U.S. Department
of Transportation
Federal Aviation Administration

Advisory Circular

Subject: Flight Test Guide for Certification of Transport Category Airplanes

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This advisory circular (AC) provides guidance for the flight test evaluation of transport category airplanes. This AC includes flight test methods and procedures to show compliance with the regulations contained in title 14, Code of Federal Regulations (14 CFR) part 25, subpart B, "Flight," which address airplane performance and handling characteristics.

This revision, AC 25-7D, clarifies paragraph 23.2.4, *Engine Restart Capability—§ 25.903(e)*; adds paragraph 34.4, *Circuit Protective Devices—§ 25.1357*; and revises appendix B, *Function and Reliability (F&R) Tests*, of this AC. This AC has been re-formatted to use a new paragraph numbering system for improved usability.

The first change revises the means of compliance associated with demonstrating the restart capability required by § 25.903(e). The second change adds a paragraph providing guidance for flight test evaluation of compliance with the requirements for circuit protective devices. It is made in response to recommendations from the National Transportation Safety Board. The third change revises appendix B concerning F&R testing. It addresses issues that arose with F&R testing on recent certification programs where the current guidance was unclear.

If you have suggestions for improving this AC, you may use the Advisory Circular Feedback form at the end of this AC.

for/

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CHAPTER 1. INTRODUCTION

1.1 Purpose.

1.1.1 This AC provides updated guidance for the flight test evaluation of transport category airplanes. These guidelines provide an acceptable means of demonstrating compliance with the pertinent regulations of Title 14, Code of Federal Regulations (14 CFR) part 25. The methods and procedures described herein have evolved through many years of flight testing of transport category airplanes and, as such, represent current certification practice.

1.1.2 See appendix A for a list of acronyms and abbreviations used in this AC.

1.2 Applicability.

1.2.1 The guidance provided in this document is directed to airplane manufacturers, modifiers, foreign regulatory authorities, and Federal Aviation Administration (FAA) certification engineers, flight test pilots, and FAA designees.

1.2.2 This material is neither mandatory nor regulatory in nature and does not constitute a regulation. It describes acceptable means, but not the only means, for demonstrating compliance with the applicable regulations. The Federal Aviation Administration will consider other methods of demonstrating compliance that an applicant may elect to present.

1.2.3 While these guidelines are not mandatory, they are derived from extensive FAA and industry experience in determining compliance with the relevant regulations. On the other hand, if we become aware of circumstances that convince us that following this AC would not result in compliance with the applicable regulations, we will not be bound by the terms of this AC, and we may require additional substantiation or design changes as a basis for finding compliance.

1.2.4 This material does not change, create any additional, authorize changes in, or permit deviations from, regulatory requirements.

1.3 Cancellation.

This AC cancels AC 25-7C, *Flight Test Guide for Certification of Transport Category Airplanes*, dated October 16, 2012.

1.4 Background.

1.4.1 Since AC 25-7 was released on April 9, 1986, it has been the primary source of guidance for flight test methods and procedures to show compliance with the regulations contained in subpart B of part 25, which address airplane performance and handling characteristics. AC 25-7 has been revised several times to reflect changes in the part 25 regulatory requirements, changes in guidance and policy, and advances in technology.

1.4.2 The first revision, AC 25-7A, updated the original AC to incorporate the policy and guidance material applicable to all sections of part 25, not just subpart B. The material related to regulations outside of subpart B superseded that contained in Order 8110.8, *Engineering Flight Test Guide for Transport Category Airplanes*, which was cancelled when AC 25-7A was issued.

1.4.3 Change 1 to AC 25-7A added acceptable means of compliance for the regulatory changes associated with amendments 25-92 and 25-98 to part 25.

1.4.4 AC 25-7B added acceptable means of compliance for the regulatory changes associated with amendments 25-108, 25-109, and 25-115 to part 25, and revised guidance for expanding takeoff and landing data for airport elevations higher than those at which flight testing was conducted. Means of compliance associated with flight in icing conditions were removed as this material is now contained in AC 25-25A, *Performance and Handling Characteristics in Icing Conditions*, dated October 27, 2014.

1.4.5 Change 1 to AC 25-7B added acceptable means of compliance for the regulatory changes associated with amendment 25-135.

1.4.6 AC 25-7C reduced the number of differences between the FAA and European Aviation Safety Agency flight test guides, provided acceptable means of compliance for the regulatory changes associated with amendments 25-107, 25-109, 25-113, 25-115, 25-119 and 25-123 to part 25, and included changes responding to safety recommendations from the FAA and National Transportation Safety Board.

1.5 **Related Documents.**

1.5.1 Orders.

The following FAA orders are related to the guidance in this AC. The latest version of each order at the time of publication of this AC is identified below. If any order is revised after publication of this AC, you should refer to the latest version for guidance, which can be downloaded from the Internet at https://www.faa.gov/regulations_policies/orders_notices/.

- Order 8100.5C, *Aircraft Certification – Organizational Structure and Functions*, dated July 14, 2017.
- Order 8110.4C, with Change 6, *Type Certification*, dated March 3, 2017.

1.5.2 Advisory Circulars.

The following FAA ACs are related to the guidance in this AC. The latest version of each AC at the time of publication of this AC is identified below. If any AC is revised after publication of this AC, you should refer to the latest version for guidance, which can be downloaded from the Internet at www.faa.gov/regulations_policies/advisory_circulars.

- AC 20-73A, *Aircraft Ice Protection*, dated August 16, 2006.
- AC 20-124, *Water Ingestion Testing for Turbine Powered Airplanes*, dated September 30, 1985.
- AC 20-131A, *Airworthiness Approval of Traffic Alert and Collision Avoidance Systems (TCAS II) and Mode S Transponders*, dated March 29, 1993.
- AC 20-138D, with Change 2, *Airworthiness Approval of Positioning and Navigation Systems*, dated April 7, 2016.
- AC 20-147A, *Turbojet, Turboprop, Turboshaft, and Turbofan Engine Induction System Icing and Ice Ingestion*, dated October 22, 2014.
- AC 20-161, *Aircraft Onboard Weight and Balance Systems*, dated April 11, 2008.
- AC 20-168, *Certification Guidance for Installation of Non-Essential, Non-Required Aircraft Cabin Systems & Equipment (CS&E)*, dated July 22, 2010,
- AC 21-29D, *Detecting and Reporting Suspected Unapproved Parts*, dated July 12, 2016.
- AC 21.101-1B, *Establishing the Certification Basis of Changed Aeronautical Products*, March 11, 2016.
- AC 25-9A, *Smoke Detection, Penetration, and Evacuation Tests and Related Flight Manual Emergency Procedures*, dated January 6, 1994.
- AC 25-11B, *Electronic Flight Displays*, dated October 7, 2014.
- AC 25-12, *Airworthiness Criteria for the Approval of Airborne Windshear Warning Systems in Transport Category Airplanes*, dated November 2, 1987.
- AC 25-13, *Reduced and Derated Takeoff Thrust (Power) Procedures*, dated May 4, 1988.
- AC 25-15 *Approval of Flight Management Systems in Transport Category Airplanes*, dated November 20, 1989.
- AC 25-17A, with Change 1, *Transport Airplane Cabin Interiors Crashworthiness Handbook*, dated May 24, 2016.
- AC 25-20, *Pressurization, Ventilation, and Oxygen Systems Assessment for Subsonic Flight Including High Altitude Operations*, dated September 10, 1996.
- AC 25-22, *Certification of Transport Airplane Mechanical Systems*, dated March 14, 2000.
- AC 25-23, *Airworthiness Criteria for Installation Approval of a Terrain Awareness and Warning System (TAWS) for Part 25 Airplanes*, dated May 22, 2000.
- AC 25-25A, *Performance and Handling Characteristics in Icing Conditions*, dated October 27, 2014.

- AC 25.735-1, *Brakes and Braking Systems Certification Tests and Analysis,* dated April 10, 2002.
- AC 25.773-1, *Pilot Compartment View Design Considerations,* dated January 8, 1993.
- AC 25.939-1, *Evaluating Turbine Engine Operating Characteristics,* dated March 19, 1986.
- AC 25.1309-1A, *System Design and Analysis*, dated June 21, 1988.
- AC 25.1329-1C, with Change 1, *Approval of Flight Guidance Systems*, dated May 24, 2016.
- AC 25.1357-1A, *Circuit Protective Devices,* dated October 22, 2007.
- AC 25.1581-1, with Change 1, *Airplane Flight Manual*, dated October 16, 2012.
- AC 43.13-1B, with Change 1, *Acceptable Methods, Techniques, and Practices—Aircraft Inspection and Repair*, dated September 27, 2001.
- AC 90-100A, with Change 2, *U.S. Terminal and En Route Area Navigation (RNAV) Operations*, dated April 14, 2015.
- AC 90-101A, with Change 1, *Approval Guidance for RNP Procedures with AR*, dated February 9, 2016.
- AC 90-105A, *Approval Guidance for RNP Operations and Barometric Vertical Navigation in the U.S. National Airspace System and in Oceanic and Remote Continental Airspace,* dated March 7, 2016.
- AC 91-79A, with Change 1, *Mitigating the Risks of a Runway Overrun Upon Landing*, dated April 28, 2016.
- AC 120-28D, *Criteria for Approval of Category III Weather Minima for Takeoff, Landing, and Rollout*, dated July 13, 1999.
- AC 120-29A, *Criteria for Approval of Category I and Category II Weather Minima for Approach,* dated August 12, 2002.
- AC 150/5320-12C, with Change 8, *Measurement, Construction, and Maintenance of Skid-Resistant Airport Pavement Surfaces*, dated February 7, 2007.

CHAPTER 2. GENERAL

2.1 Applicability—§ 25.1. [Reserved]

2.2 Special Retroactive Requirements—§ 25.2. [Reserved]

CHAPTER 3. FLIGHT: GENERAL

3.1 Proof of Compliance—§ 25.21.

3.1.1 Explanation.

In an effort to provide the necessary guidelines for the flight test evaluation of transport category airplanes, without producing a cumbersome document, this AC assumes a conventional transport airplane configuration. In general, a conventional airplane configuration is one with distinct wing and fuselage elements that are joined together, aft-mounted horizontal and vertical stabilizers that are attached to the fuselage, and propulsion provided either by turbojet/turbofan engines that do not provide any significant increase in lift due to their operation or engine-driven propellers. The effects of non-conventional airplane configurations (e.g., blown flaps) on the compliance methods should be evaluated and determined based on the intent of the guidelines presented for conventional airplane configurations.

3.1.2 Section 25.21(a)—Proof of Compliance.

3.1.2.1 The burden of showing compliance with the flight requirements for an airworthiness certificate or a type certificate rests with the applicant. The applicant should, at his own expense and risk, conduct such official flight tests as required by the FAA to demonstrate compliance with the applicable requirements. During the certification process, the applicant should make available the airplane, as well as all of the personnel and equipment necessary to obtain and process the required data.

3.1.2.2 If the airplane flight characteristics or the required flight data are affected by weight and/or center of gravity (CG), the compliance data must be presented for the most critical weight and CG position per § 25.21(a). Unless the applicant shows that the allowable CG travel in one or more axes (e.g., lateral fuel imbalance) has a negligible effect on compliance with the airworthiness requirements, the applicant must substantiate compliance at the critical CG.

3.1.2.3 The gross weight and CG tolerances specified in paragraphs 3.1.4.3 and 3.1.4.5 are test tolerances and are not intended to allow compliance to be shown at less than critical conditions.

3.1.2.4 Section 21.35(a)(3) requires that the test airplane be in conformity with its type design specifications. This means that the test airplane must be in conformity with its type design specification as it relates to the particular test being conducted. Any deviation from conformity must be clearly shown to be of no consequence to the particular test being conducted. For example, if the slip resistant escape surface required by § 25.810(c) is not installed when conducting airplane performance and flight characteristics tests, the applicant must show that its presence would have no effect on measured airplane performance and flight characteristics.

3.1.2.5 Section 21.35(b)(2) requires the applicant to conduct sufficient flight testing the FAA finds necessary to determine whether there is reasonable assurance that the airplane, its components, and its equipment are reliable and function properly. Appendix B to this AC provides guidance for showing compliance with this requirement.

3.1.2.6 **Acceptable Use of Simulation in Lieu of Flight Testing.**

It is difficult to establish guidance for using simulation in lieu of flight testing that applies in all situations. However, the following general principles can be used as guidance for determining the acceptability for using simulation in lieu of flight testing:

3.1.2.6.1 In general, flight test demonstrations are the preferred method to show compliance.

3.1.2.6.2 Simulation may be an acceptable alternative to flight demonstrations in certain situations, such as the following:

1. A flight demonstration would be too risky even after attempts are taken to mitigate these risks (e.g., by mock takeoffs/landings in the air at a safe altitude);
2. The required environmental or airplane conditions are too difficult to attain, such as (1) validation of system safety analyses failure cases involving high crosswinds; (2) development of crosswind guidance for slippery runway operations; and (3) conditions involving minimum allowable weight where the minimum allowable weight cannot be achieved because of the weight of required test equipment. In case (3), simulation data can be used to supplement flight test data obtained at the minimum practicable test weight.
3. The simulation is used to augment a reasonably broad flight test program; or
4. The simulation is used to demonstrate repeatability, or to demonstrate performance of a specific scenario for a range of pilots.

3.1.2.6.3 Simulation Criteria.

If it is agreed that a simulation will be used to establish compliance, then the simulation should meet the following criteria in order to be acceptable for showing compliance with the performance and handling qualities requirements:

1. The simulation should be of a type and fidelity that is appropriate for the task. For example, is motion or an exterior view needed, or is the fidelity or customizability of an engineering simulator needed?

2. The simulation should be suitably validated by flight test data for the conditions of interest. This does not mean that there must be flight test data at the exact conditions of interest. The reason simulation is being used may be that it is too difficult or risky to obtain flight test data at the conditions of interest. The level of substantiation of the simulator to flight correlation should be commensurate with the level of compliance (i.e., the closer the case is to being non-compliant, the higher the required fidelity of the simulation).
3. The simulation should be conducted in a manner appropriate to the case and conditions of interest. If closed-loop responses are important, the simulation should be piloted by a human pilot. For piloted simulations, the controls/displays and cues should be substantially equivalent to what would be available in the real airplane (unless it is determined that not doing so would provide added conservatism).

3.1.3 Section 25.21(c)—Proof of Compliance (Altitude Effect on Flight Characteristics).

3.1.3.1 Any of the flying qualities affected by altitude, including controllability, stability, trim, and stall characteristics, must be investigated at the most adverse altitude conditions approved for operations.

3.1.3.2 Consideration should be given in the test program to any aerodynamic control system changes that occur with changes in altitude (e.g., maximum control surface displacement or auto slats that may be inhibited by Mach number above a specific altitude).

3.1.4 Section 25.21(d)—Proof of Compliance: Flight Test Tolerances.

3.1.4.1 To allow for variations from precise test values, acceptable tolerances during flight testing must be maintained. The purpose of these tolerances is to allow for small variations in flight test values of certain variables from the targeted value. They are not intended for compliance tests to be planned for other than the critical condition, nor are they to be considered as an allowable measurement error.

3.1.4.2 Where variation in the parameter for which a tolerance is allowed will have an effect on the results of the test, the results should be corrected to the most critical value of that parameter within the approved operating envelope. If such a correction is impossible or impractical, the average test conditions should assure that the measured characteristics represent the actual critical value.

3.1.4.3 **Weight Limits.**

3.1.4.3.1 Table 3-1 below presents weight tolerances that have been found acceptable for the specified flight tests. Many flight tests need to be conducted at or very near the maximum operating weight for the airplane configuration, particularly those tests used to establish airplane flight manual (AFM) performance information. As noted in paragraph 3.1.4.1 above, the purpose of the test tolerances is to allow for variations in flight test values, not to routinely schedule tests at less than critical weight conditions or to allow compliance to be shown at less than the critical weight condition. In addition, the tolerances can be used to help determine when to interrupt a series of test conditions in order to refuel the airplane if necessary to remain within the acceptable weight tolerance.

Table 3-1. Weight Tolerance Limits

	Weight Tolerance Limit	
Flight Test Condition	±5%	±10%
Stall Speeds	X	
Stall Characteristics		X
All Other Flight Characteristics		X
Climb Performance	X	
Takeoff Flight Paths	X	
Landing Braking Distance	X	
Landing Air Distance	X	
Takeoff Distance and Speed	X	
Accelerate-Stop Distance	X	
Maximum Energy RTOs	X	
Minimum Unstick Speed		X
Minimum Control Speed	X	

Note: A -5 percent tolerance limit means that the weight for the particular test may be up to 5 percent less than the test target value. A +5 percent tolerance limit means that the weight for the particular test may be up to 5 percent higher than the test target value.

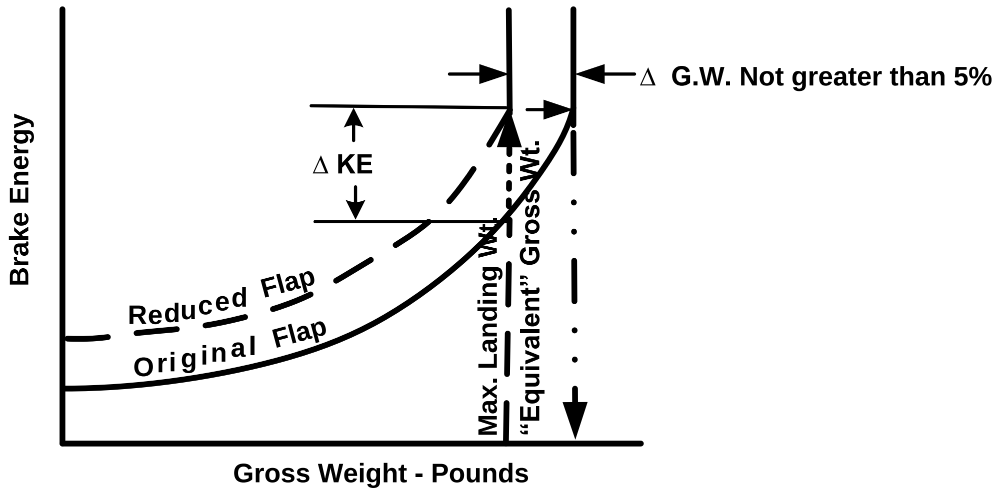
3.1.4.3.2 It can be difficult or impossible to conduct testing at the airplane's minimum allowable weight with an airplane configured for conducting a flight test program. If the minimum weight cannot be obtained (within the specified tolerance limit) and compliance at the minimum weight cannot be clearly deduced from the results at the tested weight, the testing should be conducted on a production airplane (or other airplane on which the minimum weight can be obtained). If the instrumentation or equipment needed to conduct safe testing cannot be installed on the production airplane configuration, or the weight of such instrumentation still prevents the minimum weight from being obtained, consider the use of simulation to extend the results obtained at the minimum practical test weight. (See paragraph 3.1.2.6 of this AC.)

3.1.4.3.3 For follow-on airplane certification programs involving an increase in the maximum allowable gross weight, the test weight limits of table 3-1 have been applied as extrapolation limits on the original test data in order to minimize additional testing. For the test weight tolerance limits to be applied in this manner, the original test data must be from an existing certificated database for an aerodynamically similar model of the same airplane type. The tolerance limit should be applied to the maximum weight at which the original testing was conducted, not to the maximum certified weight.

3.1.4.3.4 Equivalent Weight Extrapolation Limits.

For follow-on airplane certification programs where it is desired to increase a maximum operating weight based on existing certified performance parameters that have weight as one of their independent terms, those parameters should be examined for equivalent compliance with the weight tolerance limits of table 3-1. An example would be the reduction of an airplane's landing flap position, to one approved on a similar model of the same airplane type, which would incur an increase in landing speeds and brake energy, relative to the original certificated landing flap, at any given weight. The brake energy, at the maximum certificated landing weight, should be calculated for the reduced landing flap. This brake energy should account for the increased landing speeds and reduced aerodynamic drag associated with the reduced flap setting. It should then be determined what equivalent gross weight would have rendered that brake energy with the original landing flap. (See figure 3-1 below for an example of how this can be done.) If the resulting equivalent gross weight does not exceed the certificated maximum landing weight by more than the five percent weight extrapolation limit specified in table 3-1, the reduced flap certification may be eligible for a reduced flight test program (e.g., limited to stall speed verification, handling characteristics, and a qualitative landing demonstration). Further limitations may be imposed by the criteria of technical standard order (TSO) C135a, *Transport Airplane Wheels and Wheel and Brake Assemblies*, dated July 1, 2009.

Figure 3-1. Equivalent Weight Extrapolation



3.1.4.4 **Wind Limits.**

A wind velocity limit of 10 knots (from any direction) or 0.11 V_{SR1} (whichever is lower) is considered the maximum acceptable for obtaining valid takeoff and landing flight test data. Takeoff and landing performance data obtained under runway wind conditions greater than 5 knots may be inconsistent and unreliable because winds of that magnitude are likely to be unsteady. However, performance data obtained with winds between 5 and 10 knots should not necessarily be discarded. Their validity should be checked against data obtained in conditions with lesser winds. Wind velocity should be measured at the height of the wing mean aerodynamic chord (MAC), as determined with the airplane in a static ground attitude. When measuring test wind velocity at the wing MAC height, a height of six feet above the ground should be considered as a minimum measurement height to avoid possible measurement inaccuracies due to surface interference.

3.1.4.5 **CG Limits.**

A test tolerance of ±7 percent of the total CG range is intended to allow for inflight CG movement. This tolerance is only acceptable when the test data scatter is on both sides of the limiting CG or when adjusting the data from the test CG to the limit CG is acceptable. If compliance with a requirement is marginal at a test condition that is inside of the CG limits, the test should be repeated at the CG limits.

3.1.4.6 **Airspeed Limits.**

Normally, tests conducted within 3 percent or 3 knots (whichever is the higher) of the desired test speed are considered acceptable.

3.1.4.7 **Thrust/Power Limits.**

Thrust critical tests, such as minimum control speeds, should be conducted at the highest thrust (or power) allowable on the engine given the constraints of temperature and altitude. It is then permitted to calculate further corrections to allow extrapolation of data to cover the entire operating envelope. These thrust (or power) corrections should be limited to 5 percent of test day thrust (or power), unless a detailed analysis is performed.

3.1.4.8 It is not the purpose of these tolerances to allow flights at values in excess of those authorized in the type design. If such flights are to be conducted, adequate structural substantiation for the flight conditions should be available. These flights should always be conducted under controlled conditions and with the flight test crew's full knowledge of the situation. Examples of such flights are:

3.1.4.8.1 Takeoff at greater than maximum takeoff weight to reach a test area at the maximum takeoff weight.

3.1.4.8.2 Landing at greater than maximum landing weights during the course of conducting takeoff tests.

3.1.4.8.3 Flights to obtain data for future approvals beyond that substantiated for the initial type design.

3.1.4.8.4 Table 3-2 below indicates the cases for which corrections are normally allowed. Any corrections to flight test data should be made by methods that are agreed to by the FAA.

Table 3-2. Test Parameters that Normally can be Corrected

	Correctable Parameters					
Flight Test Condition	Weight	CG	Airspeed	Altitude	Power/ Thrust	Wind
Airspeed calibration	X	---	---	---	---	---
Stall speeds	X	X	---	---	X	---
Climb performance	X	X	X	X	X	---
Landing performance	X	---	X	X	---	X
Takeoff performance	X	X	---	X	X	X
Accelerate-stop performance	X	X	---	X	X	X
Minimum control speed	---	---	---	---	X	---
Minimum unstick speed	X	X	X	---	X	---
Buffet boundary	X	X	---	X	---	---

3.1.4.9 All instrumentation used in the flight test program should be appropriately calibrated and acceptable to the FAA test team.

3.1.5 Section 25.21(f)—Proof of Compliance: Wind Measurement and Corrections.

3.1.5.1 The relationship between the wind measured at one height and the corresponding wind at another height may be obtained by the following equation:

$$V_{W2} = V_{W1}(H_2/H_1)^{1/7}$$

Where:

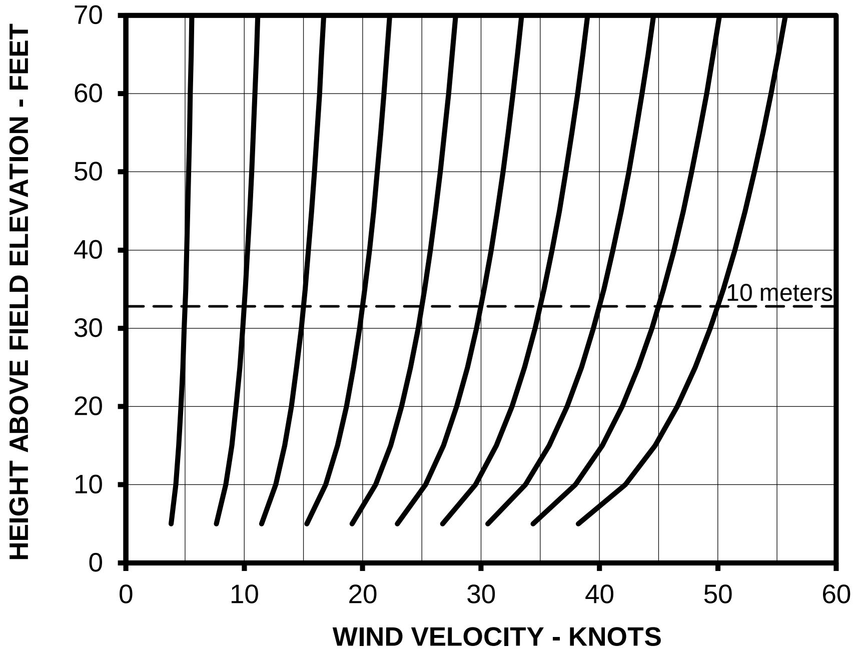
$$H = Height\ above\ the\ runway\ surface$$

$$V_{W2} = Wind\ velocity\ H_2$$

$$V_{W1} = Wind\ velocity\ H_1$$

3.1.5.2 This equation is presented graphically below. Values of H less than 5 feet should not be used in this relationship.

