1	128.0	1610	55	132.8							
0		49.8	129.0	1600	55	125.6	129.2	.975	126.0	128.5	+2.5	+1	+1.5
		44.5	135.0	1600	55	140.5							
		47.1	137.0	1600	55	132.8	136.7	.975	133.3	136.0	+2.7	0	+2.7
		40.5	148.0	1600	55	154.2							
		43.3	148.0	1600	55	144.3	149.3	.975	145.6	148.0	+2.4	-1	+3.4

* Ground Speed = $\frac{C \times \text{Course Distance (Ft)}}{\text{Time (Seconds)}}$ C = 0.5925 for course speed in Knots. Or use: C = 0.6818 for M.P.H.

** Factor $= \sqrt{\rho/\rho_o} = 4.16\sqrt{\frac{\text{Observed Pressure (In. Hg.)}}{459.7 + \text{Observed Temperature } ^{o}F}}$ (or read from chart)

Figure 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 4 in appendix 7. At 1600' 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 (TAS)	CAS	IAS	ERROR System =	Instrument +	Position
129.2	126.0	128.5	+2.5	+1	+1.5
			(CAS-IAS)	Vinst	Vpos

(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% 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 which is greater than if the flow were incompressible. We now use EAS as a basis for design airspeeds (§ 23.235). Values of CAS vs. EAS may be calculated or you may use the chart in appendix 7, figure 5, to convert knots CAS to EAS.

2. TRAILING BOMB AND/OR AIRSPEED BOOM METHOD.

a. Test Conditions.

(1) Air Quality. Smooth, stable air is needed for calibrating the airspeed indicating system using a trailing bomb or airspeed boom.

(2) Weight and C.G. Same as speed course method. See paragraph 1a(2) of this appendix.

(3) Speed Range. The calibration should range from just above 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 speed course.

(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 which 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 and Reduction. Data to be recorded at each test point:

(1) Airplane IAS.

(2) Bomb or boom IAS.

(3) Wing flap position.

(4) Landing gear position.

(5) Attitude (level or descent).

See figure 2 for sample calculations using the trailing bomb.

3. PACE AIRPLANE METHOD.

a. Test Conditions.

(1) Test conditions are the same as those required for the trailing bomb calibration with the exception of those conditions specifically applicable to use of the trailing bomb.

(2) Assurance should be obtained that the pace airplane has been accurately calibrated. The calibration should have been accomplished recently and the calibration curve available.

b. Test Procedures. The test procedures are the same as those for calibration using the trailing bomb. The pace airplane is flown at the same altitude as the test airplane and a relative velocity of zero maintained between the two at each test airspeed. The pace airplane must be close to ensure that pace and test airspeeds are the same, but far enough away so that the pressure fields of the two airplanes do not interact. Readings are coordinated by radio.

Sample Test Data

Flap Position (Degrees)	Gear Position (Up or Down)	OBSERVED DATA			Bomb Correction (knots)	Calibrated Airspeed (knots)	ERROR (knots)		
		Airplane I.A.S. (knots)	Bomb I. A. S. (knots)	Flight Attitude (Level or Diving)			Airspeed System	Instrument	Position
0	Fixed	50	63.2	Level	+0.3	63.5	-13.5	-3	-10.5
		60	67.2	"	+0.2	67.4	-7.4	-2	-5.4
		70	74.2	"	+0.2	74.4	-4.4	-2	-2.4
		80	82.5	"	+0.3	82.8	-2.8	-1	-1.8
		90	91.5	"	+0.3	91.8	-1.8	0	-1.8
		100	100.5	"	+0.4	100.9	-0.9	0	-0.9
		110	108.8	"	+0.4	109.2	0.8	1	-0.2
		120	118.2	"	+0.7	118.9	1.1	2	-0.9
		130	128.0	"	+0.7	128.7	1.3	2.5	-1.2
		140	137.5	"	+0.7	138.2	1.8	3	-1.2

Sample Calculations:

CAS = Bomb IAS + Bomb Correction
= 63.2 + 0.3 = 63.5 knots

System error = IAS - CAS
= 50 - 63.5 = -13.5 knots

System error = position error + instrument error

-13.5 = position error + (-3)
-13.5 - (-3) = position error
-10.5 = position error

Figure 2 - BOMB AIRSPEED DATA REDUCTION

c. Data to be recorded:

(1) Test airplane, IAS (knots).

(2) Test airplane pressure altitude.

(3) Pace airplane, IAS (knots).

(4) Pace airplane pressure altitude.

d. Data Reduction. The data reduction process is the same as that used for reducing data from a trailing bomb calibration.

4. 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 which provides readouts of ground speed which 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 which 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 which may result from acceleration.

(4) Test Airspeed Indicator. A mechanical airspeed indicator with known dynamic characteristics during acceleration or an electronic transducer which can provide airspeed information.

(5) Test Reference Altimeter. An altimeter which 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)(ii).