Figure 3-2. Wind Profile Variation



3.1.6 Wind Profile Variation for Test Data.

The performance data of airplanes should be obtained in such a manner that the effect of wind on the test data may be determined. The test wind velocity should be corrected from the recorded height above the test surface to the height of the airplane wing mean aerodynamic chord. If the wind profile variation is not measured, the variation may be calculated using the equation in paragraph 3.1.5 above. The following examples are methods of handling wind profile variation data. Other methods have also been found acceptable.

Example: Test Data

Given:

• Height of mean aerodynamic chord with airplane on surface	8.0 feet
• Height of wind measurement	6.0 feet
• Measured wind velocity	4.8 knots

Results:

• Test wind velocity with airplane 50 feet above landing surface	$4.8((50 + 8)/6)^{1/7} = 6.6$ knots
• Test wind velocity with airplane 35 feet above takeoff surface	$4.8((35 + 8)/6)^{1/7} = 6.4$ knots
• Test wind velocity with airplane on surface	$4.8(8/6)^{1/7} = 5.0$ knots

3.1.7 Wind Profile Variation for AFM Data.

When expanding the data to the AFM conditions, the result should include the effective velocity, at the airplane's wing mean aerodynamic chord, which corresponds to the wind condition as measured at 10 meters (32.81 feet) above the takeoff surface, and corrected for the wind factors of § 25.105(d)(1).

Example: AFM Data

Given:

• Height of mean aerodynamic chord with airplane on surface	8.0 feet
• Reported headwind at 10 meters	40.0 knots
• Section 25.105(d)(1) wind factor	0.5

Results:

• Factored wind velocity with airplane 50 feet above landing surface	$(0.5)(40)((50 + 8)/32.81)^{1/7}$ = 21.7 knots
• Factored wind velocity with airplane 35 feet above takeoff surface	$(0.5)(40)((35 + 8)/32.81)^{1/7}$ = 20.8 knots
• Factored wind velocity with airplane on surface	$(0.5)(40)(8/32.81)^{1/7}$ = 16.3 knots

3.1.8 Airplane Airspeed Variation Due to Wind Profile Variation Combined with Speed Changes Due to Airplane Dynamic Performance.

In the reduction of test data and in the expansion of such data to AFM conditions, the increase or decrease of speed due to the dynamic effect of the forces on the airplane are shown only by the change in ground speed. These changes in ground speed may be generalized either as speed increments or speed ratios. The changes in airspeed due to wind profile variation are superimposed on these speed changes.

Example: Determination of True Airspeed from Ground Speed—Takeoff Test Data

Given:

• Ground speed at liftoff, V_{LOF}	139.0 knots
• Ground speed at 35 feet above takeoff surface	140.6 knots
• Speed change due to airplane dynamic performance	1.6 knots
• Test headwind at liftoff	5.0 knots
• Test headwind with airplane 35 feet above takeoff surface	6.4 knots

Results:

• True airspeed at liftoff, V_{LOF}	139.0 + 5.0 = 144.0 knots
• True airspeed at 35 feet above takeoff surface	140.6 + 6.4 147.0 knots

Example: Determination of Rotation Speed from True Airspeed at 35-Foot Height—AFM Data	
Given:	
• Factored headwind at liftoff	16.3 knots
• Factored headwind with airplane 35 feet above takeoff surface	20.8 knots
• Ground speed change, ($V_{35} – V_{LOF}$)	1.6 knots
• Ground speed change, ($V_{LOF} – V_R$)	0.5 knots
• True airspeed required at 35 feet	150.0 knots
Results:	
• Ground speed required at 35 feet	150 - 20.8 = 129.2 knots
• Ground speed at liftoff	129.2 - 1.6 = 127.6 knots
• True airspeed at liftoff	127.6 + 16.3 = 143.9 knots
• Ground speed at rotation	127.6 - 0.5 = 127.1 knots
• True airspeed at rotation (for AFM speed and distances)	127.1+16.3 = 143.4 knots

Example: Landing—AFM Data	
Given:	
• Factored headwind with airplane 50 feet above landing surface	21.7 knots
• Factored headwind with airplane on landing surface	16.3 knots
• Ground speed change for 50 feet to touchdown ($V_{50} – V_{TD}$)	4.0 knots
• True airspeed required at 50 feet	130 knots
Results:	
• Ground speed at 50 feet	130 - 21.7 = 108.3 knots
• Ground speed at touchdown	108.3 - 4.0 = 104.3 knots
• True airspeed at touchdown	104.3 + 16.3 = 120.6 knots

3.1.9 Expansion of Takeoff and Landing Data for a Range of Airport Elevations.

3.1.9.1 These guidelines apply to expanding AFM takeoff and landing data above and below the altitude at which the airplane takeoff and landing performance tests are conducted.

3.1.9.2 Historically, limits were placed on the extrapolation of takeoff data. In the past, takeoff data could generally be extrapolated 6,000 feet above and 3,000 feet below the test field elevation when proven testing and data reduction methods were used. For extrapolations beyond these limits, a 2 percent takeoff distance penalty was to be applied for every additional 1,000 feet extrapolation. Such limitations were generally not applied to extrapolation of landing data, provided the effect of the higher true airspeed on landing distance was taken into account.

3.1.9.3 Since then, considerably more experience has since been gained both in terms of modeling airplane and propulsion system (i.e., turbine engines and propellers, where appropriate) performance and in verifying the accuracy of these models for determining high (and low) altitude takeoff and landing performance. This experience has shown that the soundness of the extrapolation is primarily a function of the accuracy of the propulsion system performance model and its integration with the airplane drag model. The basic aerodynamic characteristics of the airplane do not change significantly with altitude or ambient temperature, and any such effects are readily taken into account by standard airplane performance modeling practices.

3.1.9.4 As a result, with installed propulsion system performance characteristics that have been adequately defined and verified, airplane takeoff and landing performance data obtained at one field elevation may be extrapolated to higher and lower altitudes within the limits of the operating envelope without applying additional performance conservatisms. It should be noted, however, that extrapolation of the propulsion system data used in the determination and validation of propulsion system performance characteristics is typically limited to 3,000 feet above the highest altitude at which propulsion system parameters were evaluated for the pertinent power/thrust setting. (See paragraph 4.1 of this AC for more information on an acceptable means of establishing and verifying installed propulsion system performance characteristics.)

3.1.9.5 Note that certification testing for operation at airports that are above 8,000 feet should also include functional tests of the cabin pressurization system in accordance with paragraph 20.1.2.3 of this AC. Consideration should be given to any sensitivity to, or dependency upon airport altitude, such as: engine and auxiliary power unit (APU) starting, passenger oxygen, autopilot, autoland, autothrottle system power/thrust set/operation.

3.1.10 Tailwind Takeoff and Landing.

3.1.10.1 **Wind Velocities of 10 Knots or Less.**

Approval may be given for performance, controllability, and engine operating characteristics for operations in reported tailwind velocities up to 10 knots without conducting additional flight tests at specific wind speeds.

3.1.10.2 Wind Velocities Greater than 10 Knots.

3.1.10.2.1 Performance.

It is considered that takeoff, rejected takeoff, and landing distances, measured in tailwind conditions greater than 10 knots, are unreliable for use in determining airplane performance. Wind conditions of such magnitude are generally not sufficiently consistent over the length of the runway or over the time period required to perform the test maneuver. The 150 percent operational tailwind factor, required by §§ 25.105(d)(1) and 25.125(f), provides a satisfactory level of safety for operation in tailwinds up to 15 knots when using AFM data based on flight tests in nominally calm wind conditions.

Note: The design requirements of § 25.479, *Level landing conditions*, also require the effects of increased contact speeds to be investigated if approval for landings with tailwinds greater than 10 knots is desired.

3.1.10.2.2 Control Characteristics.

The test tailwind velocity for demonstrating handling qualities should be equal to the proposed limit tailwind factored by 150 percent. The intent of the 150 percent factor is to provide adequate margin for wind variability in operations, including currency of the wind data, averaging of the data by the measuring and reporting method, and the highly variable nature of higher wind conditions. Therefore, the test wind condition of 150 percent of the proposed tailwind limit should be an averaged or smoothed wind speed, not a peak wind speed. Airplane control characteristics should be evaluated under the following conditions with the CG at the aft limit and the test mean tailwind velocity equal to the proposed limit tailwind factored by 150 percent:

1. Takeoff. Both all-engines-operating and one-engine-inoperative (i.e., with a simulated failure of the critical engine at the engine failure speed) takeoffs should be evaluated at a light weight with maximum approved takeoff flap deflection.
2. Landing. Approach and landing at light weight with maximum approved landing flap deflection.
3. Determination of the increased ground speed effect on gear vibration or shimmy, and flight director, or autopilot instrument landing system (ILS) approaches, terrain awareness warning system (TAWS) sink rate modes, etc.
4. If engine idle power or thrust is increased to account for the increased tailwind velocity, ensure that deviations above the glideslope are recoverable.

3.1.10.2.3 Weight Limits.

Consistent with the requirements of §§ 25.105(d)(1) and 25.125(f), the maximum takeoff and maximum quick turnaround weights should be determined using brake energies and tire speeds, as appropriate, calculated with the limit tailwind velocity factored by 150 percent.

3.1.10.2.4 Engine Operating Characteristics.

Satisfactory engine operation should be demonstrated at the limit tailwind velocity factored by 150 percent. The demonstrations should include:

1. Zero groundspeed operation.
2. Takeoff power or thrust setting procedure used for AFM performance (typically completed by approximately 80 knots), both manually and automatically (autothrottle).
3. Reverse thrust operations.

3.1.10.2.5 Airplane Flight Manual.

The AFM should contain a statement that the limitation for tailwinds greater than 10 knots reflects the capability of the airplane as evaluated in terms of airworthiness but does not constitute approval for operation in tailwinds exceeding 10 knots.

3.1.11 Procedures.

3.1.11.1 The performance-related flight test procedures are discussed in the following paragraphs of this AC:

- Paragraph 4.2, Takeoff and Takeoff Speeds—§§ 25.105 and 25.107.
- Paragraph 4.3, Accelerate-Stop Distance—§ 25.109.
- Paragraph 4.4, Takeoff Path—§ 25.111.
- Paragraph 4.5, Takeoff Distance and Takeoff Run—§ 25.113.
- Paragraph 4.6, Takeoff Flight Path—§ 25.115.
- Paragraph 4.7, Climb: General—§ 25.117.
- Paragraph 4.8, Landing Climb: All-Engines-Operating—§ 25.119.
- Paragraph 4.9, Climb: One-Engine-Inoperative—§ 25.121.
- Paragraph 4.10, En Route Flight Paths—§ 25.123.
- Paragraph 4.11, Landing—§ 25.125.

3.1.11.2 **Performance Data for Multiple Flap or Additional Flap Positions.**

If approval of performance data is requested for flap settings at which no test data are available, the data may be obtained from interpolation of flight data obtained at no less than four flap settings that are within a constant configuration of other lift devices. If the span of flap settings is small and previously obtained data provide sufficient confidence (i.e., the shapes of the curves are known and lend themselves to accurate interpolation), data from three flap settings may be acceptable.

3.1.11.3 **Flight Characteristics for Abnormal Configurations.**

See § 25.671(c).

3.1.11.3.1 For purposes of this AC, an abnormal configuration is an operational configuration that results from any single failure or any combination of failures not shown to be improbable.

3.1.11.3.2 Flight characteristics for abnormal configurations may be determined by test or analysis to assure that the airplane is capable of continued safe flight and landing. Flight tests, if required, should be conducted at the critical conditions of altitude, weight, CG, and engine power or thrust associated with the configuration, and at the most critical airspeed between the speed reached one second after stall warning occurs (see paragraph 8.1.5.2.8 of this AC) and the maximum operating airspeed for the configuration.

3.2 Load Distribution Limits—§ 25.23. [Reserved]

3.3 Weight Limits and Center of Gravity Limits—§§ 25.25 and 25.27. [Reserved]

3.4 Empty Weight and Corresponding Center of Gravity—§ 25.29. [Reserved]

3.5 Removable Ballast—§ 25.31.

3.5.1 Explanation.

None.

3.5.2 Procedures.

Ballast may be carried during the flight tests whenever it is necessary to achieve a specific weight and CG 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 in order to make sure they do not fail as a result of the anticipated loads that may be imposed during the particular tests. As required by § 21.35(a), applicants must show that these structures comply with the applicable structural requirements of part 25 before conducting flight tests with these structures in place.

3.6 Propeller Speed and Pitch Limits—§ 25.33.

3.6.1 Explanation.

None.

3.6.2 Procedures.

The tachometers and the airspeed indicating system of the test airplane should have been calibrated within the last six months. With that prerequisite satisfied, the following should be accomplished:

3.6.2.1 Determine that the propeller speeds and pitch settings are safe and satisfactory during all tests that are conducted in the flight test program within the certification limits of the airplane, engine, and propeller. This includes establishing acceptable low pitch (flight idle) blade angles on turbopropeller airplanes and verifying that propeller configurations are satisfactory at V_{MO}/M_{MO} to prevent propeller overspeed.

3.6.2.2 Determine that the propeller speeds and pitch settings are safe and satisfactory during all tests that are conducted to satisfy the performance requirements.

3.6.2.3 With the propeller governors operative and the propeller controls in full high revolutions per minute (RPM) position, determine that the maximum takeoff power settings do not exceed the rated takeoff RPM of each engine during takeoff and climb at the best rate-of-climb speed.

3.6.2.4 With the propeller governors made inoperative by mechanical means, determine the maximum power, no-wind, static RPMs. With the propeller governors operating on the low pitch stop, the engine speeds must not exceed 103 percent of the maximum allowable takeoff RPM or 99 percent of an approved maximum overspeed, as required by § 25.33(c). On turbopropeller engines, the engine speeds should not exceed the maximum engine speeds allowed by engine and propeller type designs. Note which systems were disabled and how the disablement was done. If maximum takeoff power torque or sea level standard conditions cannot be obtained on the test day, correct the data to these conditions by an acceptable means. A no-wind condition is considered to be a wind of 5 knots or less. The static RPM should be the average obtained with a direct crosswind from the left and a direct crosswind from the right.

3.6.2.5 If the above determinations are satisfactory, then measure the low-pitch stop setting and the high-pitch stop setting. These data may have been obtained from the propeller manufacturer and may be used, provided the pitch stops have not been changed since the manufacturer delivered the propeller. If measured, the blade station should be recorded. Include these blade angles in the type certificate data sheet.

CHAPTER 4. FLIGHT: PERFORMANCE

4.1 General—§ 25.101.

4.1.1 Explanation of Propulsion System Behavior.

Section 25.101(c) requires that airplane performance "correspond to the propulsive thrust available under the particular ambient atmospheric conditions, the particular flight conditions…." The propulsion system's (i.e., turbine engines and propellers, where appropriate) installed performance characteristics are primarily a function of engine power or thrust setting, airspeed, propeller efficiency (where applicable), altitude, and ambient temperature. Determine the effects of each of these variables to establish the thrust available for airplane performance calculations.

4.1.2 Procedures.

4.1.2.1 The intent is to develop a model of propulsion system performance that covers the approved flight envelope. Further, it should be shown that the combination of the propulsion system performance model and the airplane performance model is validated by the takeoff performance test data, climb performance tests, and tests used to determine airplane drag. Installed propulsion system performance characteristics may be established via the following tests and analyses:

- Steady-state engine power (or thrust) setting versus power (or thrust) testing. See paragraph 4.1.2.2.
- Lapse rate takeoff testing to characterize the behavior of power or thrust setting, rotor speeds, propeller effects (i.e., torque, RPM, and blade angle), or gas temperature as a function of time, thermal state, or airspeed, as appropriate. See paragraph 4.1.2.3.
- Power/thrust calculation substantiation. See paragraph 4.1.2.4.
- Effects of ambient temperature. See paragraph 4.1.2.5.

4.1.2.2 **Steady-State Engine Power (or Thrust) Setting versus Power (or Thrust) Testing.**

Engines should be equipped with adequate instrumentation to allow the determination of thrust (or power). Data should be acquired in order to validate the model, including propeller-installed thrust, if applicable, over the range of power or thrust settings, altitudes, temperatures, and airspeeds for which approval is sought. Although it is not possible to definitively list or foresee all of the types of instrumentation that might be considered adequate for determining thrust (or power) output, two examples used in past certification programs are (1) engine pressure rakes, with engines calibrated in a ground test cell, and (2) fan speed, with engines calibrated in a ground test cell and the calibration data validated by the use of a flying test bed. In any case, the applicant should substantiate the adequacy of the instrumentation to be used for determining the thrust (or power) output.

4.1.2.3 **Lapse Rate Takeoff Testing to Characterize the Behavior of Power or Thrust Setting, Rotor Speeds, Propeller Effects, or Gas Temperature as a Function of Time, Thermal State, or Airspeed.**

These tests should include the operation of an automatic takeoff thrust control system (ATTCS), if applicable, and should cover the range of power or thrust settings for which approval is sought.

4.1.2.3.1 Data for higher altitude power or thrust settings may be acquired via overboost (i.e., operating at a higher than normal power or thrust setting for the conditions) with the consent of the engine and propeller manufacturer(s), when applicable. When considering the use of overboost on turbopropeller propulsion system installations to stimulate higher altitude and ambient temperature range conditions, the capability to achieve an appropriate simulation should be evaluated based on the engine and propeller control system(s) and aircraft performance and structural considerations. Engine (gearbox) torque, rotor speed, or gas temperature limits, including protection devices to prohibit or limit exceedances, may prevent the required amount of overboost needed for performance at the maximum airport altitude sought for approval. Overboost may be considered as increased torque, reduced propeller speed, or a combination of both, in order to achieve the appropriate blade angle for the higher altitude and ambient temperature range simulation. Consideration for extrapolations will depend on the applicant’s substantiation of the proper turbopropeller propulsion system simulated test conditions.

4.1.2.3.2 Lapse rate characteristics should be validated by takeoff demonstrations at the maximum airport altitude for which takeoff approval is being sought. Alternatively, if overboost (see paragraph above) is used to simulate the power or thrust setting parameters of the maximum airport altitude for which takeoff approval is sought, the takeoff demonstrations of lapse rate characteristics can be performed at an airport altitude up to 3,000 feet lower than the maximum airport altitude.

4.1.2.4 **Power/Thrust Calculation Substantiation.**

Installed power or thrust should be calculated via a mathematical model of the propulsion system, or other appropriate means, adjusted as necessary to match the measured inflight performance characteristics of the installed propulsion system. The propulsion system mathematical model should define the relationship of power or thrust to the power or thrust setting parameter over the range of power or thrust settings, airspeeds, altitudes, and temperatures for which approval is sought. For turbojet airplanes, the propulsion system mathematical model should be substantiated by ground tests in which thrust is directly measured via a calibrated load cell or equivalent means. For turbopropeller airplanes, the engine power measurement should be substantiated by a calibrated dynamometer or equivalent means, the engine jet thrust should be established by an acceptable engine model, and the propeller thrust and power characteristics should be substantiated by wind tunnel testing or equivalent means.

4.1.2.5 **Effects of Ambient Temperature.**

The flight tests of paragraph 4.1.2.2 of this AC will typically provide data over a broad range of ambient temperatures. Additional data may be obtained from other flight or ground tests of the same type or series of engine. The objective is to confirm that the propulsion system model accurately reflects the effect of temperature over the range of ambient temperatures for which approval is being sought (operating envelope). Because thrust (or power) data can usually be normalized versus temperature using either dimensionless variables (e.g., theta exponents or a thermodynamic cycle model), it is usually unnecessary to obtain data over the entire ambient temperature range. There is no needed to conduct additional testing if:

- The data show that the behavior of power or thrust and limiting parameters versus ambient temperature can be predicted accurately, and
- Analysis based upon the test data shows that the propulsion system will operate at rated power or thrust without exceeding propulsion system limits.

4.1.2.6 Extrapolation of propulsion system performance data to 3,000 feet above the highest airport altitude tested (but no higher than the maximum takeoff airport altitude to be approved) is acceptable, provided the supporting data, including flight test and propulsion system operations data (e.g., engine and propeller control, limits exceedance, and surge protection devices scheduling), substantiates the proposed extrapolation procedures. Considerations for extrapolation depend upon an applicant's determination, understanding, and substantiation of the critical operating modes of the propulsion system. This understanding includes a determination and quantification of the effects that propulsion system installation and variations in ambient conditions have on these modes.

4.2 Takeoff and Takeoff Speeds—§§ 25.105 and 25.107.

4.2.1 Explanation.

Section 25.105 specifies the conditions that must be considered in determining the takeoff speeds, accelerate-stop distances, takeoff path, takeoff distance, and takeoff run in accordance with part 25 requirements. The primary objective of the takeoff tests required by § 25.107 is to determine the takeoff speeds for all takeoff configurations at all weight, altitude, and temperature conditions within the operational limits selected by the applicant.

4.2.2 Procedures: General.

4.2.2.1 Section 25.105(c)(1) requires the takeoff performance data to be determined for smooth, dry and wet, hard-surfaced runways. Paragraph 4.3 of this AC describes methods for determining the accelerate-stop distances required by § 25.109. Paragraph 4.5 describes methods for determining the takeoff distance and takeoff run required by § 25.113.

4.2.2.2 In accordance with § 25.101(f), testing for determining the accelerate-stop distances, takeoff flight paths, and takeoff distances should be accomplished using procedures established by the applicant for operation in service. In accordance with §25.101(h), these procedures must be able to be consistently executed in service by crews of average skill, use methods or devices that are safe and reliable, and include allowances for any time delays in the execution of the procedures that may reasonably be expected in service. These requirements prohibit the use of exceptional piloting techniques, such as higher control force inputs or higher pitch rates than would occur in operational service, from being used to generate unrealistic takeoff distances. The intent of these requirements is to establish takeoff performance representative of that which can reasonably be expected to be achieved in operational service.

4.2.2.3 Attention should be paid to all potential sources of airspeed error, but special consideration should be given to airplanes with electronic instruments in the cockpit that apply electronic filtering to the airspeed data. This filtering, which causes a time delay in the airspeed indication, can be a source of significant systematic error in the presentation of airspeed to the flightcrew. With normal takeoff acceleration, the airplane will be at a higher speed than is indicated by the cockpit instrument, which can result in longer distances than are presented in the AFM, particularly in the event of a rejected takeoff near the indicated V_1 speed. The effects of any time delays caused by electronic filtering, pneumatic system lag, or other sources should be adequately addressed in the AFM speed and distance presentations. Further explanation of airspeed lag, particularly pertaining to airplanes with electronic instruments in the cockpit, and procedures for calibrating the airspeed indicating system (§ 25.1323(b)) are presented in paragraph 33.3 of this AC.

4.2.3 Procedures: Section 25.107(a)(1)—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 ground minimum control speed (V_{MCG}).

4.2.4 Procedures: Section 25.107(a)(2)—V_1.

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 takes action after recognizing the engine failure. This is indicated by pilot application of the first deceleration means such as brakes, throttles, spoilers, etc. during accelerate-stop tests. The applicant may choose the sequence of events. Refer to paragraph 4.3 of this AC, addressing § 25.109, for a more complete description of rejected takeoff (RTO) transition procedures and associated time delays.

4.2.5 Procedures: Section 25.107(b)—Minimum Takeoff Safety Speed (V_{2MIN}).

4.2.5.1 V_{2MIN}, in terms of calibrated airspeed, cannot be less than:

4.2.5.1.1 1.1 times the V_{MC} defined in § 25.149.

4.2.5.1.2 1.13 times V_{SR} for two-engine and three-engine turbopropeller and reciprocating engine-powered airplanes and for all turbojet airplanes that do not have provisions for obtaining a significant reduction in the one-engine-inoperative power-on stalling speed (i.e., boundary layer control, blown flaps, etc.). The value of V_{SR} to be used in determining V_{2MIN} is the stall speed in the applicable takeoff configuration, landing gear retracted, except for those airplanes with a fixed landing gear or for gear-down dispatch.

4.2.5.2 V_{2MIN} may be reduced to 1.08 times V_{SR} for turbopropeller and reciprocating engine-powered airplanes with more than three engines, and turbojet powered airplanes with adequate provisions for obtaining significant power-on stall speed reduction through the use of such things as boundary layer control, blown flaps, etc.

4.2.5.3 For propeller-driven airplanes, the difference between the two margins, based upon the number of engines installed on the airplane, is because the application of power ordinarily reduces the stalling speed appreciably. In the case of the two-engine propeller-driven airplane, at least half of this reduction is eliminated by the failure of an engine. The difference in the required factors therefore provides approximately the same margin over the actual stalling speed under the power-on conditions that are obtained after the loss of an engine, no matter what the number of engines (in excess of one) may be. Unlike the propeller-driven airplane, the turbojet/turbofan powered airplane does not show any appreciable difference between the power-on and power-off stalling speed. This is due to the absence of the propeller, which ordinarily induces a slipstream with the application of power causing the wing to retain its lift to a speed lower than the power-off stalling speed. The applicant's selection of the two speeds specified will influence the nature of the testing required in establishing the takeoff flight path.

4.2.6 Procedures: Section 25.107(c)—Takeoff Safety Speed (V_2).

4.2.6.1 V_2 is the calibrated airspeed that is attained at or before the airplane reaches a height of 35 feet above the takeoff surface after an engine failure at V_{EF} using an established rotation speed (V_R). From the liftoff point, the takeoff surface extends to the end of the takeoff distance continuing at the same slope as the runway. During the takeoff speeds demonstration, V_2 should be continued to an altitude sufficient to assure stable conditions beyond the 35-foot height. V_2 cannot be less than V_{2MIN}. In addition, V_2 cannot be less than the liftoff speed, V_{LOF}, which is defined in § 25.107(f). In accordance with § 25.107(c), V_2 in terms of calibrated airspeed may not be less than V_R plus the speed increment attained before reaching a height of 35 feet above the takeoff surface and a speed that provides the maneuvering capability specified in § 25.143(h). In addition, § 25.111(c)(2) stipulates that the airplane must reach V_2 before it is 35 feet above the takeoff surface and continue at a speed not less than V_2 until it is 400 feet above the takeoff surface. These requirements were first expressed in Special Civil Air Regulation No. SR-422, *Turbine-Powered Transport Category Airplanes of Current Design* (SR-422A), paragraphs 4T.114(b)(4) and (c)(3) and 4T.116(e). The concern that the regulation change was addressing was the overshoot of V_2 after liftoff under the previous requirement that the airplane attain V_2 on, or near, the ground. The intent of the current requirement is to allow an acceleration to V_2 after liftoff but not to allow a decrease in the field length required to attain a height of 35 feet above the takeoff surface by attaining a speed greater than V_2, under low drag ground conditions, and using the excess kinetic energy to attain the 35-foot height.

4.2.6.2 In the case of turbojet powered airplanes, when most of the one-engine-inoperative data have been collected using throttle chops, V_2, and its relationship to V_R, should be substantiated by at least a limited number of fuel cuts at V_{EF}. For derivative programs not involving a modification that would affect thrust decay characteristics, demonstrations of fuel cuts may be unnecessary.

4.2.6.3 For propeller-driven airplanes, the use of fuel cuts can be more important in order to ensure that the takeoff speeds and distances are obtained with the critical engine's propeller attaining the position it would during a sudden engine failure. The number of tests that should be conducted using fuel cuts depends on the correlation obtained with the throttle chop data and substantiation that the data analysis methodology adequately models the effects of a sudden engine failure.

4.2.7 Procedures: Section 25.107(d)—Minimum Unstick Speed (V_{MU}).

4.2.7.1 Section 25.107(d) states, "V_{MU} speeds must be selected by the applicant." An applicant can either determine the lowest possible V_{MU} speeds or select a higher speed that supports the takeoff performance targets of the airplane. Regardless of how the applicant selects the V_{MU} speeds, compliance must be shown with § 25.107(d), (e)(1)(iv), (e)(3), and (e)(4) to show that the selected V_{MU} speeds allow the airplane to safely lift off the ground and continue the takeoff.

4.2.7.2 An applicant should comply with § 25.107(d) by conducting V_{MU} tests with all engines operating and also with one engine inoperative. During these tests, the takeoff should be continued until the airplane is out of ground effect. The airplane pitch attitude should not be decreased after liftoff.

4.2.7.3 V_{MU} testing to demonstrate the lowest V_{MU} speed is a maximum performance flight test maneuver, and liftoff may occur very near the angle-of-attack for maximum lift coefficient. Also, even though pitch attitude may be held fairly constant during the maneuver, environmental conditions and transiting through ground effect may result in changes in angle-of-attack. It is permissible to lift off at a speed that is below the normal stall warning speed, provided no more than light buffet is encountered.

4.2.7.3.1 It is important for the flight test team to understand the control laws and any transitions between control laws during takeoff (e.g., based on weight on wheels) for an electronic flight control system that may present unique hazards that should be taken into account.

4.2.7.3.2 An artificial stall warning system (e.g., a stick shaker) may be disabled during V_{MU} testing, although doing so will require extreme caution and depend upon a thorough knowledge of the airplane’s stall characteristics, both in and out of ground effect.

4.2.7.3.3 If the airplane is equipped with a stick pusher, angle-of-attack limiter, or other system that may affect the conduct of the test, the angle of attack setting for activation of the system may be selected by the applicant and differ from the nominal setting. The system may alternatively be disabled or its activation delayed for test purposes until a safe altitude is reached. However, for airplanes equipped with a stick pusher that is not designed to be inhibited during takeoff, the V_{MU} test demonstrations will need to be assessed and will only remain valid if the stick pusher would not have activated with the angle-of-attack indication means set at the lowest angle within production tolerances.

4.2.7.4 In lieu of conducting one-engine-inoperative V_{MU} tests, the applicant may conduct all-engines-operating V_{MU} tests if all pertinent factors that would be associated with an actual one-engine-inoperative V_{MU} test are simulated or otherwise taken into account. To take into account all pertinent factors, it may be necessary to adjust the resulting V_{MU} test values analytically. The factors to be accounted for should include at least the following:

- Thrust/weight ratio for the one-engine-inoperative range.
- Controllability (may be related to one-engine-inoperative free air tests, such as minimum control speed in the air (V_{MCA})).
- Increased drag due to use of lateral/directional control systems.
- Reduced lift due to use of devices such as wing spoilers for lateral control.
- Adverse effects of use of any other systems or devices on control, drag, or lift.

4.2.7.5 The number of V_{MU} tests needed may be minimized by testing only the critical all-engines-operating and one-engine-inoperative thrust/weight ratios, provided the V_{MU} speeds determined at these critical conditions are used for the range of thrust/weights appropriate to the all-engines-operating and one-engine-inoperative configurations. The critical thrust/weight is established by correcting, to the V_{MU} speed, the thrust that results in the airplane achieving its limiting one-engine-inoperative climb gradient at the normally scheduled speed and in the appropriate configuration.

4.2.7.6 Amendment 25-42, effective March 1, 1978, revised §§ 25.107(d) and 25.107(e)(1)(iv) in order to permit the one-engine-inoperative V_{MU} to be determined by all-engines-operating tests at the thrust/weight ratio corresponding to the one-engine-inoperative condition. As revised, § 25.107(d) specifies that V_{MU} must be selected for the range of thrust/weight ratios to be certificated, rather than for the all-engines-operating and one-engine-inoperative conditions as was previously required. In determining the all-engines-operating thrust/weight ratio that corresponds to the one-engine-inoperative condition, consider trim and control drag differences between the two configurations in addition to the effect of the number of engines operating. The minimum thrust/weight ratio to be certificated is established by correcting, to the V_{MU} speed, the thrust that results in the airplane achieving its limiting engine-out climb gradient in the appropriate configuration and at the normally scheduled speed.

4.2.7.7 To conduct the V_{MU} tests, rotate the airplane as necessary to achieve the V_{MU} attitude. It is acceptable to use some additional nose-up trim over the normal trim setting during V_{MU} demonstrations. If additional nose-up trim is required, the additional considerations of paragraph 4.2.7.8 below apply. V_{MU} is the speed at which the weight of the airplane is completely supported by aerodynamic lift and thrust forces. Some judgment may be necessary on airplanes that have tilting main landing gear bogies.

Determining the liftoff point from gear loads and wheel speeds has been found acceptable in past programs. After liftoff, the airplane should be flown out of ground effect. During liftoff and the subsequent climbout, the airplane should be fully controllable.

4.2.7.8 **V_{MU} Testing for Airplanes having Limited Pitch Control Authority.**

4.2.7.8.1 For some airplanes with limited pitch control authority, it may not be possible, at forward CG and normal trim, to rotate the airplane to a liftoff attitude where the airplane could otherwise perform a clean flyaway at a minimum speed had the required attitude been achieved. This may occur only over a portion of the takeoff weight range in some configurations. Though generally associated with the inability of the pitch control surfaces to provide adequate pitching moment to rotate the airplane to the desired pitch attitude at low thrust/weight ratio conditions, the same phenomenon may occur at high thrust/weight ratio conditions for airplanes with high thrust lines (e.g., aft engines mounted high on the fuselage). When limited pitch control authority is clearly shown to be the case, V_{MU} test conditions may be modified to allow testing aft of the forward CG limit and/or with use of more airplane nose-up trim than normal. The V_{MU} data determined with this procedure should be corrected to those values representative of the appropriate forward limit; the variation of V_{MU} with CG may be assumed to be like the variation of free air stalling speed with CG. Although the development of scheduled takeoff speeds may proceed from these corrected V_{MU} data, additional tests are required (see paragraph 4.2.7.8.2 below) to check that the relaxed V_{MU} criteria have not neglected problems that might arise from operational variations in rotating airplanes with limited pitch control authority.

4.2.7.8.2 In the following assurance test, the airplane should demonstrate safe flyaway characteristics: Minimum speed liftoff should be demonstrated at the critical forward CG limit with normal trim. For airplanes with a cutback forward CG at heavy weight, two weight/CG conditions should be considered. The heavy weight tests should be conducted at maximum structural or maximum sea level climb-limited weight with the associated forward CG. The full forward CG tests should be conducted at the highest associated weight. Alternatively, testing may be conducted at a single weight if an analysis is provided that identifies the critical weight/CG combination with regard to limited pitch attitude capability for liftoff. These assurance tests should be conducted at the thrust/weight ratio that is most critical for attaining a pitch attitude that will provide a minimum liftoff speed.

4.2.7.8.3 For airplanes that are limited by low thrust/weight conditions, tests should be conducted at the minimum thrust/weight ratio for both the simulated one-engine-inoperative test (i.e., symmetrical reduced thrust) case and the all-engines-operating case.

4.2.7.8.4 For airplanes that are limited by high thrust/weight conditions, tests should be conducted at the highest thrust/weight ratio within the airplane's operating envelope for both the simulated one-engine-inoperative case (i.e., symmetrical reduced thrust) and the all-engines-operating case.

4.2.7.8.5 One acceptable test technique is to hold full nose-up control column as the airplane accelerates. As pitch attitude is achieved to establish the minimum liftoff speed, pitch control may be adjusted to prevent over-rotation, but the liftoff attitude should be maintained as the airplane flies off the ground and out of ground effect.

4.2.7.8.6 The resulting liftoff speeds are acceptable if the test proves successful and the liftoff speed is at least 5 knots below the normally scheduled liftoff speed.

4.2.7.8.7 This minimum 5 knot margin from the scheduled liftoff speed provides some leeway for operational variations such as mistrim, CG errors, etc., that could further limit the elevator authority. The reduced V_{MU} margins arising from this test, relative to those specified in § 25.107(e)(1)(iv), are considered acceptable because of the reduced probability of a pitch control authority-limited airplane getting into a high drag condition due to over-rotation.

4.2.7.9 **V_{MU} Testing for Geometry Limited Airplanes.**

4.2.7.9.1 For airplanes that are geometry limited (i.e., the minimum possible V_{MU} speeds are limited by tail contact with the runway), § 25.107(e)(1)(iv)(B) allows the V_{MU} to V_{LOF} speed margins to be reduced to 108 percent and 104 percent for the all-engines-operating and one-engine-inoperative conditions, respectively. The V_{MU} demonstrated should be sound and repeatable.

4.2.7.9.2 An airplane that is deemed to be geometry limited at the conditions tested is expected to be geometry limited over its entire takeoff operating envelope. If this is not the case, the airplane is not considered geometry limited and the reduced V_{MU} to V_{LOF} speed margins do not apply.

4.2.7.9.3 One acceptable means for demonstrating compliance with §§ 25.107(d) and 25.107(e)(1)(iv) with respect to the capability for a safe liftoff and fly-away from the geometry limited condition is to show that at the lowest thrust-to-weight ratio for the all-engines-operating condition:

1. In the speed range from 96 to 100 percent of the actual liftoff speed), the aft under-surface of the airplane should be in contact with the runway. Because of the dynamic nature of the test, it is recognized that contact will probably not be maintained during this entire speed range, so some judgment is necessary. It has been found acceptable for

contact to exist approximately 50 percent of the time that the airplane is in this speed range.

2. Beyond the point of liftoff to a height of 35 feet, the airplane's pitch attitude should not decrease below that at the point of liftoff, nor should the speed increase more than 10 percent.
3. The horizontal distance from the start of the takeoff to a height of 35 feet above the takeoff surface should not be greater than 105 percent of the distance determined in accordance with § 25.113(a)(2) without applying the 115 percent factor.

4.2.7.10 **V_{MU} for a Stretched Version of a Tested Airplane.**

4.2.7.10.1 V_{MU} speeds obtained by flight testing one model of an airplane type may be used to generate V_{MU} speeds for a geometry-limited stretched version of that airplane. If the short body airplane met the criteria for the 104/108 percent V_{MU}/V_{LOF} speed margin for geometry limited airplanes as permitted by § 25.107(e)(1)(iv)(B) and discussed in paragraph 4.2.7.9.1 above, then the flight tests described in paragraph 4.2.7.9.3 above should be performed on the stretched derivative. Otherwise, the flight tests described in paragraph 4.2.7.10.2.2 below should be performed on the stretched derivative.

4.2.7.10.2 Since the concern for tail strikes is increased with the stretched airplane, the following should be accomplished, in addition to normal takeoff tests, when the V_{MU} schedule of the stretched derivative is derived from that of the shorter body parent airplane:

1. The V_{MU} of the stretched derivative airplane should be determined by correcting the V_{MU} of the shorter body tested airplane for the reduced runway pitch attitude capability and revised CG range of the stretched airplane. Alternatively, stretched airplane V_{MU} speeds not determined in this manner should be substantiated by flight testing or a rational analysis. Scheduled rotation speeds for the stretched airplane should result in at least the required liftoff speed margins above the corrected V_{MU} required by § 25.107(e)(1)(iv) for the one-engine-inoperative and all-engines-operating takeoff conditions.
2. At both the forward and aft CG limits, and over the thrust-to-weight range for each takeoff flap, the following takeoff tests should be accomplished. The tests described in paragraphs a and b below should be accomplished with not more than occasional, minor (i.e., non-damaging) tail strikes.
    a. All-engines-operating, early rotation tests specified in paragraph 4.2.8.3.2 below, including both the rapid rotations and over-rotations as separate test conditions.

b. One-engine-inoperative, early rotation tests specified in paragraph 4.2.8.2 below.

c. All-engines-operating, moderate rotation rate (i.e., more rapid than normal) takeoff tests, using the scheduled V_R and normal pitch attitude after liftoff. Tail strikes should not occur for this condition.

4.2.8 Procedures: Section 25.107(e)—Rotation Speed (V_R).

4.2.8.1 V_R in terms of calibrated airspeed, must be selected by the applicant. V_R has a number of constraints that must be observed in order to comply with § 25.107(e):

4.2.8.1.1 V_R may not be less than V_1; however, it can be equal to V_1 in some cases.

4.2.8.1.2 V_R may not be less than 105 percent of V_{MCA}.

4.2.8.1.3 V_R must be a speed that will allow the airplane to reach V_2 at or before reaching a height of 35 feet above the takeoff surface.

4.2.8.1.4 V_R must be a speed that will result in liftoff at a speed not less than 110 percent of V_{MU} (unless geometry limited) for the all-engines-operating condition and not less than 105 percent of the V_{MU} (unless geometry limited) determined at the thrust/weight ratio corresponding to the one-engine-inoperative condition for each set of conditions such as weight, altitude, temperature, and configuration when the airplane is rotated at its maximum practicable rate.

4.2.8.2 **Early Rotation, One-Engine-Inoperative Test.**

4.2.8.2.1 In showing compliance with § 25.107(e)(3), some guidance relative to the airspeed attained at the 35-foot height during the associated flight test is necessary. As this requirement only specifies an early rotation (V_R-5 knots), it is interpreted that pilot technique is to remain the same as normally used for a one-engine-inoperative condition. With these considerations in mind, it is apparent that the airspeed achieved at the 35-foot point 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 below.

4.2.8.2.2 These test criteria apply to all unapproved, new, basic model airplanes. They also apply to previously approved airplanes when subsequent testing is warranted. However, for those airplanes where these criteria are more stringent than those previously applied, consideration will be given to permitting some latitude in the test criteria.

4.2.8.2.3 In conducting the flight tests required by § 25.107(e)(3), the test pilot should use the normal/natural rotation technique associated with the use of scheduled takeoff speeds for the airplane being tested. Intentional tail or tail skid contact is not considered acceptable. Non-damaging contact due to inadvertent over-rotation is acceptable provided there is a prompt recovery to the normal one-engine-inoperative takeoff pitch attitude. Further, the airspeed attained at the 35-foot height during this test should not be less than the scheduled V_2 value minus 5 knots. These speed limits should not be considered or used as target V_2 test speeds, but rather are intended to provide an acceptable range of speed departure below the scheduled V_2 value.

4.2.8.2.4 In this test, the simulated engine failure should be accomplished sufficiently in advance of the V_R test speed to allow for engine spin-down, unless this would be below the V_{MCG}, in which case V_{MCG} should govern. The normal one-engine-inoperative takeoff distance may be analytically adjusted to compensate for the effect of the early power or thrust reduction. Further, in those tests where the airspeed achieved at the 35-foot height is slightly less than the V_2-5 knots limiting value, it will be permissible, in lieu of conducting the tests again, to analytically adjust the test distance to account for the excessive speed decrement.

4.2.8.3 **All-Engines-Operating Tests.**

4.2.8.3.1 Section 25.107(e)(4) states that there must 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 has been interpreted as requiring takeoff tests with all engines operating with:

- A lower than scheduled rotation speed, and
- Out-of-trim conditions, but with rotation at the scheduled V_R speed.

Note: The expression "marked increase" in the takeoff distance is considered to be any amount in excess of 1 percent of the scheduled takeoff distance. Thus, the tests should not result in field lengths more than 101 percent of the takeoff field lengths calculated in accordance with the applicable requirements of part 25 for presentation in the AFM.

4.2.8.3.2 For the early rotation condition with all engines operating, and at a weight as near as practicable to the maximum sea level standard day takeoff weight limit, it should be shown by tests that when the airplane is rotated at a speed below the scheduled V_R, no "marked increase" in the scheduled AFM field length will result. For these tests, the airplane should be rotated at a speed equal to the scheduled V_R minus 7 percent or the scheduled V_R minus 10 knots, whichever results in the higher rotation speed. Tests should be conducted at (1) a rapid rotation rate to the normal takeoff attitude, and (2) an over-rotation of 2° above normal attitude after liftoff at the normal rotation rate. For tests using over rotations, the resulting increased pitch attitude should be maintained until the airplane is out of ground effect. Tail strikes during this demonstration are acceptable if they are minor and do not result in unsafe conditions.

4.2.8.3.3 For reasonably expected out-of-trim conditions with all engines operating and as near as practicable to the maximum weight allowed under sea level standard day conditions, it should be shown that there will not be a "marked increase" in the scheduled AFM takeoff distance when rotation is initiated in a normal manner at the scheduled V_R speed. The amount of mistrim should be the maximum mistrim that would not result in a takeoff configuration warning, including taking into account the takeoff configuration warning system rigging tolerance. It is permissible to accept an analysis in lieu of actual testing if the analysis shows that the out-of-trim condition would not present unsafe flight characteristics or a "marked increase" in the scheduled AFM field lengths.

4.2.8.3.4 Section 25.107(e)(4) also states that the reasonably expected variations in service from the established takeoff procedures for the operation of the airplane may not result in unsafe flight characteristics. For example, for an airplane loaded to obtain a forward CG position and mistrimmed for an aft CG loading, it may not be possible to rotate at the normal operating speeds due to excessive control force or lack of primary pitch control authority. This may result in an excessive delay in accomplishing the rotation. Such a condition would be considered an unsafe flight characteristic. Similarly, for an airplane loaded to obtain an aft CG position and mistrimmed for a forward CG loading, it may not be possible to readily arrest a self-rotating tendency. This rotation, if abrupt enough and rapid enough, could lead to stall. Qualitative assessments should be made by the test pilot in the following takeoff tests with all engines operating:

1. The test pilot should determine that no unsafe characteristics exist with the airplane loaded to the forward CG limit and the stabilizer mistrimmed in the airplane nose-down direction. The amount of mistrim should be the maximum mistrim that would not result in a configuration warning (including taking into account takeoff warning system tolerances). Rotation should be initiated at the scheduled rotation speed for the airplane weight and ambient conditions. Unsafe characteristics include an excessive pitch control force to obtain normal airplane response or an excessive time to achieve perceptible rotation.
2. The test pilot should determine that no unsafe characteristics exist with the airplane loaded to the aft CG limit and the stabilizer mistrimmed in the airplane nose-up direction. The amount of mistrim should be the maximum mistrim that would not result in a configuration warning (including taking into account takeoff warning system tolerances). The airplane should be rotated at the scheduled rotation speed for the airplane weight and ambient conditions. Unsafe characteristics include an abrupt self-rotating tendency that cannot be checked with normal

control input, or an excessive pitch control force required to maintain the airplane in the normal pitch attitude prior to the scheduled rotation speed or during rotation and initial climb.

3. For the tests described in paragraphs 1 and 2 above, the flight characteristics should be assessed at the most critical combinations of airplane weight, wing flap position and engine power or thrust for the out of trim position being considered.

4.2.8.4 Stall Warning during Takeoff Speed Tests.

The presumption is that if an operational pilot was to make an error in takeoff speeds that resulted in an encounter with stall warning, the likely response would be to recover aggressively to a safe flight condition rather than trying to duplicate the AFM takeoff flight path. Therefore, the activation of any stall warning devices, or the occurrence of airframe buffeting during takeoff speed testing, is unacceptable.

4.2.8.5 Stick Forces during Takeoff Speed Tests.

According to § 25.143(a)(1) and (b), stick forces to initiate rotation and continue the takeoff during takeoff flight testing must comply with the control force limits of § 25.143(d). This includes the mistrim takeoff tests described in paragraphs 1 and 2 (on page 4-14) to show compliance with § 25.107 (e)(4), which are considered to represent probable operating conditions under § 25.143(b). Stick forces should be those that result from using the takeoff procedures established by the manufacturer for use in operational service in accordance with § 25.101(f) and must comply with § 25.101(h).

4.2.9 Procedures: Section 25.107(f)—Liftoff Speed (V_{LOF}).

4.2.9.1 V_{LOF} is defined as the calibrated airspeed at which the airplane first becomes airborne (i.e., no contact with the runway). This allows comparison of liftoff speed with tire limit speed. V_{LOF} differs from V_{MU} in that V_{MU} is the minimum possible V_{LOF} speed for a given configuration, and depending upon landing gear design, V_{MU} liftoff is shown to be the point where all of the airplane weight is being supported by airplane lift and thrust forces and not any portion by the landing gear. For example, after the V_{MU} speed is reached, a truck tilt actuator may force a front or rear wheel set to be in contact with the runway, even though the liftoff is in progress by virtue of lift being greater than weight.

4.2.9.2 The maximum ground speed at liftoff, considering the entire takeoff operating envelope and taking into account 50 percent of the headwind and 150 percent of the tailwind, in accordance with § 25.105(d)(1), must not exceed the tire speed rating established under § 25.733(a) or (c).

4.3 Accelerate-Stop Distance—§ 25.109.

4.3.1 Explanation.

4.3.1.1 The accelerate-stop distance is the horizontal distance from a reference point on the airplane at initial brake release to that same reference point after the airplane is brought to a stop.

4.3.1.2 This section describes test demonstrations and data expansion methods necessary to determine accelerate-stop distances for publication in the FAA-approved AFM, as required by § 25.1583(h) (by reference to § 25.1533). Amendment 25-92 revised some aspects of the part 25 accelerate-stop criteria and added new requirements related to the stopping capability of the airplane as affected by brake wear and wet runways. The changes imparted to the accelerate-stop requirements by amendment 25-92 are listed below. (For other material related to the use of accelerate-stop distances, see 14 CFR parts 121 and 135.)

4.3.1.2.1 Section 25.101(i) was added to require accelerate-stop distances to be determined with all the airplane wheel brake assemblies at the fully worn limit of their allowable wear range.

4.3.1.2.2 Section 25.105(c)(1) was revised to require takeoff data to be determined for wet, in addition to dry, hard surfaced runways. At the applicant's option, takeoff data may also be determined for wet runways that have grooved or porous friction course surfaces.

4.3.1.2.3 Section 25.107(a)(2) was revised to remove the reference to "takeoff decision speed" from the definition of V_1. V_1 is the speed by which the pilot has already made the decision to either continue or reject the takeoff and, if the latter, has initiated the first action to stop the airplane.

4.3.1.2.4 Section 25.109 was revised to add a requirement to determine accelerate-stop distances for wet runways. Additionally, the requirement for the AFM expansion to include two seconds of continued acceleration beyond V_1, with the operating engines at takeoff power or thrust, as introduced by amendment 25-42, was replaced with a distance increment equivalent to two seconds at V_1. Also, the text of § 25.109(a) was modified to clarify that the accelerate-stop distances must take into account the highest speed reached during the rejected takeoff maneuver, including, as applicable, speeds higher than V_1.