(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 vs. 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 the runway. The two airspeed indicators should be located in close proximity to 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 3 for system schematic.

(1) Test Conditions.

(i) Air Quality. The surface winds should be light with a minimum of gusting.

(ii) 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.

(iii) Speed Range. The speeds should range from .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.

(iv) Configuration. The airspeed system should be calibrated during the accelerate-takeoff ground run for each approved takeoff flap setting.

(2) Test Procedures.

(i) Align the airplane with the runway.

(ii) 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.

(iii) Close the cabin door.

(iv) 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.

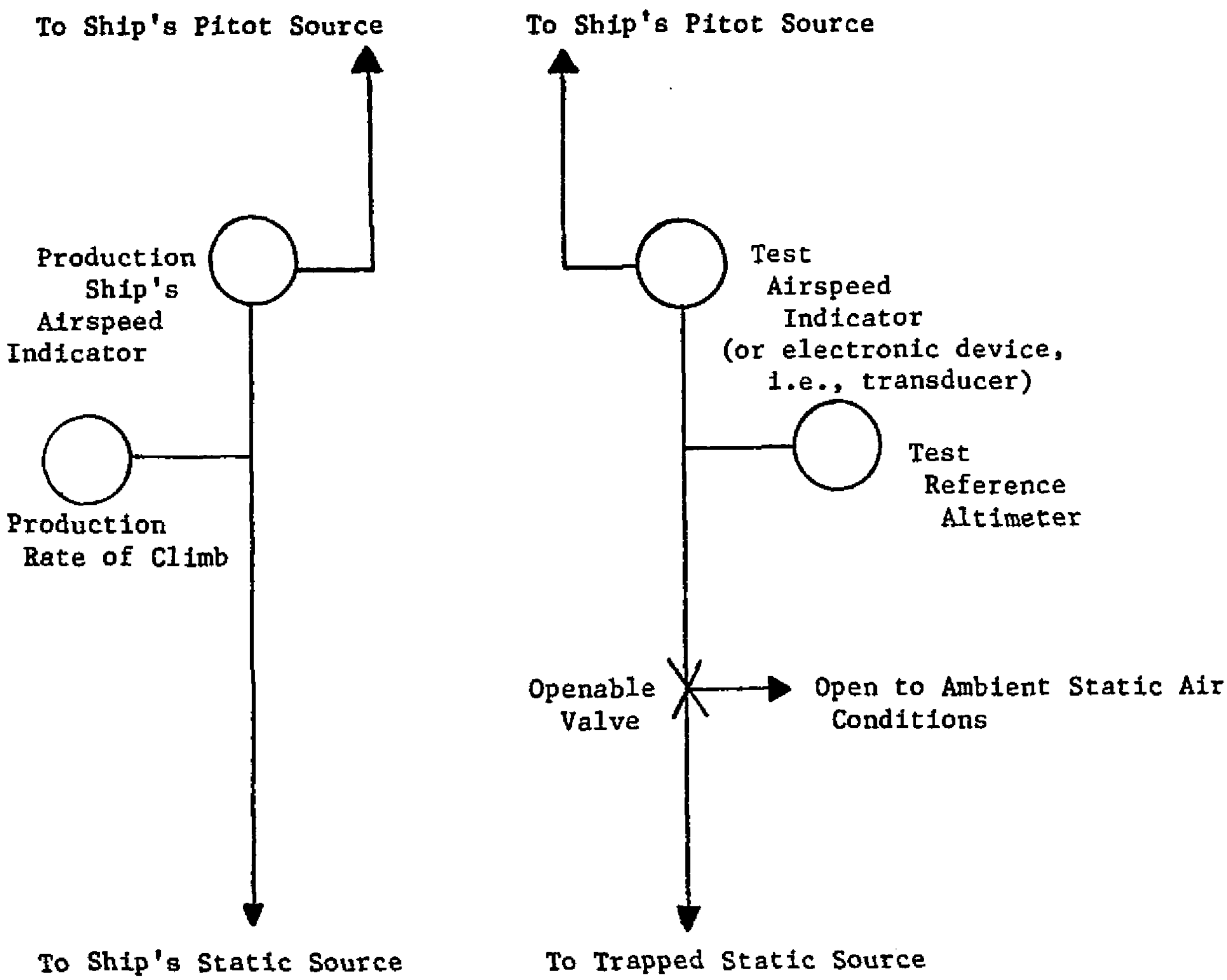


Figure 3 - TRAPPED STATIC SOURCE SCHEMATIC

(v) 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.

(vi) Repeat steps (i) thru (v) 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 figure 4 for a sample data reduction. Record and perform the following:

Figure 4 - TRAPPED STATIC 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
2. Corrected ship's IAS minus corrected trapped static IAS

(i) Production indicated airspeed, test indicated airspeed, and configuration.

(ii) 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.

(iii) Calculate the amount of system error (difference between corrected test indicated airspeed and production indicated airspeed). It may be appropriate to correct for differences in the ship's airspeed error between the test instrument and the average error identified in design specifications of like production indicators.