4.3.1.2.5 Section 25.109(f) was added to permit credit for the use of reverse thrust in determining wet runway accelerate-stop distances (subject to the requirements of § 25.109(e)) and to explicitly deny reverse thrust credit for determining dry runway accelerate-stop distances.

4.3.1.2.6 Section 25.109(i) was added to require a maximum brake energy accelerate-stop test to be conducted with not more than 10 percent of the allowable brake wear range remaining on each individual wheel-brake assembly.

4.3.1.2.7 Section 25.735(h) was added to require the maximum rejected takeoff brake energy absorption capacity rating used during qualification testing to the applicable TSO to be based on the fully worn limit of the brake's allowable wear range.

Note: Section 25.735 was revised by amendment 25-107, which moved the rejected takeoff kinetic energy rating requirements into § 25.735(f).

4.3.1.2.8 Section 25.1533(a)(3) was revised to add runway surface condition (dry or wet) as a variable that must be accounted for in establishing minimum takeoff distances. Section 25.1533(a)(3) was also revised to allow wet runway takeoff distances on grooved and porous friction course (PFC) runways to be established as additional operating limitations, but approval to use these distances is limited to runways that have been designed, constructed, and maintained in a manner acceptable to the FAA Administrator.

4.3.2 Applicable Regulations.

The applicable part 25 regulations are § 25.109, and the following:

- Section 25.101(f) regarding airplane configuration and procedures.
- Section 25.101(h) regarding pilot action time delay allowances.
- Section 25.101(i) regarding worn brake stopping performance.
- Section 25.105 regarding takeoff configuration and environmental and runway conditions.
- Section 25.107(a)(l) and (a)(2) regarding V_1 and V_{EF} speed definitions.
- Section 25.735 regarding brakes and braking systems.
- Section 25.1301 regarding function and installation.
- Section 25.1309 regarding equipment, systems, and installation.
- Section 25.1533 regarding additional operating limitations—maximum takeoff weights and minimum takeoff distances.
- Section 25.1583(h) regarding AFM operating limitations.
- Section 25.1587 regarding AFM performance information.

4.3.3 Procedures: General.

The following paragraphs provide guidance for accomplishing accelerate-stop flight tests and expanding the resulting data for the determination of AFM performance information.

4.3.4 Procedures: Accelerate-Stop Testing.

The following guidance applies to turbine-powered airplanes with and without propellers. Guidance regarding flight testing applies only to dry runway accelerate-stop distances. Guidance for expanding the flight test data to determine AFM distances applies to both dry and wet runways, unless otherwise noted. Further guidance for determining wet runway accelerate-stop distances is provided in paragraph 4.3.7 of this AC.

4.3.4.1 In order to establish a distance that would be representative of the distance needed in the event of a rejected takeoff, where the first action to stop the airplane is taken at V_1, a sufficient number of test runs should be conducted for each airplane configuration specified by the applicant. (For intermediate configurations, see paragraph 3.1 of this AC.)

4.3.4.2 The guidance outlined in paragraph 4.3.6 of this AC describes how to include allowances for any time delays, as required by § 25.101(h)(3), for the flightcrew to accomplish the rejected takeoff operating procedures.

4.3.4.3 Section 25.101(i) states that the accelerate-stop distances must be determined with all the airplane wheel-brake assemblies at the fully worn limit of their allowable wear range. The fully worn limit is defined as the maximum amount of wear allowed before the brake is to be removed from the airplane for overhaul. The allowable wear should be defined in terms of a linear dimension in the axial direction, which is typically determined by measuring the wear pin extension.

4.3.4.3.1 The only accelerate-stop test that must be conducted at a specific brake wear state is the maximum brake kinetic energy demonstration, which must use brakes that have no more than 10 percent of the allowable brake wear range remaining, as required by § 25.109(i). (See paragraph 4.3.5.3 of this AC). The remainder of the accelerate-stop tests may be conducted with the brakes in any wear state as long as a suitable combination of airplane and dynamometer tests is used to determine the accelerate-stop distances corresponding to fully worn brakes. For example, dynamometer testing may be used to determine whether there is a reduction in brake performance from the wear state used in the airplane tests to a fully worn brake. The airplane test data could then be adjusted analytically for this difference without additional airplane testing.

4.3.4.3.2 Either airplane-worn or mechanically-worn brakes (i.e., machined or dynamometer worn) may be used. If mechanically-worn brakes are used, it should be shown that they can be expected to provide similar results to airplane-worn brakes. This comparison can be based on service experience on the test brake or an appropriate equivalent brake, or on dynamometer wear test data when service data are unavailable.

4.3.4.4 Section 25.109(f)(1) denies credit for the use of reverse thrust as a decelerating means in determining the accelerate-stop distance for a dry runway. This provision applies to both turbine engine and propeller engine reverse thrust (but not to any drag resulting from the ground idle power setting for a propeller engine). Credit for the additional deceleration available from reverse thrust is permitted for wet runway accelerate-stop distances, provided the thrust reverser system is shown to be safe, reliable, capable of giving repeatable results, and does not require exceptional skill to control the airplane. (See paragraph 4.3.7.10 of this AC for guidance related to obtaining accelerate-stop performance credit for reverse thrust on wet runways.)

4.3.4.5 The accelerate-stop test runs should be conducted at weight/speed combinations that will provide an even distribution of test conditions over the range of weights, speeds, and brake energies for which takeoff data will be provided in the AFM. The effects of different airport elevations can be simulated at one airport elevation, provided the braking speeds employed are relevant for the range of airplane energies to be absorbed by the brakes. The limiting brake energy value in the AFM should not exceed the maximum demonstrated in these tests or the maximum for which the brake has been approved. (See paragraph 4.3.5 of this AC for further guidance related to tests and analyses for the demonstration of the maximum brake energy absorption capability.)

4.3.4.6 The V_1 speeds used in the accelerate-stop tests need not correspond precisely to the AFM values for the test conditions since it may be necessary to increase or decrease the AFM V_1 speed to investigate fully the energy range and weight envelope.

4.3.4.7 A total of at least six accelerate-stop flight tests should be conducted. Unless sufficient data are available for the specific airplane type showing how braking performance varies with weight, kinetic energy, lift, drag, ground speed, torque limit, etc., at least two tests should be conducted for each configuration when the same braking coefficient of friction is being claimed for multiple aerodynamic configurations. These tests should be conducted on smooth, hard surfaced, dry runways.

4.3.4.8 For approval of dispatch capability with anti-skid inoperative, nose wheel brakes or specified main wheel-brake(s) inoperative, automatic braking systems, etc., a full set of tests, as described in paragraph 4.3.4.7 above, should normally be conducted. A lesser number of tests may be accepted for “equal or better” demonstrations, to establish small increments or if adequate conservatism is used during testing.

4.3.4.9 Either ground or airborne instrumentation should include means to determine the horizontal distance time-history.

4.3.4.10 The wind speed and direction relative to the test runway should be determined and corrected to a height corresponding to the approximate height of the mean aerodynamic chord. (See paragraph 3.1 of this AC.)

4.3.4.11 The accelerate-stop tests should be conducted in the following configurations:

4.3.4.11.1 Heavy to light weight as required.

4.3.4.11.2 Most critical CG position.

4.3.4.11.3 Wing flaps in the takeoff position(s).

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

4.3.4.11.5 Engine idle power or thrust: set at the recommended upper limit for use on the ground or the effect of maximum ground idle power or thrust may be accounted for in data analyses. For maximum brake energy and fuse plug no-melt tests, data analysis may not be used in place of maximum ground idle power or thrust.

4.3.4.12 Engine power or thrust should be appropriate to each segment of the rejected takeoff and should include accounting for power or thrust decay rates (i.e., spin down) for failed or throttled back engines.

4.3.4.12.1 <u>Turbojet Powered Airplanes.</u>

For AFM calculation purposes, the critical engine failure accelerate-stop data may be based on the failed engine spinning down to a windmilling condition.

Note: If, due to the certification basis of the airplane, all-engine-accelerate-stop distances are not being considered, the one-engine-inoperative AFM distances should be based on the critical engine failing to maximum ground idle power or thrust rather than the windmilling condition.

4.3.4.12.2 The power or thrust from the operative engine(s) should be consistent with a throttle chop to maximum ground idle power or thrust. For determining the all-engines-operating dry runway accelerate-stop AFM distances, the stopping portion should be based on all engines producing maximum ground idle power or thrust (after engine spin down), as noted in paragraph 4.3.4.11.5 above. The accelerate-stop tests may be conducted with either concurrent or sequential throttle chops to idle power or thrust as long as the data are adjusted to take into account pilot reaction time, and any control, system, or braking differences (e.g., electrical or hydraulic/mechanical transients associated with an engine failing to a windmilling condition resulting in reduced braking effectiveness). Test data should also be analytically corrected for any differences between maximum ground idle power or thrust and the idle power or thrust level achieved during the test. For the criteria relating to reverse thrust credit for wet runway accelerate-stop distances, see paragraph 4.3.7.10 of this AC.

4.3.4.12.3 Turbopropeller-Powered Airplanes.

For the one-engine-inoperative accelerate-stop distances, the critical engine's propeller should be in the position it would normally assume when an engine fails and the power levers are closed. For dry runway one-engine-inoperative accelerate-stop distances, the high drag ground-idle position of the operating engines' propellers (defined by a pitch setting that results in not less than zero total thrust, i.e., propeller plus jet thrust, at zero airspeed) may be used provided adequate directional control is available on a wet runway and the related operational procedures comply with § 25.101(f) and (h). Wet runway controllability may either be demonstrated by using the guidance available in paragraph 4.3.7.10.6 of this AC at the appropriate power level, or adequate control can be assumed to be available at ground idle power if reverse thrust credit is approved for determining the wet runway accelerate-stop distances. For the all-engines-operating accelerate-stop distances on a dry runway, the high drag ground-idle propeller position may be used for all engines (subject to § 25.101(f) and (h)). For the criteria relating to reverse thrust credit for wet runway accelerate-stop distances, see paragraph 4.3.7.10 of this AC.

4.3.4.13 System transient effects (e.g., engine spin-down, brake pressure ramp-up, etc.) should be determined and properly accounted for in the calculation of AFM accelerate-stop distances. (See paragraph 4.3.6.10 of this AC.)

4.3.5 Procedures: Maximum Brake Energy Testing.

The following paragraphs describe regulatory requirements and acceptable test methods for conducting an accelerate-stop test run to demonstrate the maximum energy absorption capability of the wheel brakes.

4.3.5.1 The maximum brake energy accelerate-stop demonstration should be conducted at not less than the maximum takeoff weight. It should be preceded by at least a 3-mile taxi with all engines operating at maximum ground idle power or thrust, including three full stops using normal braking. Following the maximum brake energy stop, it will not be necessary to demonstrate the airplane's ability to taxi.

4.3.5.2 Section 25.735(f)(2) requires the maximum kinetic energy accelerate-stop absorption capability of each wheel, tire, and brake assembly to be determined. It also requires dynamometer testing to show that the wheel, brake, and tire assembly is capable of absorbing not less than this level of kinetic energy throughout the defined wear range of the brake. The calculation of maximum brake energy limited takeoff weights and speeds, for presentation in the AFM performance section, therefore should be based on the most critical wear range of the brake.

4.3.5.3 Section 25.109(i) requires a flight test demonstration of the maximum brake kinetic energy accelerate-stop distance to be conducted with not more than 10 percent of the allowable brake wear range remaining on each of the airplane wheel-brakes. The 10 percent allowance on the brake wear state is intended to ease test logistics and increase test safety, not to allow the accelerate-stop distance to be determined with less than fully worn brakes. If the brakes are not in the fully worn state at the beginning of the test, the accelerate-stop distance should be corrected as necessary to represent the stopping capability of fully worn brakes.

4.3.5.4 The maximum airplane brake energy allowed for dispatch should not exceed the value for which a satisfactory after-stop condition exists, or the value documented under the applicable TSO (or an acceptable equivalent), whichever value is less. A satisfactory after-stop condition is defined as one in which fires are confined to tires, wheels, and brakes, such that progressive engulfment of the rest of the airplane would not occur during the time of passenger and crew evacuation. The application of firefighting means or artificial coolants should not be required for a period of 5 minutes following the stop.

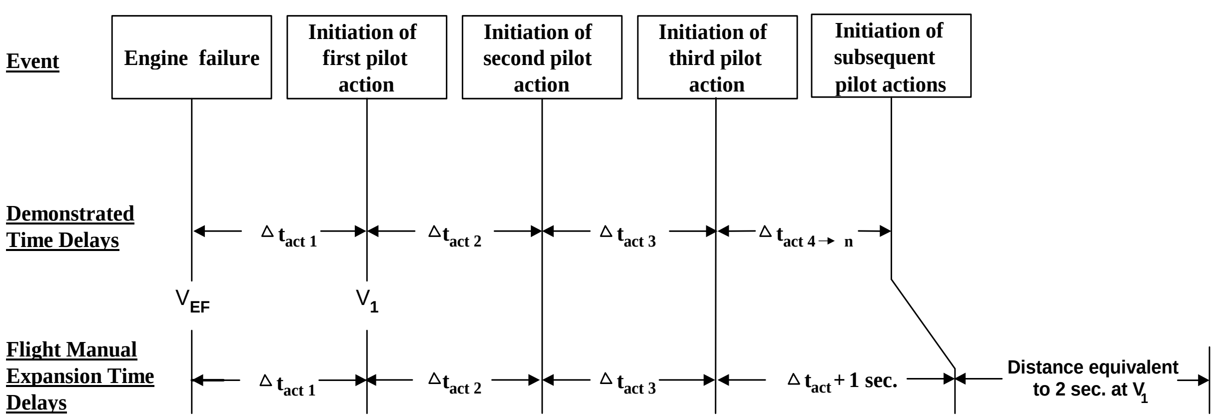
4.3.5.5 Landings are not an acceptable means for demonstrating the maximum rejected takeoff brake energy. Though permitted in the past, service experience has shown that methods used to predict brake and tire temperature increases that would have occurred during taxi and acceleration, as specified in paragraph 4.3.5.1 of this AC, were not able to accurately account for the associated energy increments.

4.3.6 Procedures: Accelerate-Stop Time Delays.

4.3.6.1 Section 25.101(h) requires allowance for time delays in the execution of procedures. Amendment 25-42 (effective March 1, 1978) amended the airworthiness standards to clarify and standardize the method of applying these time delays to the accelerate-stop transition period. Amendment 25-42 also added the critical engine failure speed, V_{EF}, and clarified the meaning of V_1 with relation to V_{EF}. The preamble to amendment 25-42 states that "V_1 is determined by adding to V_{EF} (the speed at which the critical engine is assumed to fail) the speed gained with the critical engine inoperative during the time interval between the instant at which the critical engine is failed and the instant at which the test pilot recognizes and reacts to the engine failure, as indicated by the pilot's application of the first retarding means during accelerate-stop tests." Thus it can be seen that V_1 is not only intended to be at the end of the decision process, but it also includes the time it takes for the pilot to perform the first action to stop the airplane. (See appendix C of this AC for further discussion on the historical development of accelerate-stop time delays.) The purpose of the time delays is to allow sufficient time (and distance) for a pilot, in actual operations, to accomplish the procedures for stopping the airplane. The time delays are not intended to allow extra time for making a decision to stop as the airplane passes through V_1. Since the typical transport category airplane requires three pilot actions (i.e., brakes-throttles-spoilers) to achieve the final braking configuration, amendment 25-42 defined a two-second time period, in § 25.109, to account for delays in activating the second and third deceleration devices. Amendment 25-92 (effective March 20, 1998) redefined, and reinterpreted the application of that two-second delay time as a distance increment equivalent to two seconds at V_1. No credit may be taken for system transient effects (e.g., engine spin-down, brake pressure ramp-up, etc.) in determining this distance. The following paragraphs provide guidance related to the interpretation and application of delay times to show compliance with the accelerate-stop requirements of amendment 25-92.

4.3.6.2 Figure 4-1 below presents a pictorial representation of the accelerate-stop time delays considered acceptable for compliance with § 25.101(h) as discussed above.

Figure 4-1. Accelerate-Stop Time Delays



4.3.6.3 V_{EF} is the calibrated airspeed selected by the applicant at which the critical engine is assumed to fail. The relationship between V_{EF} and V_1 is defined in § 25.107.

4.3.6.4 $\Delta t_{act\ 1}$ is the demonstrated time interval between engine failure and initiation of the first pilot action to stop the airplane. This time interval is defined as beginning at the instant the critical engine is failed and ending when the pilot recognizes and reacts to the engine failure, as indicated by the pilot's first action taken to stop the airplane during accelerate-stop tests. A sufficient number of demonstrations should be conducted using both applicant and FAA test pilots to assure that the time increment is representative and repeatable. The pilot's feet should be on the rudder pedals, not the brakes, during the tests. For AFM data expansion purposes, in order to provide a recognition time increment that can be executed consistently in service, this time increment should be equal to the demonstrated time or one second, whichever is greater. If the airplane incorporates an engine failure warning light, the recognition time includes the time increment necessary for the engine to spool down to the point of warning light activation, plus the time increment from light "on" to the first pilot action to stop the airplane.

4.3.6.5 $\Delta t_{act\ 2}$ is the demonstrated time interval between initiation of the first and second pilot actions to stop the airplane.

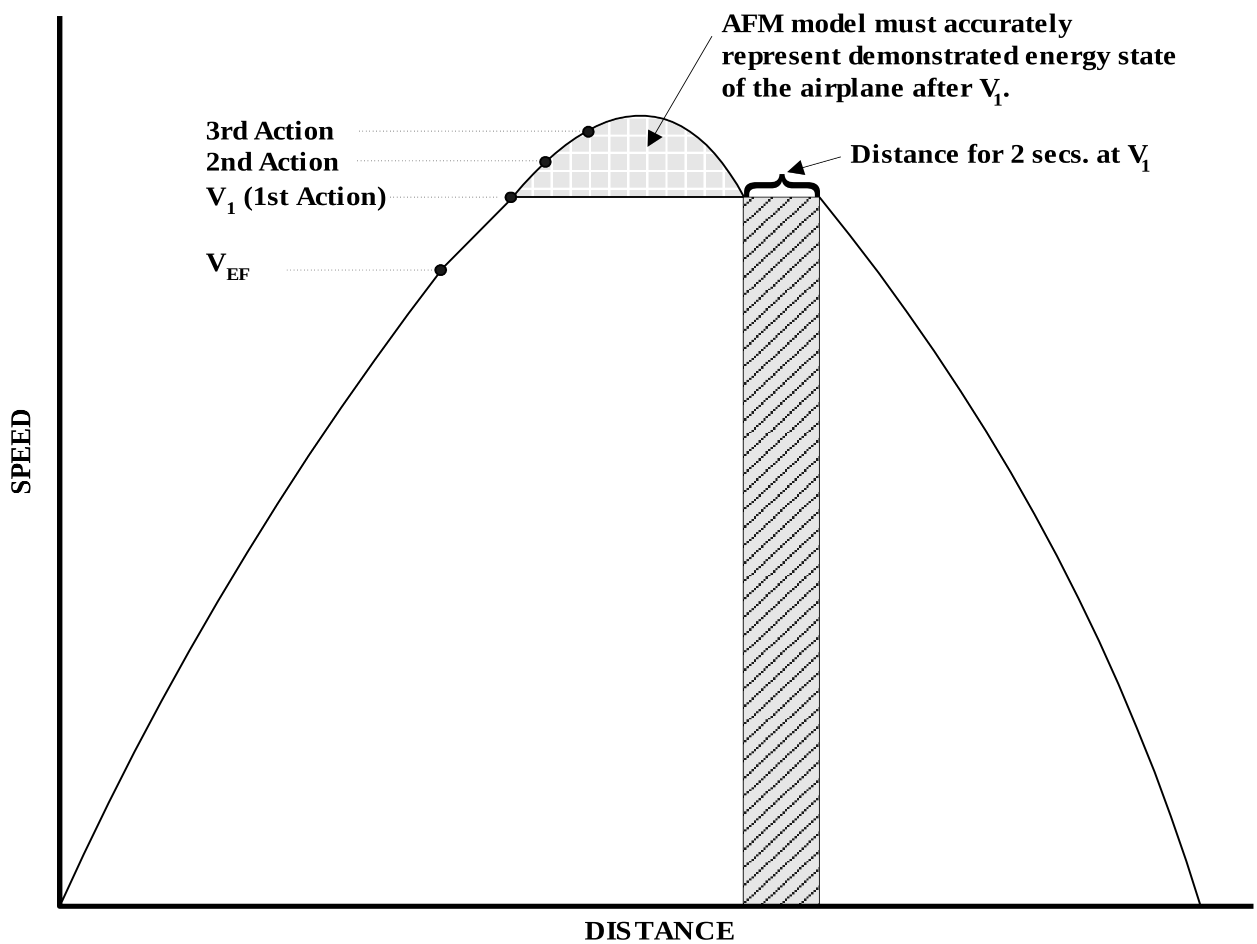
4.3.6.6 $\Delta t_{act\ 3}$ is the demonstrated time interval between initiation of the second and third pilot actions to stop the airplane.

4.3.6.7 $\Delta t_{act\ 4 \rightarrow n}$ is the demonstrated time interval between initiation of the third and fourth (and any subsequent) pilot actions to stop the airplane. For AFM expansion, a one-second reaction time delay to account for in-service variations should be added to the demonstrated time interval between the third and fourth (and any subsequent) pilot actions. If a command is required for another crewmember to initiate an action to stop the airplane, a two-second delay, in lieu of the one-second delay, should be applied for each action. For automatic deceleration devices that are approved for performance credit for AFM data expansion, established systems actuation times determined during certification testing may be used without the application of the additional time delays required by this paragraph.

4.3.6.8 The sequence of pilot actions may be selected by the applicant, but it must match the sequence established for operation in service, as prescribed by § 25.101(f). If, on occasion, the specified sequence is not achieved during testing, the test need not be discarded; however, sufficient testing should be conducted to establish acceptable values of Δt_{act}.

4.3.6.9 Section 25.109(a)(1)(iv) and (a)(2)(iii) require the one-engine-inoperative and all-engines-operating accelerate-stop distances, respectively, to include a distance increment equivalent to two seconds at V_1. (Although the requirement for the distance increment equivalent to two seconds at V_1 is explicitly stated in the "dry runway" criteria of § 25.109, it is also applied to the "wet runway" accelerate-stop distances by reference in § 25.109(b).) This distance increment is represented pictorially on the right side of the "Flight Manual Expansion Time Delays" presentation in figure 4-1 below, and in the speed versus distance plot of figure 4-2 below, on the following page. The two-second time period is only provided as a method to calculate the required distance increment, and is not considered to be a part of the accelerate-stop braking transition sequence. Consequently, no credit for pilot actions, or engine and systems transient responses (e.g., engine spin-down) may be taken during this two-second time period. Similarly, the two-second time period may not be reduced for airplanes incorporating automated systems that decrease the number of pilot actions required to obtain the full braking configuration (e.g., automatic spoiler systems).

Figure 4-2. Accelerate-Stop Speed versus Distance



4.3.6.10 Section 25.109(a)(1)(ii) requires that any residual acceleration causing the airplane to exceed V_1, while the airplane and its systems become stabilized in the braking configuration, be included in the accelerate-stop distance. The effects of system transients, such as engine spin-down, brake pressure ramp-up, spoiler actuation times, etc., should be accounted for in this time period. The area of interest is noted at the top of the graphical representation of the speed versus distance relationship in figure 4-2 above.

4.3.6.11 **All-Engine Accelerate-Stop Distance.**

For the all-engines-operating accelerate-stop distance prescribed by § 25.109(a)(2), apply the demonstrated time intervals and associated delays, of paragraphs 4.3.6.5 through 4.3.6.7 of this AC, after the airplane has accelerated to V_1.

4.3.6.12 Describe the procedures used to determine the accelerate-stop distance in the performance section of the AFM.

4.3.7 Procedures: Wet Runway Accelerate-Stop Distance.

4.3.7.1 The following guidance is provided for showing compliance with the requirements stated in § 25.109(b) through (d) for determining accelerate-stop distances applicable to wet runways. In general, the wet runway accelerate-stop distance is determined in a similar manner to the dry runway accelerate-stop distance. The only differences are in reflecting the reduced stopping force available from the wheel brakes on the wet surface and in provisions for performance credit for the use of reverse thrust as an additional decelerating means. The general method for determining the reduced stopping capability of the wheel brakes on a smooth wet runway is as follows: First, determine the maximum tire-to-ground wet runway braking coefficient of friction versus ground speed from the relationships provided in § 25.109(c)(1). Then, adjust this braking coefficient to take into account the efficiency of the anti-skid system. (See paragraph 4.3.7.3 of this AC for a definition of anti-skid efficiency. See paragraphs 4.3.7.5 and 4.3.7.6 for material on how to determine the wet runway anti-skid efficiency.) Next, determine the resulting braking force and adjust this force for the effect of the distribution of the normal load between braked and unbraked wheels at the most adverse CG position approved for takeoff, as prescribed by § 25.109(b)(2)(ii). (See paragraph 4.3.7.8 for a discussion of normal load distribution.) In accordance with § 25.109(b)(2)(i), apply further adjustments, if necessary, to ensure that the resulting stopping force attributed to the wheel brakes on a wet runway never exceeds (i.e., during the entire stop) the wheel brakes stopping force used to determine the dry runway accelerate-stop distance (under § 25.109(a)). Neither the dry runway brake torque limit nor the dry runway friction (i.e., anti-skid) limit should be exceeded. Alternative methods of determining the wet runway wheel brakes stopping force may be acceptable as long as that force does not exceed the force determined using the method just described.

4.3.7.2 **Maximum Tire-to-Ground Braking Coefficient of Friction.**

The values specified in § 25.109(c)(1) were derived from data contained in Engineering Sciences Data Unit (ESDU) 71026, *Frictional and Retarding Forces on Aircraft Types, Part II: Estimation of Braking Force*, dated August 1981). The data in ESDU 71026 is a compilation from many different sources, including the National Aeronautics and Space

Administration, the British Ministry of Aviation, and others. ESDU 71026 contains curves of wet runway braking coefficients versus speed for smooth and treaded tires at varying inflation pressures. These data are presented for runways of various surface roughness, including grooved and porous friction course runways. Included in the data presentation are bands about each of the curves, which represent variations in water depths from damp to flooded, runway surface texture within the defined texture levels, tire characteristics, and experimental methods. In defining the standard curves of wet runway braking coefficient versus speed that are prescribed by the equations in § 25.109(c)(1), the effects of the following variables were considered: tire pressure, tire tread depth, runway surface texture, and the depth of the water on the runway.

4.3.7.2.1 Tire Pressure.

Lower tire pressures tend to improve the airplane's stopping capability on a wet runway. The effect of tire pressure is taken into account by providing separate curves (equations) in § 25.109(c)(1) for several tire pressures. As stated in the rule, the tire pressure used to determine the maximum tire-to-ground braking coefficient of friction must be the maximum tire pressure approved for operation. Linear interpolation may be used for tire pressures other than those listed.

4.3.7.2.2 Tire Tread Depth.

The degree to which water can be channeled out from under the tires significantly affects wet runway stopping capability. The standard curves of braking coefficient versus speed prescribed in § 25.109(c)(1) are based on a tire tread depth of 2 mm. This tread depth is consistent with tire removal and retread practices reported by airplane and tire manufacturers and tire retreaders. It is also consistent with FAA guidance provided in AC 121.195(d)-1A, regarding the tread depth for tires used in flight tests to determine operational landing distances on wet runways. Although operation with zero tread depth is not prohibited, it is unlikely that all of the tires on an airplane would be worn to the same extent.

4.3.7.2.3 Runway Surface Texture.

ESDU 71026 groups runways into five categories. These categories are labeled "A" through "E," with "A" being the smoothest and "C" the most heavily textured ungrooved runways. Categories "D" and "E" represent grooved and other open textured surfaces. Category A represents a very smooth texture (an average texture depth of less than 0.004 inches), and is not very prevalent in runways used by transport category airplanes. The majority of ungrooved runways fall into the category C grouping. The curves represented in § 25.109(c)(1) represent a texture midway between categories B and C.

4.3.7.2.4 Depth of Water on the Runway.

Obviously, the greater the water depth, the greater the degradation in braking capability. The curves prescribed in § 25.109(c)(1) represent a well-soaked runway, but with no significant areas of standing water.

4.3.7.3 **Anti-Skid System Efficiency.**

Section 25.109(c)(2) requires adjusting the maximum tire-to-ground braking coefficient determined in § 25.109(c)(1) to take into account the efficiency of the anti-skid system. The anti-skid system efficiency is defined as the relative capability of the anti-skid system to obtain the maximum friction available between the tire and the runway surface. It is expressed as either a percentage or a factor based on that percentage (e.g., 85 percent or 0.85). Applicants can either use one of the anti-skid efficiency values specified in § 25.109(c)(2), or derive the efficiency from flight tests on a wet runway. Regardless of which method is used, § 25.109(c)(2) requires that an appropriate level of flight testing be performed to verify that the anti-skid system operates in a manner consistent with the efficiency value used, and that the system has been properly tuned for operation on wet runways.

4.3.7.4 **Classification of Types of Anti-Skid Systems.**

4.3.7.4.1 The efficiency values specified in § 25.109(c)(2) are a function of the type of anti-skid system installed on the airplane. Three broad system types are identified in the rule: on/off, quasi-modulating, and fully modulating. These classifications represent evolving levels of technology and differing performance capabilities on dry and wet runways. The classification of anti-skid system types and the assigned efficiency values are based on information contained in Society of Automotive Engineers (SAE) Aerospace Information Report (AIR) 1739, *Information on Anti-Skid Systems*.

4.3.7.4.2 On/off systems are the simplest of the three types of anti-skid systems. For these systems, full-metered brake pressure (as commanded by the pilot) is applied until wheel locking is sensed. Brake pressure is then released to allow the wheel to spin back up. When the system senses that the wheel is accelerating back to synchronous speed (i.e., ground speed), full-metered pressure is again applied. The cycle of full pressure application/complete pressure release is repeated throughout the stop (or until the wheel ceases to skid with pressure applied).

4.3.7.4.3 Quasi-modulating systems attempt to continuously regulate brake pressure as a function of wheel speed. Typically, brake pressure is released when the wheel deceleration rate exceeds a pre-selected value. Brake pressure is re-applied at a lower level after a length of time appropriate to the depth of the skid. Brake pressure is then gradually increased until another incipient skid condition is sensed. In general, the corrective actions taken by these systems to exit the skid condition are based on a pre-programmed sequence rather than the wheel speed time history.

4.3.7.4.4 Fully modulating systems are a further refinement of the quasi-modulating systems. The major difference between these two types of anti-skid systems is in the implementation of the skid control logic. During a skid, corrective action is based on the sensed wheel speed signal, rather than a pre-programmed response. Specifically, the amount of pressure reduction or reapplication is based on the rate at which the wheel is going into or recovering from a skid.

4.3.7.4.5 In addition to examining the control system for the differences noted above, a time history of the response characteristics of the anti-skid system during a wet runway stop should be used to help identify the type of anti-skid system. Comparing the response characteristics between wet and dry runway stops can also be helpful.

4.3.7.4.6 Figure 4-3 and figure 4-4 below show an example of the response characteristics of a typical on-off system on both dry and wet runways, respectively. In general, the on-off system exhibits a cyclic behavior of brake pressure application until a skid is sensed, followed by the complete release of brake pressure to allow the wheel to spin back up. Full-metered pressure (as commanded by the pilot) is then re-applied, starting the cycle over again. The wheel speed trace exhibits deep and frequent skids (the troughs in the wheel speed trace), and the average wheel speed is significantly less than the synchronous speed (which is represented by the flat-topped portions of the wheel speed trace). Note that the skids are deeper and more frequent on a wet runway than on a dry runway. For the particular example shown in figure 4-3, the brake becomes torque-limited toward the end of the dry runway stop, and it is unable to generate enough torque to cause further skidding.

Figure 4-3. Anti-Skid System Response Characteristics: On-Off System on Dry Runway

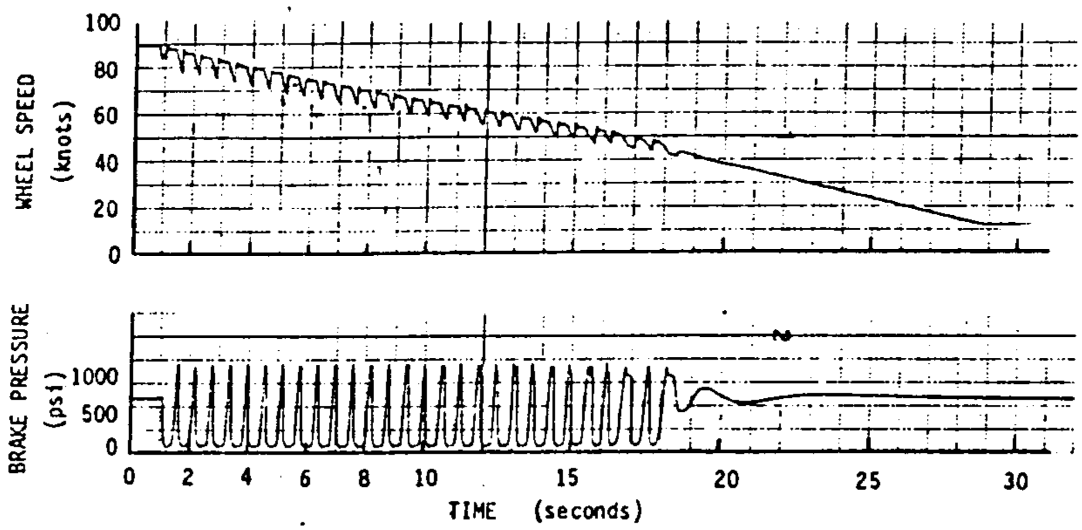
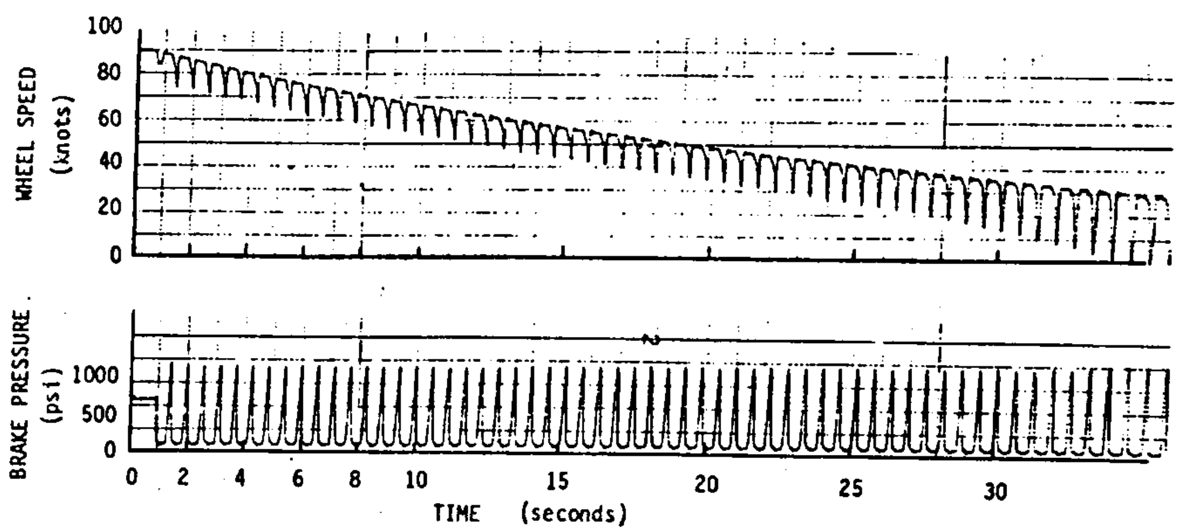


Figure 4-4. Anti-Skid System Response Characteristics: On-Off System on Wet Runway



4.3.7.4.7 The effectiveness of quasi-modulating systems can vary significantly depending on the slipperiness of the runway and the design of the particular control system. On dry runways, these systems typically perform very well; however, on wet runways their performance is highly dependent on the design and tuning of the particular system. An example of the response characteristics of one such system on dry and wet runways is shown in figure 4-5 and figure 4-6 below, respectively. On both dry and wet runways, brake pressure is released to the extent necessary to control skidding. As the wheel returns to the synchronous speed, brake pressure is quickly increased to a pre-determined level and then gradually ramped up to the full-metered brake pressure. On a dry runway, this type of response reduces the depth and frequency of skidding compared to an on-off system. However, on a wet runway, skidding occurs at a pressure below that at which the gradual ramping of brake pressure occurs. As a result, on wet runways the particular system shown in figure 4-6 operates very similarly to an on-off system.

Figure 4-5. Anti-Skid System Response Characteristics: Quasi-Modulating System on Dry Runway

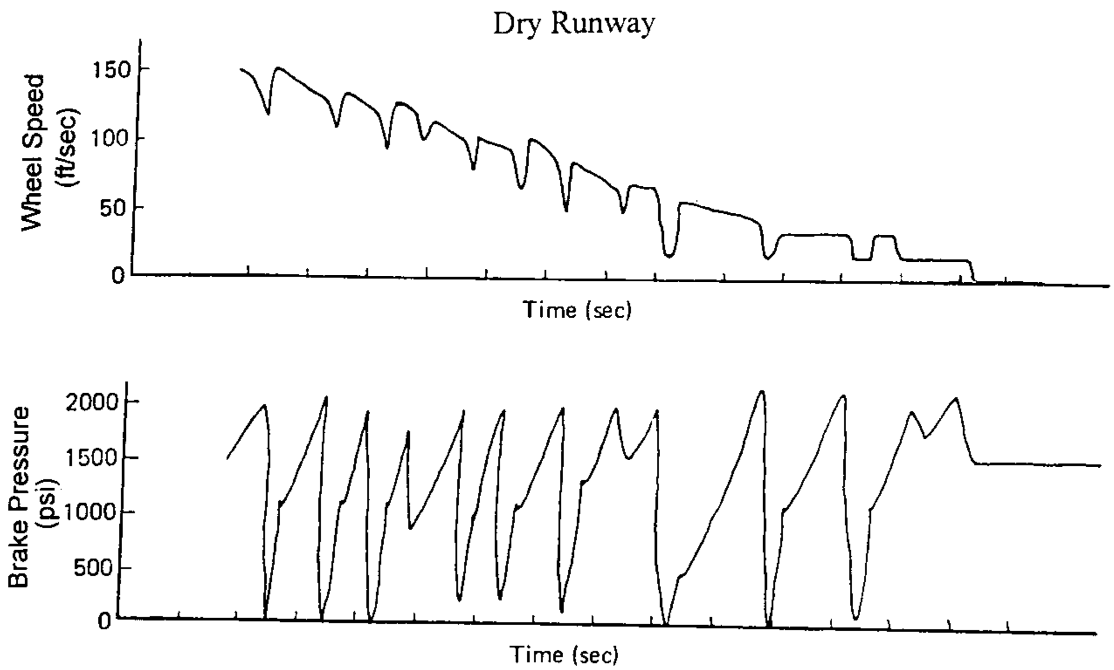
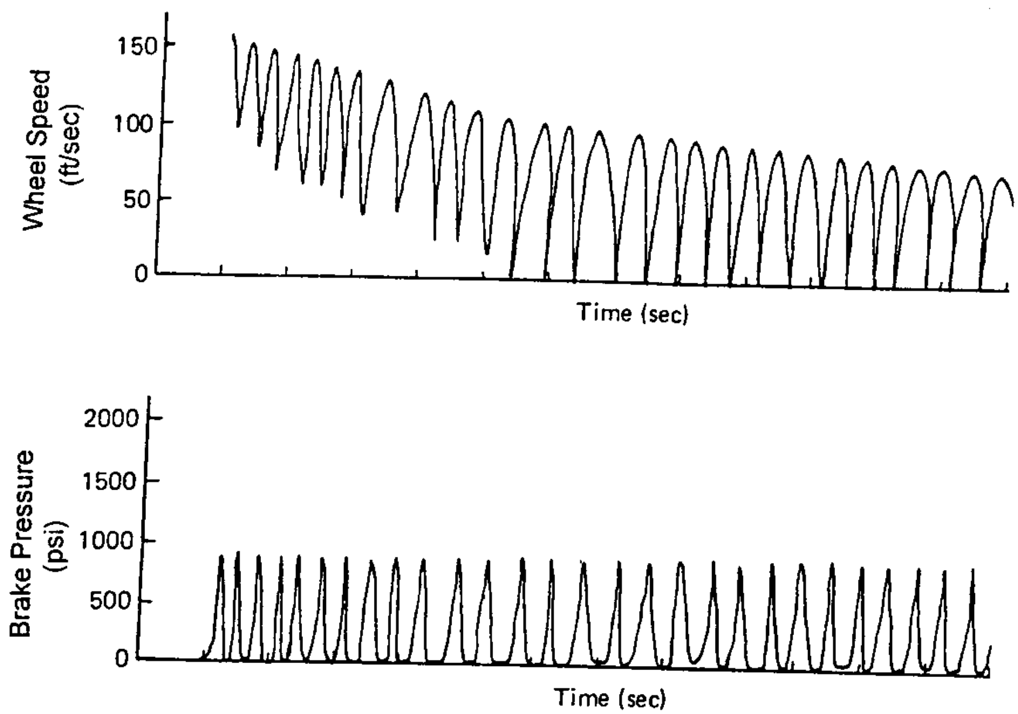


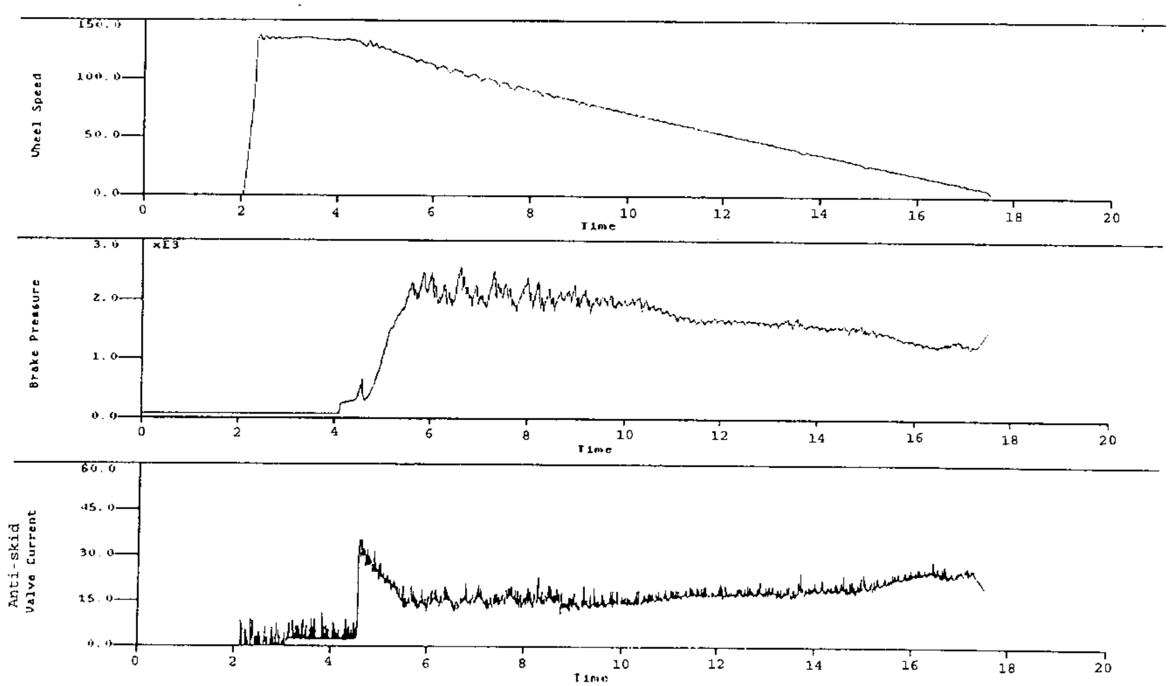
Figure 4-6 Anti-Skid System Response Characteristics: Quasi-Modulating System on Wet Runway



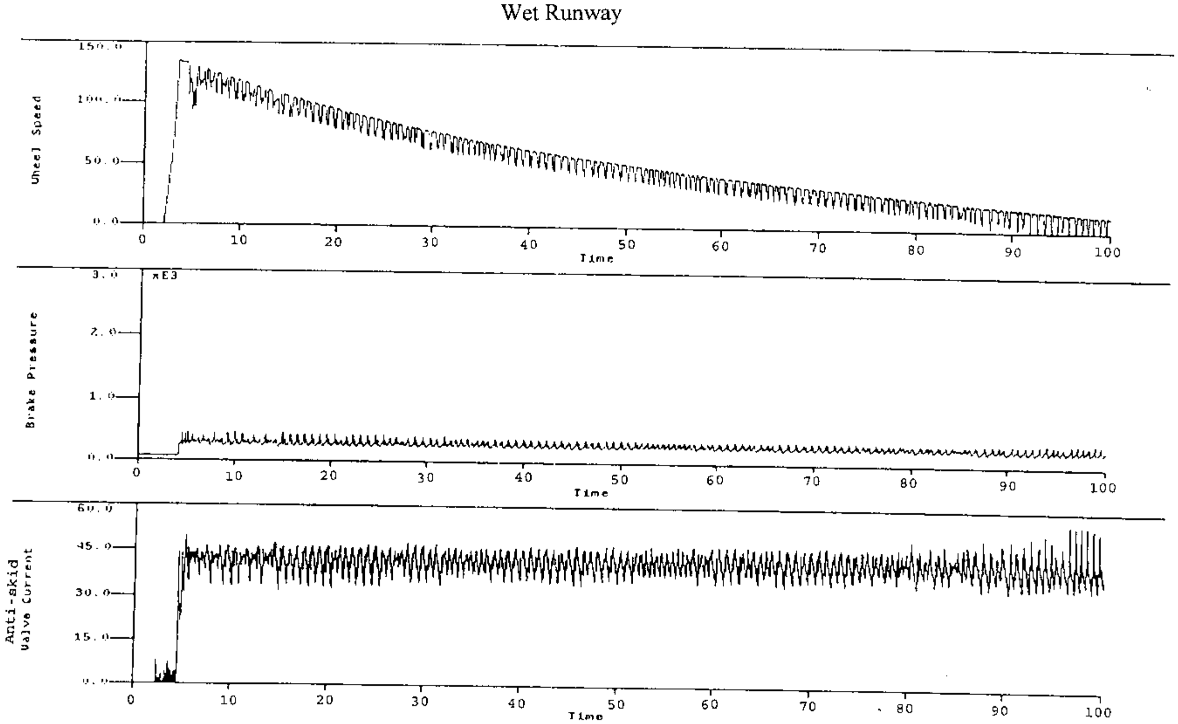
4.3.7.4.8 When properly tuned, fully modulating systems are characterized by much smaller variations in brake pressure around a fairly high average value. These systems can respond quickly to developing skids, and are capable of modulating brake pressure to reduce the frequency and depth of skidding. As a result, the average wheel speed remains much closer to the synchronous wheel speed. Figure 4-7 below illustrates an example of the response characteristics of a fully modulating system on dry and wet runways.

Figure 4-7. Anti-Skid System Response Characteristics: Fully Modulating System

Dry Runway



Wet Runway



4.3.7.5 Demonstration of Anti-Skid System Operation when Using the Anti-Skid Efficiency Values Specified in § 25.109(c)(2).

4.3.7.5.1 If the applicant elects to use one of the anti-skid efficiency values specified in § 25.109(c)(2), a limited amount of flight testing must still be conducted, per § 25.109(c)(2), to demonstrate anti-skid system operation on a wet runway. This testing should be used to verify that the anti-skid system operates in a manner consistent with the type of anti-skid system declared by the applicant, and that the anti-skid system has been properly tuned for operation on wet runways.

4.3.7.5.2 A minimum of one complete stop, or equivalent segmented stops, should be conducted on a smooth (i.e., not grooved or porous friction course) wet runway at an appropriate speed and energy to cover the critical operating mode of the anti-skid system. Since the objective of the test is to observe the operation (i.e., cycling) of the anti-skid system, this test will normally be conducted at an energy level well below the maximum brake energy condition.

4.3.7.5.3 The section of the runway used for braking should be well soaked (i.e., not just damp), but not flooded. The runway test section should be wet enough to result in a number of cycles of anti-skid activity, but should not cause hydroplaning.

4.3.7.5.4 Before taxi and with cold tires, the tire pressure should be set to the highest value appropriate to the takeoff weight for which approval is being sought.

4.3.7.5.5 The tires and brakes should not be new, but need not be in the fully worn condition. They should be in a condition considered representative of typical in-service operations.

4.3.7.5.6 Sufficient data should be obtained to determine whether the system operates in a manner consistent with the type of anti-skid system declared by the applicant, provide evidence that full brake pressure is being applied upstream of the anti-skid valve during the flight test demonstration, determine whether the anti-skid valve is performing as intended, and show that the anti-skid system has been properly tuned for a wet runway. Typically, the following parameters should be plotted versus time:

1. The speed of a representative number of wheels.
2. The hydraulic pressure at each brake (i.e., the hydraulic pressure downstream of the anti-skid valve or the electrical input to each anti-skid valve).
3. The hydraulic pressure at each brake metering valve (i.e., upstream of the anti-skid valve).

4.3.7.5.7 A qualitative assessment of anti-skid system response and airplane controllability should be made by the test pilot(s). In particular, pilot observations should confirm that:

1. Anti-skid releases are neither excessively deep nor prolonged;
2. The landing gear is free of unusual dynamics; and
3. The airplane tracks essentially straight, even though runway seams, water puddles, and wetter patches may not be uniformly distributed in location or extent.

4.3.7.6 **Determination of a Specific Wet Runway Anti-Skid System Efficiency.**

4.3.7.6.1 If the applicant elects to derive the anti-skid system efficiency from flight test demonstrations, sufficient flight testing, with adequate instrumentation, should be conducted to ensure confidence in the value obtained. An anti-skid efficiency of 92 percent (i.e., a factor of 0.92) is considered to be the maximum efficiency on a wet runway normally achievable with fully modulating digital anti-skid systems.

4.3.7.6.2 A minimum of three complete stops, or equivalent segmented stops, should be conducted on a wet runway at appropriate speeds and energies to cover the critical operating modes of the anti-skid system. Alternatively, if the operation and efficiency of the anti-skid system on a wet runway can be predicted by laboratory simulation data and validated by flight test demonstrations, a lesser number of stops may be acceptable. In this case, as many complete stops, or equivalent segmented stops, as necessary to present six independent anti-skid efficiency calculations should be conducted on a wet runway at appropriate speeds and energies to cover the critical operating modes of the anti-skid system. An independent anti-skid efficiency calculation can be presented for each stop for each independently controlled wheel, or set of wheels.