(iv) Plot IAS vs. CAS within the required range of speeds. See figure 5 for a sample plot.

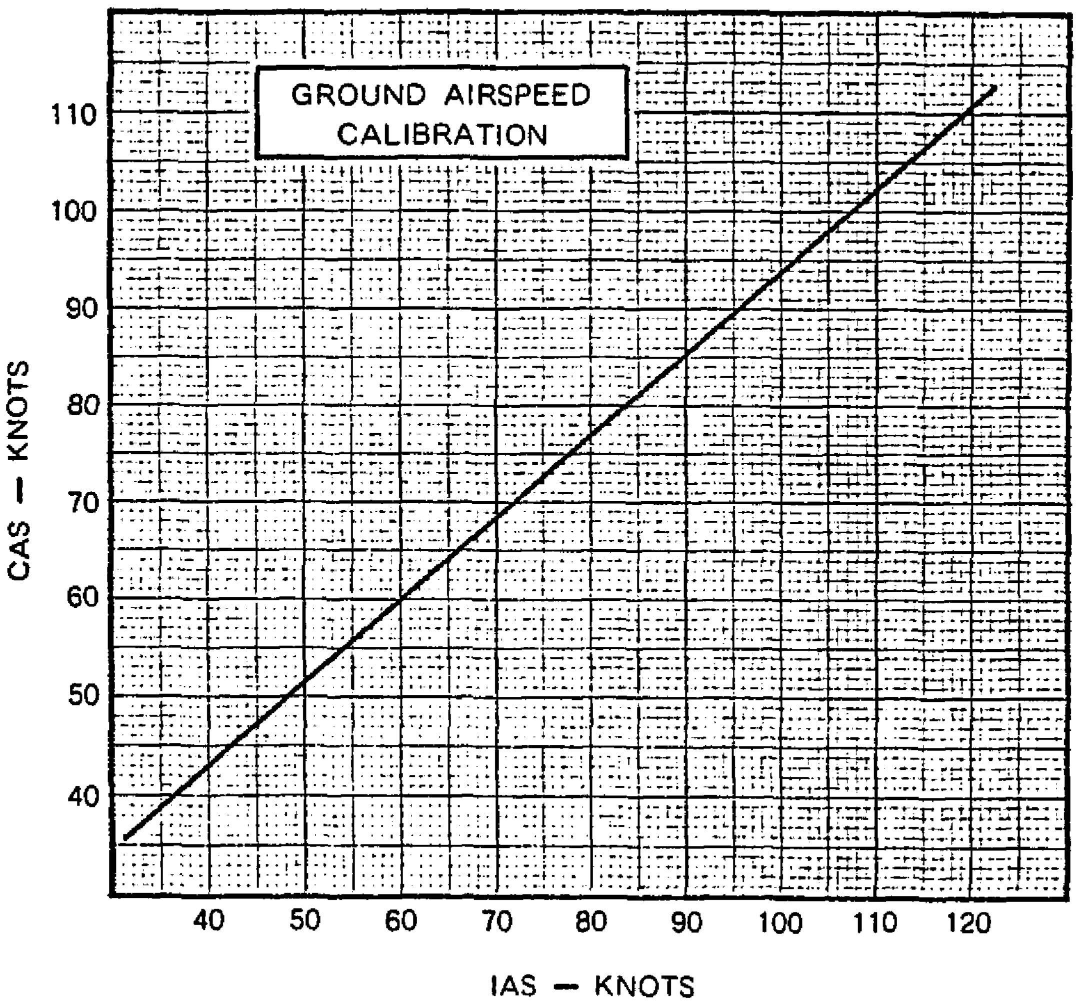


Figure 5 - GROUND AIRSPEED CALIBRATION

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.

(i) 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.

(ii) Weight and C.G. Same as for the trapped static source method.

(iii) Speed Range. Same as for the trapped static source method.

(iv) Configuration. Same as for the trapped static source method.

(2) Test Procedures.

(i) Align the airplane with the runway.

(ii) 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.

(iii) The takeoff may continue or be aborted when beyond the maximum required speed.

(iv) Record surface wind velocity and direction; surface air temperature and runway pressure altitude for each run.

(v) Repeat steps (i) thru (iv) 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 figure 6 for a sample data reduction. Record and perform the following:

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

NOTES:

1. CAS = TAS ($\sqrt{\sigma}$)
2. Obtain from instrument calibration
3. Corrected Ship's IAS minus CAS

Figure 6 - SAMPLE GROUND AIRSPEED CALIBRATION USING A DISTANCE MEASURING UNIT

(i) Production indicated airspeed, ground speed, surface air temperature, runway pressure altitude, wind velocity and wind direction with respect to runway heading.

(ii) 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.

(iii) Calculate the amount of system error (difference between CAS and production indicated airspeed).

(iv) Plot IAS vs. CAS within the required range of speeds. See figure 5 for a sample plot.