4.3.7.6.3 Since the objective of the test is to determine the efficiency of the anti-skid system, these tests will normally be conducted at energies well below the maximum brake energy condition. A sufficient range of speeds should be covered to investigate any variation of the anti-skid efficiency with speed.

4.3.7.6.4 The testing should be conducted on a smooth (i.e., not grooved or porous friction course) runway. If the applicant chooses to determine accelerate-stop distances for grooved and porous friction course (PFC) surfaces under § 25.109(d)(2), testing should also be conducted on a grooved or porous friction course runway to determine the anti-skid efficiency value applicable to those surfaces. Other means for determining the anti-skid efficiency value for grooved and PFC surfaces may also be acceptable, such as using the efficiency value previously determined for smooth runways, if that value is shown to also be representative of or conservative for grooved and PFC runways.

4.3.7.6.5 The section of the runway used for braking should be well soaked (i.e., not just damp), but not flooded. The runway test section should be wet enough to result in a number of cycles of anti-skid activity, but should not cause hydroplaning.

4.3.7.6.6 Before taxi and with cold tires, the tire pressure should be set to the highest value appropriate to the takeoff weight for which approval is being sought.

4.3.7.6.7 The tires and brakes should not be new, but need not be in the fully worn condition. They should be in a condition considered representative of typical in-service operations.

4.3.7.6.8 A qualitative assessment of anti-skid system response and airplane controllability should be made by the test pilot(s). In particular, pilot observations should confirm that:

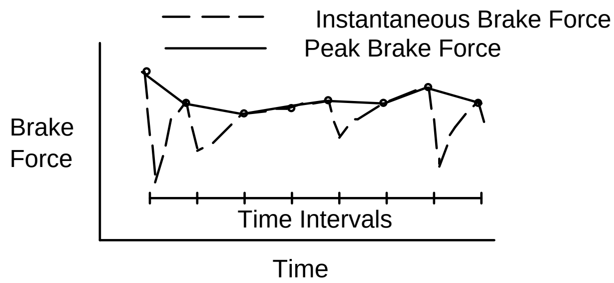
- The landing gear is free of unusual dynamics; and
- The airplane tracks essentially straight, even though runway seams, water puddles, and wetter patches may not be uniformly distributed in location or extent.

4.3.7.6.9 Two acceptable methods, referred to as the torque method and the wheel slip method, for determining the wet runway anti-skid efficiency value from wet runway stopping tests are described below. Other methods may also be acceptable if they can be shown to give equivalent results. The test instrumentation and data collection should be consistent with the method used.

4.3.7.6.10 Torque Method.

1. Under the torque method, the anti-skid system efficiency is determined by comparing the energy absorbed by the brake during an actual wet runway stop to the energy that is determined by integrating, over the stopping distance, a curve defined by connecting the peaks of the instantaneous brake force curve. (See figure 4-8 below.) The energy absorbed by the brake during the actual wet runway stop is determined by integrating the curve of instantaneous brake force over the stopping distance.

Figure 4-8. Instantaneous Brake Force and Peak Brake Force



2. Using data obtained from the wet runway stopping tests of paragraph 4.3.7.6 of this AC, instantaneous brake force can be calculated from the following relationship:

$$F_b = \frac{(T_b + \propto I)}{R_{tire}}$$

Where:

$$F_b = brake\ force$$

$$T_b = brake\ torque$$

$$\propto = wheel\ acceleration$$

$$I = wheel\ and\ tire\ moment\ of\ inertia$$

$$R_{tire} = tire\ radius$$

3. For brake installations where measuring brake torque directly is impractical, torque may be determined from other parameters (e.g., brake pressure) if a suitable correlation is available. Wheel acceleration is obtained from the first derivative of wheel speed. Instrumentation recording rates and data analysis techniques for wheel speed and torque data should be well matched to the anti-skid response characteristics to avoid introducing noise and other artifacts of the instrumentation system into the data.
4. Since the derivative of wheel speed is used in calculating brake force, smoothing of the wheel speed data is usually necessary to give good results. The smoothing algorithm should be carefully designed as it can affect the resulting efficiency calculation. Filtering or smoothing of the brake torque or brake force data should not normally be done. If conditioning is applied, it should be done in a conservative manner (i.e., result in a lower efficiency value) and should not misrepresent actual airplane/system dynamics.
5. Both the instantaneous brake force and the peak brake force should be integrated over the stopping distance. The anti-skid efficiency value

for determining the wet runway accelerate-stop distance is the ratio of the instantaneous brake force integral to the peak brake force integral:

$$Anti\text{--}\ skid\ effiencency = \int \frac{instantaneous\ break\ force\ ds}{\int peak\ brake\ force\ ds}$$

Where:

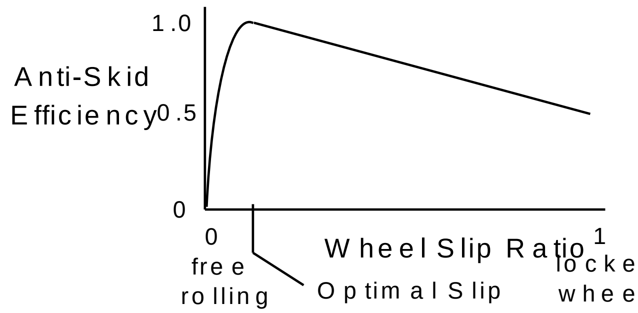
$$s\ =\ stopping\ distance$$

6. The stopping distance is defined as the distance traveled during the specific wet runway stopping demonstration, beginning when the full braking configuration is obtained and ending at the lowest speed at which anti-skid cycling occurs (i.e., the brakes are not torque-limited), except that this speed need not be less than 10 knots. Any variation in the anti-skid efficiency with speed should also be investigated, which can be accomplished by determining the efficiency over segments of the total stopping distance. If significant variations are noted, this variation should be reflected in the braking force used to determine the accelerate-stop distances (either by using a variable efficiency or by using a conservative single value).

4.3.7.6.11 Wheel Slip Method.

1. At brake application, the tire begins to slip with respect to the runway surface (i.e., the wheel speed slows down with respect to the airplane's ground speed). As the amount of tire slip increases, the brake force also increases until an optimal slip is reached. If the amount of slip continues to increase past the optimal slip, the braking force will decrease.
2. Using the wheel slip method, the anti-skid efficiency is determined by comparing the actual wheel slip measured during a wet runway stop to the optimal slip. Since the wheel slip varies significantly during the stop, sufficient wheel and ground speed data should be obtained to determine the variation of both the actual wheel slip and the optimal wheel slip over the length of the stop. A sampling rate of at least 16 samples per second for both wheel speed and ground speed has been found to yield acceptable fidelity.
3. For each wheel and ground speed data point, the instantaneous anti-skid efficiency value should be determined from the relationship shown in figure 4-9 below.

Figure 4-9. Anti-Skid Efficiency–Wheel Slip Relationship



$$\text{for} \quad \text{WSR} < \text{OPS} \quad \text{Efficiency} = 1.5\left(\frac{\text{WSR}}{\text{OPS}}\right) - 0.5\left(\frac{\text{WSR}}{\text{OPS}}\right)^3$$

$$\text{WSR} = \text{OPS} \quad \text{Efficiency} = 1.0$$

$$\text{WSR} > \text{OPS} \quad \text{Efficiency} = 0.5\left(1 + \frac{(1-\text{WSR})}{(1-\text{OPS})}\right)$$

$$\text{where} \quad \text{WSR} = \text{the wheel slip ratio} = 1 - \left(\frac{\text{Wheel speed}}{\text{Ground speed}}\right)$$

$$\text{and} \quad \text{OPS is the optimal slip ratio}$$

4. To determine the overall anti-skid efficiency value for use in calculating the wet runway accelerate-stop distance, the instantaneous anti-skid efficiencies should be integrated with respect to distance and divided by the total stopping distance:

$$Anti\text{--}\ skid\ efficiency = \int \frac{instantaneous\ break\ force\ ds}{s}$$

Where:

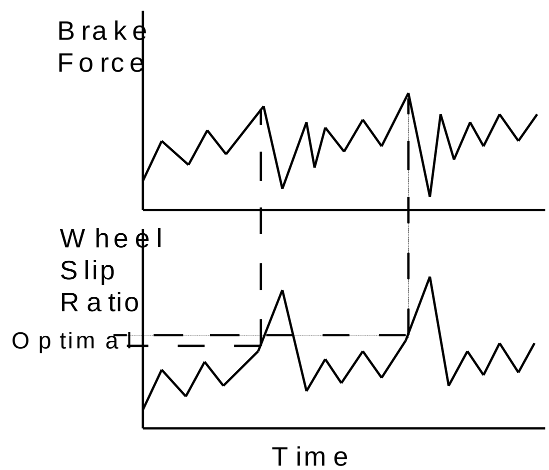
$$s = stopping\ distance$$

5. The stopping distance is defined as the distance traveled during the specific wet runway stopping demonstration, beginning when the full braking configuration is obtained and ending at the lowest speed at which anti-skid cycling occurs (i.e., the brakes are not torque-limited), except that this speed need not be less than 10 knots. Any variation in the anti-skid efficiency with speed should also be investigated, which can be accomplished by determining the efficiency over segments of the total stopping distance. If significant variations are noted, this variation should be reflected in the braking force used to determine the

accelerate-stop distances (either by using a variable efficiency or by using a conservative single value).

6. The applicant should provide substantiation of the optimal wheel slip value(s) used to determine the anti-skid efficiency value. An acceptable method for determining the optimal slip value(s) is to compare time history plots of the brake force and wheel slip data obtained during the wet runway stopping tests. For brake installations where measuring brake force directly is impractical, brake force may be determined from other parameters (e.g., brake pressure) if a suitable correlation is available. For those skids where wheel slip continues to increase after a reduction in the brake force, the optimal slip is the slip value corresponding to the brake force peak. See figure 4-10 below for an example and note how both the actual wheel slip and the optimal wheel slip can vary during the stop.

Figure 4-10. Substantiation of the Optimal Slip Value



4.3.7.7 For dispatch with an inoperative anti-skid system (if approved), the wet runway accelerate-stop distances should be based on an efficiency no higher than that allowed by § 25.109(c)(2) for an on-off type of anti-skid system. The safety of this type of operation should be demonstrated by flight tests conducted in accordance with paragraph 4.3.7.5 of this AC.

4.3.7.8 **Distribution of the Normal Load between Braked and Unbraked Wheels.**

In addition to taking into account the efficiency of the anti-skid system, § 25.109(b)(2)(ii) also requires adjusting the braking force for the effect of the distribution of the normal load between braked and unbraked wheels at the most adverse CG position approved for takeoff. The stopping force due to braking is equal to the braking coefficient multiplied by the normal load (i.e., weight) on each braked wheel. The portion of the airplane's weight being supported by the unbraked wheels (e.g., unbraked nose wheels) does not contribute to the stopping force generated by the brakes. In accordance with § 25.21(a), this effect must be taken into account for the most adverse CG position approved for takeoff, considering any redistribution in loads that occur due to the dynamics of the stop. The most adverse CG position is the position that results in the least load on the braked wheels.

4.3.7.9 **Grooved and Porous Friction Course (PFC) Runways.**

4.3.7.9.1 Properly designed, constructed, and maintained grooved and PFC runways can offer significant improvements in wet runway braking capability. A conservative level of performance credit is provided by § 25.109(d) to reflect this performance improvement and to provide an incentive for installing and maintaining such surfaces.

4.3.7.9.2 In accordance with §§ 25.105(c) and 25.109(d), applicants may optionally determine the accelerate-stop distance applicable to wet grooved and PFC runways. These data would be included in the AFM in addition to the smooth runway accelerate-stop distance data. The braking coefficient for determining the accelerate-stop distance on grooved and PFC runways is defined in § 25.109(d) as either 70 percent of the braking coefficient used to determine the dry runway accelerate-stop distances, or a curve based on ESDU 71026 data and derived in a manner consistent with that used for smooth runways. In either case, the brake torque limitations determined on a dry runway may not be exceeded.

4.3.7.9.3 Using a simple factor applied to the dry runway braking coefficient is acceptable for grooved and PFC runways because the braking coefficient's variation with speed is much lower on these types of runways. On smooth wet runways, the braking coefficient varies significantly with speed, which makes it inappropriate to apply a simple factor to the dry runway braking coefficient.

4.3.7.9.4 For applicants who choose to determine the grooved/PFC wet runway accelerate-stop distances in a manner consistent with that used for smooth runways, § 25.109(d)(2) provides the maximum tire-to-ground braking coefficient applicable to grooved and PFC runways. This maximum tire-to-ground braking coefficient must be adjusted for the anti-skid system efficiency, either by using the value specified in § 25.109(c)(2) appropriate to the type of anti-skid system installed, or by using a specific efficiency established by the applicant. As anti-skid system performance depends on the characteristics of the runway surface, a system that has been tuned for optimum performance on a smooth surface may not achieve the same level of efficiency on a grooved or porous friction course runway, and vice versa. Consequently, if the applicant elects to establish a specific efficiency for use with grooved or PFC surfaces, anti-skid efficiency testing should be conducted on a wet runway with such a surface, in addition to testing on a smooth runway. Means other than flight testing may be acceptable, such as using the efficiency previously determined for smooth wet runways, if that efficiency is shown to be representative of, or conservative for, grooved and PFC runways. Per § 25.109(b)(2)(ii), the resulting braking force for grooved/PFC wet runways must be adjusted for the effect of the distribution of the normal load between braked and unbraked wheels. This adjustment will be similar to that used for determining the braking force for smooth wet runways, except that the braking dynamics should be appropriate to the braking force achieved on grooved and PFC wet runways. Due to the increased braking force on grooved and PFC wet runways, an increased download on the nose wheel and corresponding reduction in the download on the main gear is expected.

4.3.7.9.5 In accordance with §§ 25.1533(a)(3) and 25.1583(h), grooved and PFC wet runway accelerate-stop distances may be established as operating limitations and be presented in the AFM, but approval to use these distances is limited to runways that have been designed, constructed, and maintained in a manner acceptable to the FAA Administrator. Airplane operators who wish to use the grooved or PFC runway accelerate-stop distances will need to determine that the design, construction, and maintenance aspects are acceptable for each runway for which such credit is sought. AC 150/5320-12C provides guidance relative to acceptable design, construction, and maintenance practices for grooved and PFC runway surfaces.

4.3.7.10 **Reverse Thrust Performance Credit.**

In accordance with § 25.109(f), reverse thrust may not be used to determine the accelerate-stop distances for a dry runway. For wet runway accelerate-stop distances, however, § 25.109(f) allows credit for the stopping force provided by reverse thrust, if the requirements of § 25.109(e) are met. In addition, the procedures associated with the use of reverse thrust, which § 25.101(f) requires the applicant to provide, must meet the requirements of § 25.101(h). The following criteria provide acceptable means of demonstrating compliance with these requirements:

4.3.7.10.1 Procedures for using reverse thrust during a rejected takeoff should be developed and demonstrated. These procedures should include all of the pilot actions necessary to obtain the recommended level of reverse thrust, maintain directional control and safe engine operating characteristics, and return the reverser(s), as applicable, to either the idle or the stowed position. These procedures need not be the same as those recommended for use during a landing stop, but should not result in additional hazards (e.g., cause a flameout or any adverse engine operating characteristics), nor should they significantly increase flightcrew workload or training needs.

4.3.7.10.2 It should be demonstrated that using reverse thrust during a rejected takeoff complies with the engine operating characteristics requirements of § 25.939. The reverse thrust procedures may specify a speed at which the reverse thrust is to be reduced to idle in order to maintain safe engine operating characteristics.

4.3.7.10.3 The time sequence for the actions necessary to obtain the recommended level of reverse thrust should be demonstrated by flight test. The time sequence used to determine the accelerate-stop distances should reflect the most critical case relative to the time needed to deploy the thrust reversers. For example, on some airplanes the outboard thrust reversers are locked out if an outboard engine fails. This safety feature prevents the pilot from applying asymmetric reverse thrust on the outboard engines, but it may also delay the pilot's selection of reverse thrust on the operable reversers. In addition, if the selection of reverse thrust is the fourth or subsequent pilot action to stop the airplane (e.g., after manual brake application, thrust/power reduction, and spoiler deployment), a one-second delay should be added to the demonstrated time to select reverse thrust. (See figure 4-1 of this AC.)

4.3.7.10.4 The response times of the affected airplane systems to pilot inputs should be taken into account. For example, delays in system operation, such as thrust reverser interlocks that prevent the pilot from applying reverse thrust until the reverser is deployed, should be taken into account. The effects of transient response characteristics, such as reverse thrust engine spin-up, should also be included.

4.3.7.10.5 To enable a pilot of average skill to consistently obtain the recommended level of reverse thrust under typical in-service conditions, a lever position that incorporates tactile feedback (e.g., a detent or stop) should be provided. If tactile feedback is not provided, a conservative level of reverse thrust should be assumed.

4.3.7.10.6 The applicant should demonstrate that exceptional skill is not required to maintain directional control on a wet runway with a ten-knot crosswind from the most adverse direction. For demonstration purposes, a wet runway may be simulated by using a nose wheel free to caster on a dry runway. Symmetric braking should be used during the demonstration, and both all-engines-operating and critical-engine-inoperative reverse thrust should be considered. The brakes and thrust reversers may not be modulated to maintain directional control. The reverse thrust procedures may specify a speed at which the reverse thrust is reduced to idle in order to maintain directional controllability.

4.3.7.10.7 Compliance with the requirements of §§ 25.901(b)(2), 25.901(c), 25.1309(b), and 25.1309(c) will be accepted as providing compliance with the "safe and reliable" requirements of §§ 25.101(h)(2) and 25.109(e)(1).

4.3.7.10.8 The number of thrust reversers used to determine the wet runway accelerate-stop distance data provided in the AFM should reflect the number of engines assumed to be operating during the rejected takeoff, along with any applicable system design features. The all-engines-operating accelerate-stop distances should be based on all thrust reversers operating. The one-engine-inoperative accelerate-stop distances should be based on failure of the critical engine. For example, if the outboard thrust reversers are locked out when an outboard engine fails, the one-engine-inoperative accelerate stop distances can only include reverse thrust from the inboard engine thrust reversers.

4.3.7.10.9 For the engine failure case, it should be assumed that the thrust reverser does not deploy (i.e., no reverse thrust or drag credit for deployed thrust reverser buckets on the failed engine).

4.3.7.10.10 For approval of dispatch with one or more inoperative thrust reverser(s), the associated performance information should be provided either in the AFM or the master minimum equipment list (MMEL).

4.3.7.10.11 The effective stopping force provided by reverse thrust in each, or at the option of the applicant, the most critical takeoff configuration, should be demonstrated by flight test. (One method of determining the reverse thrust stopping force would be to compare unbraked runs with and without the use of thrust reversers.) Regardless of the method used to demonstrate the effective stopping force provided by reverse thrust, flight test demonstrations should be conducted using all of the stopping means on which the AFM wet runway accelerate-stop distances are based in order to substantiate the accelerate-stop distances and ensure that no adverse combination effects are overlooked. These demonstrations may be conducted on a dry runway.

4.3.7.10.12 For turbopropeller powered airplanes, the criteria of paragraphs 4.3.7.10.1 through 4.3.7.10.11 above remain generally applicable. Additionally, the propeller of the inoperative engine should be in the position it would normally assume when an engine fails and the power lever is closed. Reverse thrust may be selected on the remaining engine(s). Unless this selection is achieved by a single action to retard the power lever(s) from the takeoff setting without encountering a stop or lockout, it should be regarded as an additional pilot action for the purposes of assessing delay times. If this action is the fourth or subsequent pilot action to stop the airplane, a one-second delay should be added to the demonstrated time to select reverse thrust.

4.4 Takeoff Path—§ 25.111.

4.4.1 Section 25.111(a).

4.4.1.1 Explanation.

The takeoff path requirements of § 25.111, and the reductions to that path required by § 25.115, are established so that performance data can be provided in the AFM for use in assessing vertical clearance of obstacles under the takeoff flight path.

4.4.1.2 Procedures.

The height references in § 25.111 should be interpreted as geometric heights. Section 25.111(a) requires the actual takeoff path (from which the net takeoff flight path is derived) to extend to the higher of where the airplane is 1,500 feet above the takeoff surface or to the altitude at which the transition to en route configuration is complete and the final takeoff speed (V_{FTO}) is reached.

4.4.2 Section 25.111(a)(1)—Takeoff Path Power/Thrust Conditions.

4.4.2.1 Explanation.

In accordance with § 25.111(d), the takeoff path must be established either from continuous demonstrated takeoffs or by synthesis from segments. If determined from segments, it must be shown by continuous demonstrated takeoff to be conservative, in accordance with § 25.111(d)(4).

4.4.2.2 Procedures.

4.4.2.2.1 To be assured that the predicted takeoff path is representative of actual performance, construct the path using the power or thrust required by § 25.101(c). This requires, in part, that the power or thrust be based on the particular ambient atmospheric conditions that are assumed to exist along the path. The standard lapse rate for ambient temperature as specified in the 1962 U.S. Standard Atmosphere part 1 should be used for power or thrust determination associated with each pressure altitude during the climb.

4.4.2.2.2 In accordance with § 25.111(c)(4), the power or thrust up to 400 feet above the takeoff surface must represent the power or thrust available along the path resulting from the power lever setting established during the initial ground roll in accordance with AFM procedures. This resulting power or thrust may be less than that available from the rated inflight setting schedule.

4.4.2.2.3 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 or thrust lapse for a fixed power or thrust lever setting. An analysis may be used to account for various engine bleeds (e.g., ice protection, air conditioning, etc.) and for electrical, pneumatic, and mechanical power extraction. In some airplanes, the power or thrust growth characteristics are such that less than full rated power or thrust is used for AFM takeoff power/thrust limitations and performance. This is to preclude engine limitations from being exceeded during the takeoff climbs to 400 feet above the takeoff surface.

4.4.2.2.4 Engine power or thrust lapse with speed and altitude during the takeoff and climb, at fixed power or thrust lever settings), can be affected by takeoff pressure altitude.

4.4.2.2.5 Most turbine engines are sensitive to crosswind or tailwind conditions, when setting takeoff power under static conditions, and may stall or surge. To preclude this problem, it is acceptable to establish a rolling takeoff power or thrust setting procedure, provided the AFM takeoff field length and the takeoff power or thrust setting charts are based on this procedure. Demonstrations and analyses have been accepted in the past showing a negligible difference in distance between static and rolling takeoffs. A typical test procedure is as follows:

1. After stopping on the runway, set an intermediate power or thrust on all engines (power setting selected by applicant).
2. Release brakes and advance power or thrust levers.
3. Set target power or thrust setting as rapidly as possible prior to reaching 60 to 80 knots.
4. No adverse engine operating characteristics should exist after completion of the power setting through the climb to 1,500 feet above the airport and attainment of the en route configuration. Tests should be conducted to determine if any engine operating problems exist for takeoffs conducted throughout the altitude range for which takeoff operations are to be scheduled in the AFM.

4.4.2.2.6 If the applicant wishes to use a different procedure, it should be evaluated and, if found acceptable, the procedure should be reflected in the AFM.

4.4.3 <u>Section 25.111(a)(2)—Engine Failure.</u>

4.4.3.1 **Explanation.**

4.4.3.1.1 Since the regulations cannot dictate what type of engine failures may actually occur, it could be assumed that the engine failure required by the regulation occurs catastrophically. Such a failure would cause the power or thrust to drop immediately, with the associated performance going from all-engines-operating to one-engine-inoperative at the point of engine failure.

4.4.3.1.2 This conservative rationale notwithstanding, there is a basis for assuming that the failed engine power or thrust will not decay immediately. Unlike reciprocating engines, the locking-up of a jet engine fan without causing the engine to separate from the airplane is highly unlikely. Separation of the engine or fan, or fan disintegration, would remove weight and/or the ram drag included in the engine inoperative performance, providing compensation for the immediate thrust loss.

4.4.3.1.3 With these considerations, it may be acceptable to use the transient power or thrust as the failed engine spools down at V_{EF}. The power or thrust time history used for data reduction and expansion should be substantiated by test results.

4.4.3.1.4 In the case of propeller-driven airplanes, consideration should also be given to the position of the failed engine's propeller during the engine failure. These airplanes typically incorporate an automatic system to drive the propeller to a low drag position when an engine fails. The loss of power in this case will be much more sudden than the turbojet engine spooldown described above.

4.4.3.2 **Procedures.**

4.4.3.2.1 For turbojet powered airplanes, if transient thrust credit is used during engine failure in determining the one-engine-inoperative AFM takeoff performance, sufficient tests should be conducted using actual fuel cuts to establish the thrust decay as contrasted to idle engine cuts. For derivative programs not involving a new or modified engine type (i.e., a modification that would affect thrust decay characteristics), fuel cuts are unnecessary if thrust decay characteristics have been adequately substantiated.

4.4.3.2.2 For propeller driven airplanes, the use of fuel cuts can be more important in order to ensure that the takeoff speeds and distances are obtained with the critical engine's propeller attaining the position it would during a sudden engine failure. The number of tests that should be conducted using fuel cuts, if any, depends on the correlation obtained with the idle cut data and substantiation that the data analysis methodology adequately models the effects of a sudden engine failure.

4.4.4 <u>Section 25.111(a)(3)—Airplane Acceleration.</u>

4.4.4.1 **Explanation.**

None.

4.4.4.2 **Procedures.**

None.

4.4.5 Section 25.111(b)—Airplane Rotation and Gear Retraction.

4.4.5.1 **Explanation.**

The rotation speed, V_R, is intended to be the speed at which the pilot initiates action to raise the nose wheel(s) off the ground during the acceleration to V_2. Consequently, the takeoff path, determined in accordance with § 25.111(a) and (b), should assume that pilot action to raise the nose wheel(s) off the ground will not be initiated until the speed V_R has been reached.

4.4.5.2 **Procedures.**

The time between liftoff and initiation of gear retraction during takeoff distance demonstrations should not be less than that necessary to establish an indicated positive rate of climb plus one second. For the purposes of flight manual expansion, the average demonstrated time delay between liftoff and initiation of gear retraction may be assumed; however, this value should not be less than 3 seconds.

4.4.6 Section 25.111(c)(1)—Takeoff Path Slope.

4.4.6.1 **Explanation.**

4.4.6.1.1 Establishing a horizontal segment as part of the takeoff flight path is considered to be acceptable, per § 25.115(c), for showing compliance with the positive slope required by § 25.111(c)(1).

4.4.6.1.2 The net takeoff flight path is the flight path used to determine compliance with the airplane obstacle clearance requirements of the applicable operating rules. Section 25.115(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 decreasing the level flight path by the amount required by § 25.115(b), § 25.115(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 § 25.115(b). By this method, the altitude reduction is exchanged for increased distance to accelerate in the level flight portion of the net takeoff path.

4.4.6.2 **Procedures.**

The level acceleration segment in the AFM net takeoff profile should begin at the horizontal distance along the takeoff flight path where the actual airplane height, without the gradient reductions of § 25.115(b), reaches the AFM specified acceleration height.

4.4.7 Section 25.111(c)(2)—Takeoff Path Speed.

4.4.7.1 **Explanation.**

4.4.7.1.1 It is intended that the airplane be flown at a constant indicated airspeed to at least 400 feet above the takeoff surface. This speed must meet the constraints on V_2 of § 25.107(b) and (c).

4.4.7.1.2 The specific wording of § 25.111(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.

4.4.7.2 **Procedures.**

4.4.7.2.1 For those airplanes that take advantage of reduced stall speeds at low pressure altitude, the scheduling of V_2 should not be factored against the stall speed obtained at the takeoff surface pressure altitude. Such a procedure would result in a reduced stall speed margin during the climb, which would be contrary to the intent of § 25.107(b).

4.4.7.2.2 For those airplanes mentioned in paragraph 4.4.7.1 above, the V_2 should be constrained, in addition to the requirements of § 25.107(b) and (c), by the stall speed 1,500 feet above the takeoff surface. Weight reduction along the takeoff path, due to fuel burn, may be considered in the calculation of the stall speed ratios, provided it is well established. However, many applicants have measured stall speeds at 10,000 to 15,000 feet, which provides a conservative stall margin at lower takeoff field pressure altitudes.

4.4.8 Section 25.111(c)(3)—Required Gradient.

4.4.8.1 **Explanation.**

None.

4.4.8.2 **Procedures.**

None.

4.4.9 Section 25.111(c)(4)—Configuration Changes.

4.4.9.1 **Explanation.**

4.4.9.1.1 The intent of this requirement is to permit only those crew actions that are conducted routinely to be used in establishing the one-engine-inoperative takeoff path. The power/thrust levers may only be adjusted early during the takeoff roll and then left fixed until at least 400 feet above the takeoff surface.

4.4.9.1.2 Simulation studies and accident investigations have shown that when high workload occurs in the cockpit, as with an engine failure during takeoff, the crew might not advance the power/thrust on the operative engines, even if the crew knows the operative engines have been set at reduced power/thrust and a power/thrust increase is needed for terrain avoidance. This same finding applies to manually feathering a propeller. The landing gear may be retracted, however, as this is accomplished routinely once a positive rate of climb is observed. Also, automatic propeller feathering is specifically allowed by the rule. Guidance related to performance credit for automatic propeller feathering is provided in paragraph 4.4.9.2 below.

4.4.9.1.3 Although performance credit for pilot action to increase power/thrust below 400 feet above the takeoff surface is not permitted, performance credit is allowed for an automatic power advance. ATTCS are addressed in § 25.904, and the related performance requirements are described in appendix I to part 25.

4.4.9.2 **Procedures.**

4.4.9.2.1 Propeller pitch setting generally has a significant effect on minimum control speeds and airplane drag. The magnitude of these effects is such that continued safe flight may not be possible should a combined failure of an engine and its automatic propeller feathering system occur at a takeoff speed based on operation of that system. When this is the case, § 25.1309(b)(1) requires the probability of this combined failure to be extremely improbable (on the order of 10^{-9} per flight hour).

4.4.9.2.2 In determining the combined engine and automatic propeller drag reduction system failure rate of paragraph 4.4.9.2.1 above, the engine failure rate should be substantiated. Notwithstanding the in-service engine failure rate, the failure of the automatic propeller drag reduction system should be shown not to exceed 10^{-4} per flight hour.

4.4.9.2.3 The automatic propeller feathering system should be designed so that it will automatically be disabled on the operating engine(s) following its activation on the failed engine. The probability of an unwanted operation of the automatic propeller drag reduction system on an operating engine, following its operation on the failed engine, should be shown to be extremely improbable (on the order of 10^{-9} per flight hour).

4.4.9.2.4 If performance credit is given for operation of the automatic propeller feathering system in determining the takeoff distances, the propeller of the failed engine must also be assumed to be in the reduced drag position in determining the accelerate-stop distances.

4.4.9.2.5 The limitations section of the AFM should require the flightcrew to perform a functional check of the automatic propeller feathering system.

The frequency with which flightcrew functional checks and ground maintenance checks must be performed should be considered in the evaluation of the system reliability.

4.4.9.2.6 Clear annunciations should be provided to the flightcrew to indicate the following when:

- The automatic propeller drag reduction system is “ARMED”; and
- A malfunction exists in the automatic propeller feathering system.

4.4.10 Section 25.111(d)—Takeoff Path Construction.

4.4.10.1 **Explanation.**

This regulation should not be construed to mean that the takeoff path must be constructed entirely from a continuous demonstration or entirely from segments. To take advantage of ground effect, typical AFM takeoff paths use a continuous takeoff path from V_{LOF} to the gear up point, covering the range of thrust-to-weight ratios. From that point free air performance, in accordance with § 25.111(d)(2), is added segmentally. This methodology may yield an AFM flight path that is steeper with the gear down than up.

4.4.10.2 **Procedures.**

The AFM should include the procedures necessary to achieve this performance.

4.4.11 Section 25.111(d)(1)—Takeoff Path Segment Definition.

4.4.11.1 **Explanation.**

None.

4.4.11.2 **Procedures.**

None.

4.4.12 Section 25.111(d)(2)—Takeoff Path Segment Conditions.

4.4.12.1 **Explanation.**

Section 25.111(d)(2) states: “The weight of the airplane, the configuration, and the power or thrust must be constant throughout each segment and must correspond to the most critical condition prevailing in the segment.” The intent is that, for simplified analysis, the performance is based on that value available at the most critical point in time during the segment, not that the individual variables (weight, approximate power or thrust setting, etc.) are each picked at their most critical value and then combined to produce the performance for the segment.

4.4.12.2 **Procedures.**

The performance during the takeoff path segments should be obtained using one of the following methods:

4.4.12.2.1 The critical level of performance as explained in paragraph 4.4.12.1 above;

4.4.12.2.2 The average performance during the segment; or

4.4.12.2.3 The actual performance variation during the segment.

4.4.13 Section 25.111(d)(3)—Segmented Takeoff Path Ground Effect.

4.4.13.1 **Explanation.**

This requirement does not intend the entire flight path to 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 or thrust 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. (Also, see the explanation of § 25.111(d) in paragraph 4.4.12.1 of this AC.)

4.4.13.2 **Procedures.**

None.

4.4.14 Section 25.111(d)(4)—Segmented Takeoff Path Check.

4.4.14.1 **Explanation.**

None.

4.4.14.2 **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 with all-engines-operating and one-engine-inoperative), the path should be checked by continuous demonstrated takeoffs. A sufficient number of these, employing the AFM established takeoff procedures and speeds and covering the range of thrust-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 thrusts and test speeds.

4.4.15 Section 25.111(e)—Flight Path with Standby Power Rocket Engines.

[Reserved]

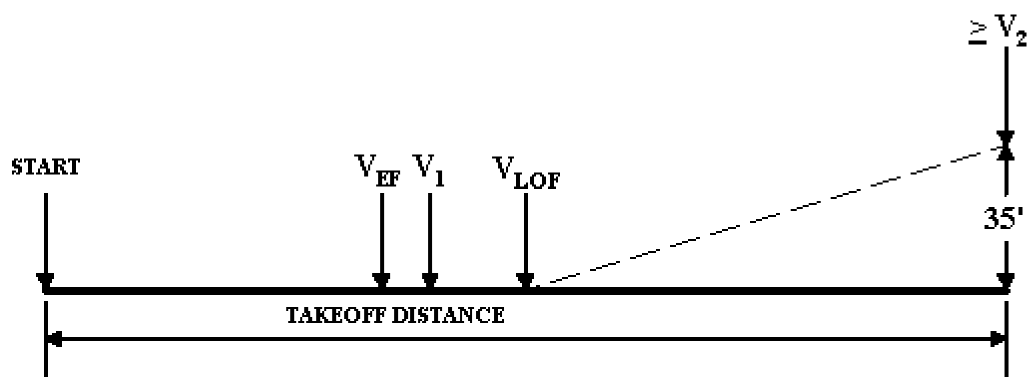
4.5 Takeoff Distance and Takeoff Run—§ 25.113.

4.5.1 Takeoff Distance on a Dry Runway—§ 25.113(a).

4.5.1.1 The takeoff distance on a dry runway is the longer of the two distances described in paragraphs 4.5.1.1.1 and 4.5.1.1.2 below. The distances indicated below are measured horizontally from the main landing gears at initial brake release to that same point on the airplane when the lowest part of the departing airplane is 35 feet above the surface of the runway.

4.5.1.1.1 The distance measured to 35 feet with a critical engine failure occurring at V_{EF} as shown in figure 4-11 below.

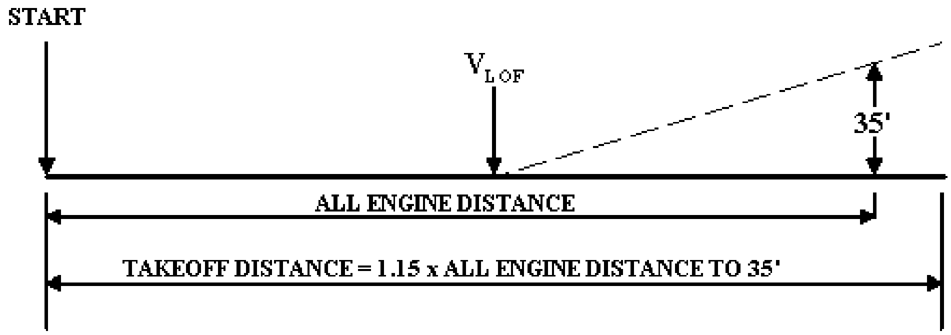
Figure 4-11. Takeoff Distance on a Dry Runway: Critical Engine Fails at V_{EF}



4.5.1.1.2 One hundred fifteen percent of the distance measured to the 35 feet height above the takeoff surface with all-engines-operating as shown in figure 4-12 below. In establishing the all-engines-operating takeoff distance, § 25.113(a)(2) requires the distance to be "...determined by a procedure consistent with § 25.111" (Takeoff Path). The interpretation of this statement is that the all-engines-operating takeoff distance should:

- Be based on the airplane reaching a speed of V2 before it is 35 feet above the takeoff surface; and
- Be consistent with the achievement of a smooth transition to the steady initial climb speed at a height of 400 feet above the takeoff surface.

Figure 4-12. Takeoff Distance: All-Engines-Operating



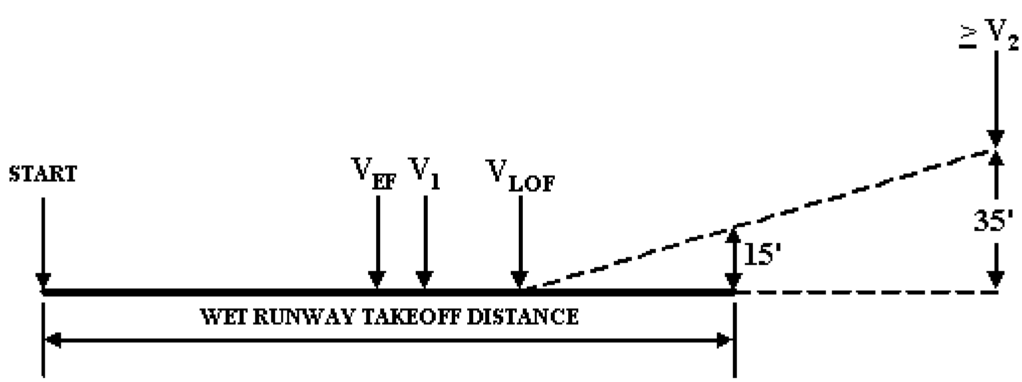
4.5.1.2 In accordance with § 25.101(f), the takeoff distance must be based on the procedures established for operation in service.

4.5.2 <u>Takeoff Distance on a Wet Runway—§ 25.113(b).</u>

4.5.2.1 The takeoff distance on a wet runway is the longer of the takeoff distance on a dry runway (using the dry runway V_1 speed), determined in accordance with paragraphs 4.5.1.1.1 and 4.5.1.1.2 of this AC, or the distance on a wet runway using a reduced height at the end of the takeoff distance (and the wet runway V_1 speed) as described in paragraph 4.5.2.2 below.

4.5.2.2 The takeoff distance on a wet runway is determined as the horizontal distance the main landing gear travels from brake release to the point where the lowest part of the airplane is 15 feet above the takeoff surface. The airplane must attain a height of 15 feet above the takeoff surface in a manner that will allow V_2 to be achieved before reaching a height of 35 feet above the takeoff surface in accordance with § 25.113(b)(2) and as shown in figure 4-13 below.

Figure 4-13. Takeoff Distance on a Wet Runway: Critical Engine Fails at V_{EF}

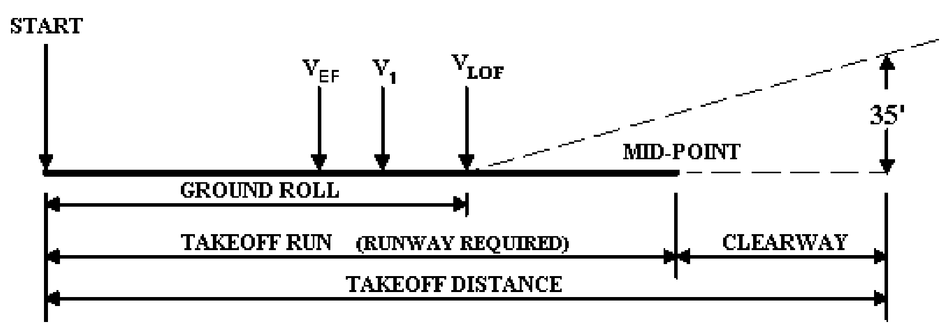


4.5.3 Takeoff Run—§ 25.113(c).

4.5.3.1 The concept of takeoff run was introduced by SR-422A to allow credit for a portion of the airborne part of the takeoff distance to be flown over a clearway. (See paragraph 4.5.3.3 of this AC for a definition of clearway.) The takeoff run is the portion of the takeoff distance that must take place on or over the runway in accordance with the applicable operating rules. If there is no clearway, the takeoff run is equal to the takeoff distance. If there is a clearway, the takeoff run is the longer described in paragraph 4.5.3.1.1 or 4.5.3.1.2 below. These distances are measured as described in paragraph 4.5.1.1 for § 25.113(a). When using a clearway to determine the takeoff run, no more than one half of the air distance from V_{LOF} to V_{35} may be flown over the clearway.

4.5.3.1.1 The takeoff runway is the distance from the start of the 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 occurring at V_{EF}, as shown in figure 4-14 below. For takeoff on a wet runway, the takeoff run is equal to the takeoff distance (i.e., there is no clearway credit allowed on a wet runway).

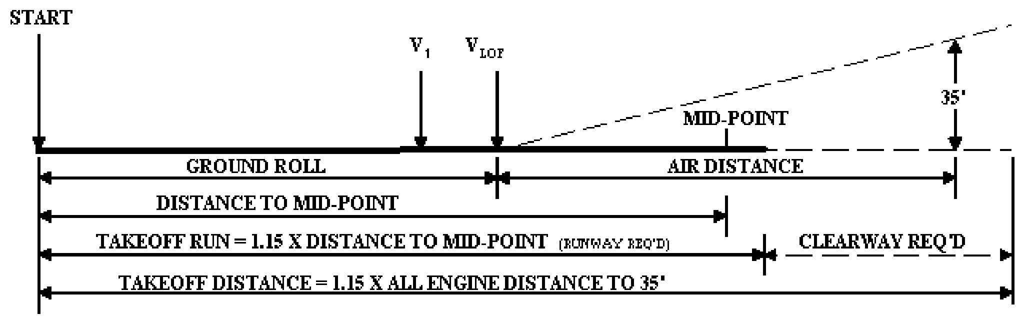
Figure 4-14. Takeoff Run: Critical Engine Fails at V_{EF}



4.5.3.1.2 One hundred fifteen percent of the distance from the start of the 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 all engines operating, as shown in figure 4-15 of this AC. In establishing the all-engines-operating takeoff run, § 25.113(c)(2) requires the distance to be "...determined by a procedure consistent with § 25.111" (Takeoff Path). The interpretation of that statement is that the all-engines-operating takeoff run should:

- Be based on the airplane reaching a speed of V2 before it is 35 feet above the takeoff surface; and
- Be consistent with the achievement of a smooth transition to the steady initial climb speed at a height of 400 feet above the takeoff surface.

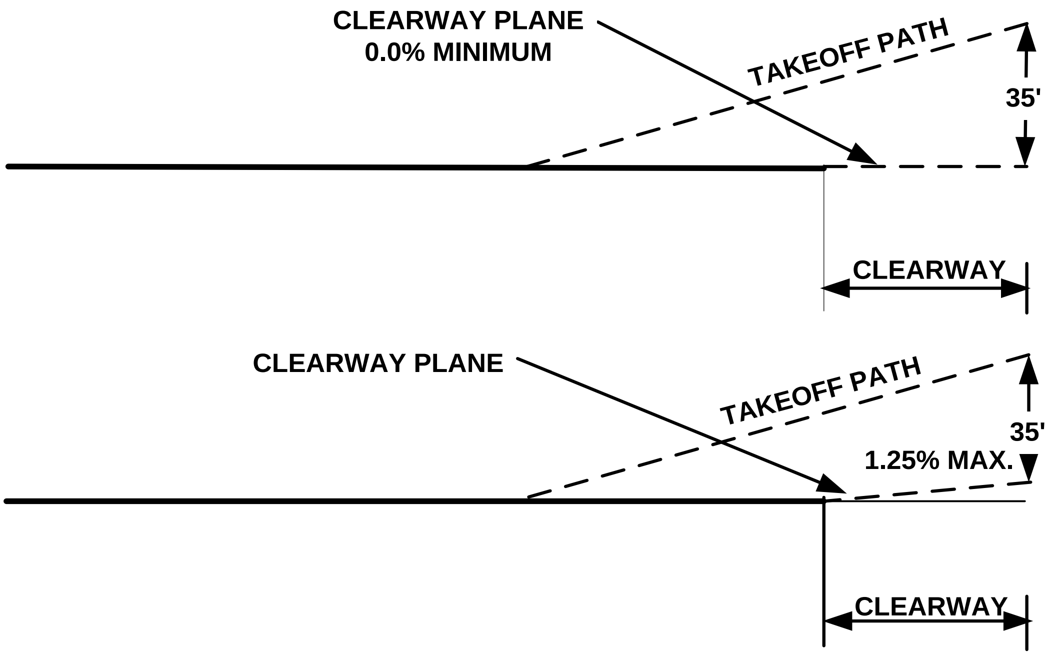
Figure 4-15. Takeoff Run: All-Engines-Operating



4.5.3.2 There may be situations where the takeoff run may be longer for the one-engine-inoperative condition (paragraph 4.5.3.1.1 of this AC) while the takeoff distance is longer for the all-engines-operating condition (paragraph 4.5.3.1.2 of this AC), or vice versa. Therefore, both conditions should always be considered.

4.5.3.3 Clearway is defined in 14 CFR part 1 as a plane extending from the end of the runway with an upward slope not exceeding 1.25 percent, above which no object nor any terrain protrudes. For the purpose of establishing takeoff distances and the length of takeoff runs, the clearway is considered to be part of the takeoff surface extending with the same slope as the runway, and the 35 feet height should be measured from that surface. (See figure 4-16 of this AC.)

Figure 4-16. Clearway Profiles



4.6 Takeoff Flight Path—§ 25.115.

4.6.1 Takeoff Flight Path—§ 25.115(a).

4.6.1.1 Explanation.

The takeoff flight path begins at the end of the takeoff distance and at a height of 35 feet above the takeoff surface. The takeoff flight path ends when the airplane's actual height is the higher of 1,500 feet above the takeoff surface or at an altitude at which the en route configuration and final takeoff speed have been achieved. (See paragraph 4.4 of this AC for additional discussion.) Section 25.115(a) states that the takeoff "shall be *considered* to begin 35 feet above the takeoff surface," recognizing that in the case of a wet runway the airplane's actual height will only be 15 feet. This wording allows the same takeoff flight path determined under § 25.115 for a dry runway takeoff to also be used for a wet runway takeoff. For takeoffs from wet runways, the actual airplane height will be 20 feet lower than the takeoff flight path determined under § 25.115 for takeoff from a dry runway. Therefore, the airplane will be 20 feet closer vertically to obstacles after taking off from a wet runway compared to taking off from a dry runway.

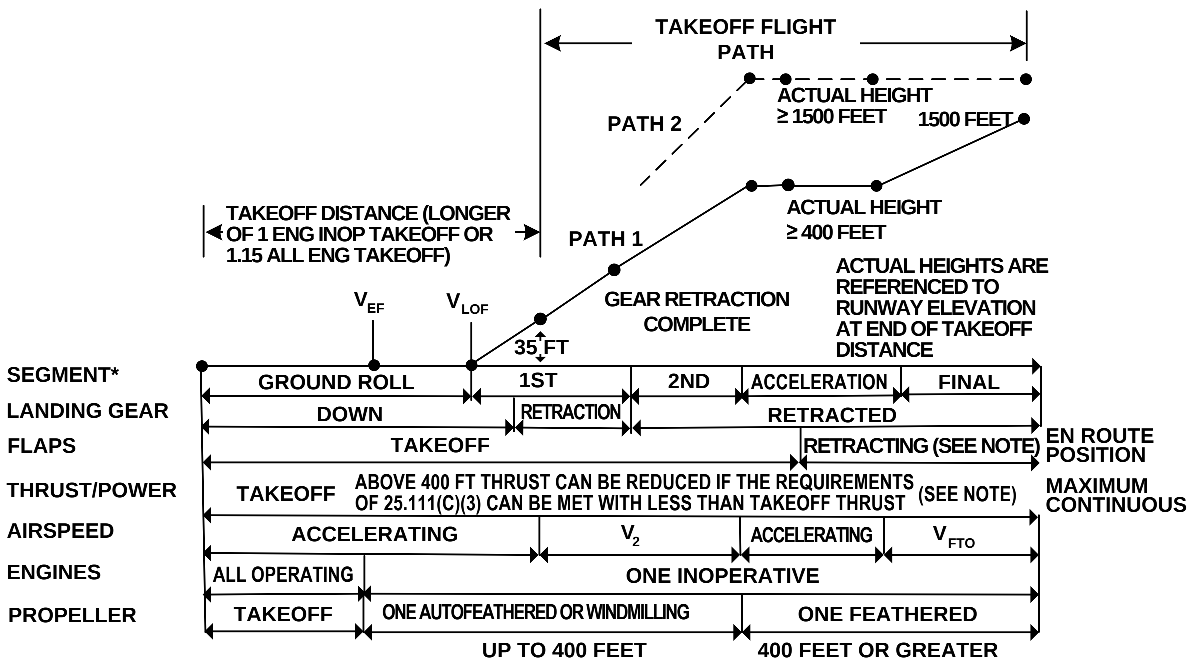
4.6.1.2 Procedures.

See figure 4-17 of this AC.

4.6.1.2.1 In figure 4-17, the final takeoff segment will usually begin with the airplane in the en route configuration and with maximum continuous power or thrust, but it is not required that these conditions exist until the end of the takeoff path when compliance with § 25.121(c) is shown. The time limit on takeoff power or thrust cannot be exceeded.

4.6.1.2.2 In figure 4-17, path 1 depicts a flight path based on a minimum 400-foot level-off for acceleration and flap retraction following the second segment climb portion of the flight path. Path 2 depicts the upper limit of the takeoff flight path following an extended second segment. Depending on obstacle clearance needs, the second segment may be extended to a height of more than 1500 feet above the takeoff surface.

Figure 4-17. Takeoff Segments and Nomenclature



4.6.2 <u>Net Takeoff Flight Path—§ 25.115(b) and (c).</u>

4.6.2.1 **Explanation.**

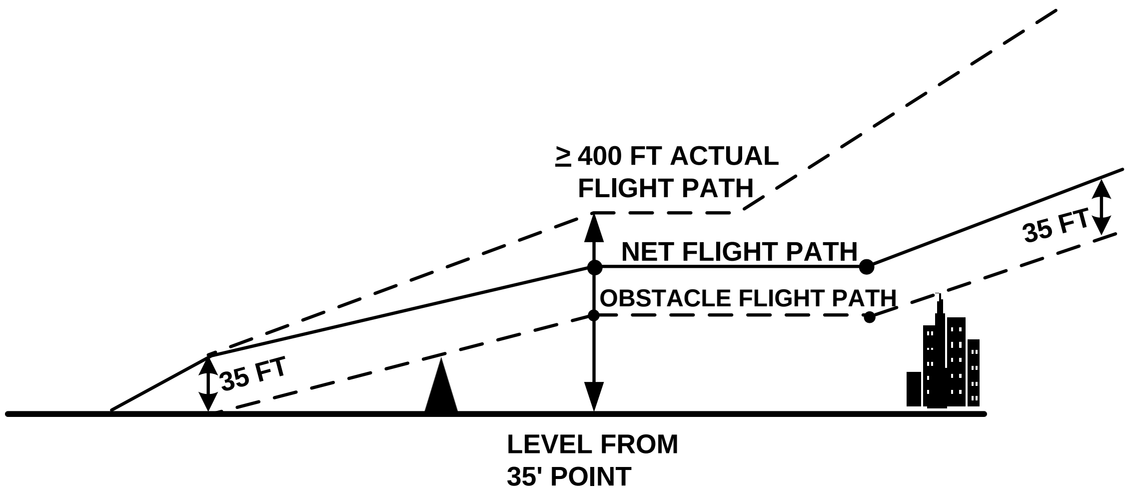
4.6.2.1.1 The net takeoff flight path is the actual flight path diminished by a gradient of 0.8 percent for two-engine airplanes, 0.9 percent for three-engine airplanes, and 1.0 percent for four-engine airplanes.

4.6.2.1.2 For the level flight acceleration segment, these prescribed gradient reductions may be applied as an equivalent reduction in acceleration in lieu of reduction in net flight path. (See paragraph 4.4.6 of this AC for additional discussion.)

4.6.2.2 **Procedures.**

See figure 4-18 below.

Figure 4-18. Net Takeoff Flight Path



4.7 Climb: General—§ 25.117.

4.7.1 Explanation.

This section states the climb requirements of §§ 25.119 and 25.121 must be complied with at each weight, altitude, and ambient temperature within the operational limits established for the airplane and with the most unfavorable CG for each configuration. The effects of changes in the airplane's true airspeed during a climb at the recommended constant indicated (or calibrated) climb speed should be taken into account when showing compliance with these climb requirements.

4.7.2 Procedures.

None.

4.8 Landing Climb: All-Engines-Operating—§ 25.119.

4.8.1 Explanation.

Section 25.119(a) states that the engines are to be set at the power or thrust that is available 8 seconds after starting to move the power or thrust controls from the minimum flight idle position to the go-around power or thrust setting. Use the procedures given below for the determination of this maximum power or thrust for showing compliance with the climb requirements of § 25.119.

4.8.2 Procedures.

4.8.2.1 The engines should be trimmed to the low side of the idle trim band, if applicable, as defined in the airplane maintenance manual. The effect of any variation in the idle fuel flow schedule for engines with electronic fuel controllers is typically negligible (but any such claim should be adequately substantiated).

4.8.2.2 At the most adverse test altitude, not to exceed the maximum field elevation for which certification is sought plus 1,500 feet, and with the most adverse bleed configuration expected in normal operations, stabilize the airplane in level flight with symmetrical power or thrust on all engines, landing gear down, flaps in the landing position, at a speed of V_{REF}. Retard the throttle(s) of the test engine(s) to flight idle and determine the time needed to reach a stabilized RPM, as defined below, for the test engine(s) while maintaining level flight or the minimum rate of descent obtainable with the power or thrust of the remaining engine(s) not greater than maximum continuous thrust (MCT). Engine flight idle RPM is considered to be stabilized when the initial rapid deceleration of all rotors is completed. This has usually been 8-20 seconds. This can be determined in the cockpit as the point where rapid movement of the tachometer ceases. For some airplanes it may be desirable to determine the deceleration time from plots of RPM versus time.

4.8.2.3 For the critical air bleed and power extraction configuration, stabilize the airplane in level flight with symmetric power or thrust on all engines, landing gear down, flaps in the landing position, at a speed of V_{REF}, simulating the estimated minimum climb-limited landing weights at an altitude sufficiently above the selected test altitude so that time to descend to the test altitude with the throttles closed equals the appropriate engine RPM stabilization time determined in paragraph 4.8.2.2 above. Retard the throttles to the flight idle position and descend at V_{REF} to approximately the test altitude. When the appropriate time has elapsed, rapidly advance the power or thrust controls to the go-around power or thrust setting. The power or thrust controls may first be advanced to the forward stop and then retarded to the go-around power or thrust setting. At the applicant’s option, additional less critical bleed configurations may be tested.

4.8.2.4 The power or thrust that is available 8 seconds after starting to move the power or thrust controls from the minimum flight idle position, in accordance with paragraph 4.8.2.3 above, is the maximum permitted for showing compliance with the landing climb requirements of § 25.119(a), and Section 4T.119(a) of SR-422B (see appendix D of this AC) for each of the bleed and power extraction combinations tested in accordance with paragraph 4.8.2.3 above. Unless AFM performance data are presented for each specific bleed and power extraction level, the AFM performance data should be based on the power or thrust obtained with the most critical power extraction level.

4.8.2.5 For airplanes equipped with autothrottles that will be used for approach and go-around, the effect of using the autothrottle to set go-around power or thrust should be determined. One way to do this would be to complete the test procedure given in paragraph 4.8.2.3, except that the airplane should be stabilized on -3° approach path, nominal power extraction, at the weight that gives the lowest power or thrust for that condition. The autothrottle should then be used to increase the power or thrust to the go-around power or thrust setting. The power or thrust used to show compliance with § 25.119(a) should be the lesser of:

4.8.2.5.1 The power or thrust that is available 8 seconds after selection of go-around power or thrust using the autothrottle; or

4.8.2.5.2 The power or thrust determined under paragraph 4.8.2.4 of this AC.

4.9 Climb: One-Engine-Inoperative—§ 25.121.

4.9.1 Explanation.

Section 25.121 contains one-engine-inoperative climb gradient capability requirements for the first, second, and final takeoff segments as well as for approach.

4.9.2 Procedures.

4.9.2.1 Two methods for establishing one-engine-inoperative climb performance follow:

4.9.2.1.1 Reciprocal heading climbs are conducted at several thrust-to-weight conditions from which the performance for the AFM is extracted. These climbs are flown with the wings nominally level. Control forces should be trimmed out as much as possible, except for the takeoff climbs with gear extended where the takeoff trim settings are to be retained to represent an operationally realistic drag level. Reciprocal climbs may not be necessary if inertial corrections (or another equivalent means) are applied to account for wind gradients.

4.9.2.1.2 Drag polars and one-engine-inoperative yaw drag data are obtained for expansion into AFM climb performance. These data are obtained with the wings nominally level. Reciprocal heading check climbs are conducted to verify the predicted climb performance. These check climbs may be flown with the wings maintained in a near level attitude. Reciprocal climbs may not be necessary if inertial corrections (or another equivalent means) are applied to account for wind gradients.

4.9.2.2 If full rudder with wings level cannot maintain constant heading, small bank angles of up to 2° to 3° into the operating engine(s), with full rudder, should be used to maintain constant heading. Unless the landing lights automatically retract with engine failure, testing should be conducted with the lights extended for § 25.121(a) Takeoff; landing gear extended, § 25.121(b) Takeoff; landing gear retracted, and § 25.121(d) Approach.

4.9.2.3 The climb performance tests with landing gear extended, in accordance with § 25.121(a), may be conducted with the landing gear and gear doors in a stable fully extended position. However, the critical configuration for the landing gear extended climb is considered to be that which presents the largest frontal area to the local airflow. This would normally be with no weight on the landing gear (full strut extension and trucks tilted) and all gear doors open. Since the takeoff path will be determined either from continuous takeoffs, or checked by continuous takeoffs if constructed by the segmental method (Refer to § 25.111(d)), any non-conservatism arising from the gear doors “closed” climb data will be evident and should be corrected for. Also, some measure of conservatism is added to the landing gear extended climb performance by the requirement of § 25.111(d)(3) for the takeoff path data to be based on the airplane’s performance without ground effect. While during an actual takeoff the airplane may accelerate from V_{LOF} towards V_2, the climb gradient for showing compliance with § 25.121(a) is based on the V_{LOF} speed as specified in the rule.

4.9.2.4 If means, such as variable intake doors, are provided to control powerplant cooling air supply during takeoff, climb, and en route flight, they should be set in a position that will maintain the temperature of major powerplant components, engine fluids, 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. (See § 25.1043.)

4.9.2.5 The latter parts of § 25.121(a)(1) and (b)(1), which state “...unless there is a more critical power operating condition existing later along the flight path...” are intended to cover those cases similar to where a wet engine depletes its water and reverts to dry engine operation. This is not intended to cover normal altitude power or thrust lapse rates above the point where retraction of the landing gear is begun.

4.9.2.6 Section 25.121(d) requires that the reference stall speed for the approach configuration not exceed 110 percent of the reference stall speed for the related landing configuration. This stall speed ratio requirement is to ensure that an adequate margin above the stall speed in the selected approach configuration is maintained during flap retraction in a go-around. An alternative means of providing an adequate operating speed margin during flap retraction in a go-around would be to increase V_{REF} for the landing configuration to provide an equivalent operating speed margin. That is, V_{REF} could be increased such that the reference stall speed for the approach configuration does not exceed 110 percent of $V_{REF}/1.23$. An equivalent level of safety finding should be used to document the use of this alternative versus direct compliance with § 25.121(d). To maintain equivalent safety, the increase in V_{REF} should not be excessive (for example, greater than 5 knots) to minimize the effect on safety of longer landing distances, higher brake energy demands, and reduced margins between V_{REF} and V_{FE}.

4.9.2.7 Section 25.121(d) permits the use of a climb speed established in connection with normal landing procedures, but not more than 1.4 V_{SR}. Section 25.101(g) requires that the procedures for the execution of missed approaches associated with the conditions prescribed in § 25.121(d) be established. Consequently, the speeds and flap configuration used to show compliance with the minimum climb gradient requirements of § 25.121(d) need to be consistent with the speeds and flap configurations specified for go-around in the AFM operating procedures. In order to demonstrate the acceptability of recommended procedures, the applicant should conduct go-around demonstrations to include a weight, altitude, temperature (WAT)-limited or simulated WAT-limited thrust condition. In accordance with § 25.101(h), the established procedures must:

- Be able to be consistently executed in service by crews of average skill,
- Use methods or devices that are safe and reliable, and
- Include allowance for any time delays in the execution of the procedures that may reasonably be expected in service.

4.9.2.8 FAA policy, as explained in policy PS-ANM100-1995-00058, *Go-Around Power/Thrust Settings on Transport Category Airplanes*, dated August 15, 1995, states that there should only be one power/thrust setting procedure used to show compliance with both §§ 25.119 and 25.121(d).

4.9.2.8.1 This policy is based on crew workload issues as discussed in the preamble for the ATTCS final rule (amendment 25-62):

4.9.2.8.2 That preamble states, ". . . current regulations preclude a higher thrust for approach climb (§ 25.121(d)) than for landing climb (§ 25.119). The workload required for the flightcrew to monitor and select from multiple inflight thrust settings in the event of an engine failure during a critical point in the approach, landing, or go-around operation is excessive."

4.9.2.8.3 If the approach climb power/thrust setting is higher than the landing climb power/thrust setting, a throttle push would be required to obtain the AFM performance in the event of an engine failure after an all-engines-operating go-around has been initiated. The FAA considers the need to manually reset the engine power/thrust setting in a high workload environment to be unacceptable.

4.9.2.8.4 Systems that automatically reset power/thrust to a higher value after an engine failure (for example, ATTCS used for go-arounds) have been found acceptable as long as there is a single go-around power/thrust setting procedure for the one-engine-inoperative (approach climb) and all-engines-operating (landing climb) conditions.

4.10 **En Route Flight Paths—§ 25.123.**

4.10.1 <u>Explanation.</u>

This guidance is intended for showing compliance with the requirements of § 25.123.

4.10.2 <u>Procedures.</u>

4.10.2.1 Sufficient en route climb performance data should be presented in the AFM to permit the determination of the net climb gradient and the net flight path in accordance with § 25.123(b) and (c) for all gross weights, altitudes, and ambient temperatures within the operating limits of the airplane. This en route climb performance data should be presented for altitudes up to the all-engines-operating ceiling to permit the calculation of drift-down data in the event of an en route engine failure.

4.10.2.2 <u>Fuel Consumption Accountability.</u>

The effect of the variation of the airplane's weight along the flight path due to the progressive consumption of fuel may be taken into account using fuel flow rates obtained from airplane manufacturers' test data. If measured fuel flow data is unavailable, a conservative fuel flow rate not greater than 80 percent of the engine specification flow rate at maximum continuous thrust (MCT) may be used.

4.10.2.3 The procedures and flight conditions upon which the en route flight path data are based should be provided to the flightcrew. Credit for fuel dumping, if available and included in the flightcrew procedures, may be used to achieve the performance capability presented in the AFM. A conservative analysis should be used in taking into account the ambient conditions of temperature and wind existing along the flight path. All performance should be based on the net flight path and with MCT on the operating engine(s).

4.11 Landing—§ 25.125.

4.11.1 Explanation.

4.11.1.1 The landing distance is the horizontal distance from the point at which the main gear of the airplane is 50 feet above the landing surface (treated as a horizontal plane through the touchdown point) to the position of the nose gear when the airplane is brought to a stop. (For water landings, a speed of approximately 3 knots is considered "stopped.") The beginning of the landing distance is referenced to the main gear because it is the lowest point of the airplane when the airplane is 50 feet above the landing surface. The end of the landing distance is referenced to the nose gear because it is the most forward part of the airplane in contact with the landing surface, and it should not extend beyond the certified landing distance. In this AC, the landing distance is divided into two parts: the airborne distance from 50 feet to touchdown, and the ground distance from touchdown to stop. The latter may be further subdivided into a transition phase and a full braking phase if the applicant prefers this method of analysis.

4.11.1.2 The minimum allowable value of V_{REF} is specified in § 25.125(a)(2)(i) and (ii). It is intended to provide an adequate margin above the stall speed to allow for likely speed variations during an approach in light turbulence and to provide adequate maneuvering capability. If the landing demonstrations show that a higher speed is needed for acceptable airplane handling characteristics, the landing distance data presented in the AFM must be based upon the higher reference landing speed per § 25.125(b)(2). Further, if procedures recommend the use of approach speeds that are higher than V_{REF} for reasons other than wind, flight tests should be conducted to determine whether the recommended V_{REF} speeds are readily achievable at the landing threshold. If V_{REF} is not readily achievable, then the AFM landing distances must include the effect of the excess speed at the landing threshold.

4.11.1.3 The engines should be set to the high side of the flight idle trim band, if applicable, for the landing flight tests. The effect of any variation in the idle fuel flow schedule for engines with electronic fuel controllers is typically negligible (but any such claim should be adequately substantiated).

4.11.2 Procedures for Determination of the Airborne Distance.

Three acceptable means of compliance are described in paragraphs 4.11.2.1, 4.11.2.2 and 4.11.2.3 on the following page.

Note: If it is determined that the constraints on approach angle and touchdown rate-of-sink described in paragraphs 4.11.2.2 and 4.11.2.3 below are not appropriate due to novel or unusual features of the airplane's design, new criteria may be established.

Such a change would be acceptable only if it is determined that an equivalent level of safety to existing performance standards and operational procedures is maintained.

4.11.2.1 Experience shows an upper bound to the part 25 zero-wind airborne distances achieved in past certifications and, similarly, a minimum speed loss.

4.11.2.1.1 These are approximated by the following:

$$Air\ Distance\ (feet) = 1.55(V_{REF} - 80)^{1.35} + 800\ where\ V_{REF}\ is\ in\ Knots\ TAS$$

$$Touchdown\ Speed = V_{REF} - 3\ Knots$$

4.11.2.1.2 An applicant may choose to use these relationships to establish landing distance in lieu of measuring airborne distance and speed loss. If an applicant chooses to use these relationships, the applicant should show by test or analysis that they do not result in air distances or touchdown speeds that are nonconservative.

4.11.2.2 If an applicant chooses to measure airborne distance or time, at least six tests covering the landing weight range are required for each airplane configuration for which certification is desired. These tests should meet the following criteria:

4.11.2.2.1 A stabilized approach, targeting a glideslope of -3° and an indicated airspeed of V_{REF}, should be maintained for a sufficient time prior to reaching a height of 50 feet above the landing surface to simulate a continuous approach at this speed. During this time, there should be no appreciable change in the power or thrust setting, pitch attitude, or rate of descent. The average glideslope of all landings used to show compliance should not be steeper than -3°.

4.11.2.2.2 Below 50 feet, there should be no nose depression by use of the longitudinal control and no change in configuration that requires action by the pilot, except for reduction in power or thrust.

4.11.2.2.3 The target rate of descent at touchdown should not exceed 6 feet per second. Although target values may not be precisely achieved, the average touchdown rate of descent should not exceed 6 feet per second.

4.11.2.3 If the applicant conducts enough tests to allow a parametric analysis (or equivalent method) that establishes, with sufficient confidence, the relationship between airborne distance (or time) as a function of the rates of descent at 50 feet and touchdown, the part 25 airborne distances may be based on an approach angle of -3.5°, and a touchdown sink rate of 8 feet per second. (See paragraph 4.11.8 for an example of this analysis method.) The parametric analysis method with these approach angle and touchdown sink rate values should only be used for landing distances for which the operational safety margins required by § 121.195(b) or (c), § 135.385(b), (c), or (f), or equivalent will be applied.

4.11.2.3.1 At a given weight, the air distance or air time established by this method should not be less than 90 percent of the lowest demonstrated value obtained using the target values for approach angle and touchdown sink rate specified in paragraph 4.11.2.3.2 below. Test data with approach angles steeper than -3.5°, or touchdown sink rates greater than 8 feet per second, should not be used to satisfy this requirement.

4.11.2.3.2 In order to determine the parametric relationships, it is recommended that test targets span approach angles from -2.5° to –3.5°, and sink rates at touchdown from 2 to 6 feet per second. Target speed for all tests should be V_{REF}.

4.11.2.3.3 Below 50 feet, there should be no nose depression by use of the longitudinal control and no change in configuration that requires action by the pilot, except for reduction in power or thrust.

4.11.2.3.4 If an acceptable method of analysis is developed by the applicant, a sufficient number of tests should be conducted in each aerodynamic configuration for which certification is desired to establish a satisfactory confidence level for the resulting air distance. Autolands may be included in the analysis but should not comprise more than half of the data points. If it is apparent that configuration is not a significant variable, all data may be included in a single parametric analysis.

4.11.2.3.5 If an applicant proposes any other method as being equivalent to a parametric analysis, that method should be based on a developed mathematical model that employs performance-related variables such as power or thrust, attitude, angle-of-attack, and load factor to adequately reproduce the flight test trajectory and airspeed variation from the 50-foot point to touchdown. Such a mathematical model should be validated by a sufficient number of tests to establish a satisfactory confidence level, and be justified by a comparison of tested and calculated landing airborne distances.

4.11.2.3.6 For a derivative airplane with an aerodynamic configuration that has been previously certificated, if new tests are necessary to substantiate performance to a weight higher than that permitted by the extrapolation limits of § 25.21(d), two landings per configuration should be conducted for each 5 percent increase in landing weight (but no more than a total of six landings should be needed). These may be merged with previous certification tests for parametric analysis, regardless of whether the previous certification was conducted by this method or not. If a new aerodynamic configuration is proposed, the guidance described in paragraph 4.11.2.3.4 above, should be used.

4.11.2.3.7 In calculating the AFM landing distances, the speed loss from 50 feet to touchdown, as a percentage of V_{REF}, may be determined using the conditions described in paragraph 4.11.2.3.

4.11.2.4 Whichever method is chosen to establish airborne distances, satisfactory flight characteristics should be demonstrated in the flare maneuver when a final approach speed of V_{REF}-5 knots is maintained down to 50 feet.

4.11.2.4.1 Below 50 feet, the application of longitudinal control to initiate flare should occur at the same altitude as for a normal "on-speed" landing; no nose depression should be made and power or thrust should not be increased to facilitate the flare.

4.11.2.4.2 All power/thrust levers should be in their minimum flight idle position prior to touchdown.

4.11.2.4.3 The normal flare technique should be used, resulting in a touchdown speed approximately 5 knots less than the touchdown speed used to establish the landing distance. The rate of descent at touchdown should not be greater than 6 feet per second.

4.11.2.4.4 This demonstration should be performed over a range of weights (typically at maximum landing weight and near minimum landing weight), or at the most critical weight and CG combination as established by analysis or other acceptable means.

4.11.2.4.5 These V_{REF}-5 knots landing demonstrations should not require the use of high control forces or full control deflections.

4.11.3 Procedures for Determination of the Transition and Stopping Distances.

4.11.3.1 The transition distance extends from the initial touchdown point to the point where all approved deceleration devices are operating. The stopping distance extends from the end of transition to the point where the airplane is stopped. The two phases may be combined at the applicant's option.

4.11.3.2 If sufficient data are not available, there should be a minimum of six landings in the primary landing configuration. Experience has shown that if sufficient data are available for the airplane model to account for variation of braking performance with weight, lift, drag, ground speed, torque limit, etc., at least two test runs are necessary for each configuration when correlation for multiple configurations is being shown.

4.11.3.3 A series of at least six measured landing tests covering the landing weight range should be conducted on the same set of wheels, tires, and brakes in order to substantiate that excessive wear of wheel brakes and tires is not produced in accordance with the provisions of § 25.125(c)(2). The landing tests should be conducted with the normal operating brake pressures for which the applicant desires approval. The brakes may be in any wear state as long as an acceptable means is used to determine the landing distances with fully worn brakes for presentation in the AFM. The main gear tire pressure should be set to not less than the maximum pressure desired for certification corresponding to the specific test weight. Longitudinal control and brake application procedures should be such that they can be consistently applied in a manner that permits the airplane to be de-rotated at a controlled rate to preclude an excessive nose gear touchdown rate and so that the requirements of § 25.125(b)(4) and (5) are met. Nose gear touchdown rates in the certification landing tests should not be greater than eight feet per second. Certification practice has not allowed manually applied brakes before all main gear wheels are firmly on the ground. An automatic braking system can be armed before touchdown.

4.11.3.4 Describe the airplane operating procedures appropriate for determination of landing distance in the performance section of the AFM.

4.11.3.5 Propeller pitch position used in determining the normal all-engines-operating landing stopping distance should be established using the criteria of § 25.125(g) for those airplanes that may derive some deceleration benefit from operating engines. Section 25.125(g) states that if the landing distance determined using a "device" that depends on the operation of any engine would be "noticeably increased" when a landing is made with that engine inoperative, the landing distance must be determined with that engine inoperative, unless a "compensating means" will result in one-engine-inoperative landing distances not greater than those with all engines operating. Acceptable interpretations of the terms "device," "noticeably increased," and "compensating means" are described below.

4.11.3.5.1 If, with the normal operational ground idle setting procedure, the propeller produces drag at any speed during the stopping phase of the normal all-engines-operating landing distance, the maximum drag from this "device" for which performance credit may be taken is that which results from a propeller pitch position that gives not more than a slight negative thrust at zero airspeed. A slight negative thrust is that which will not cause the airplane, at light weight and without brakes being applied, to roll on a level surface. If the normal operational ground idle setting produces greater negative thrust at zero airspeed, the all-engines-operating stopping distances should be determined using a special flight test power lever stop to limit the propeller blade angle.

4.11.3.5.2 Distances should be measured for landings made with the propeller feathered on one engine, and ground idle selected after touchdown on the operating engines. The airplane configuration for this test, including the ground idle power lever position, should be the same as that used for the all-engines-operating landing distance determination. Differential braking may be used to maintain directional control. This testing should be conducted at the critical weight/CG position and landing speed. The propeller/engine rigging should be at the most adverse allowable tolerance. If the resulting distance does not exceed the all-engines-operating landing distance by more than two percent (2 percent), it is not “noticeably increased” and no further testing is required to take performance credit for all-engines-operating ground idle drag in the certified landing distances.

4.11.3.5.3 If the distances determined in paragraph 4.11.3.5.2 above are more than two percent greater than the all-engines-operating landing distances, there should be a “compensating means” in order to take performance credit for the all-engines-operating ground idle drag. Reverse propeller thrust on the operating engines is considered a “compensating means” if the resulting landing distances, with one propeller feathered, are demonstrated to be not longer than those determined for all-engines-operating with the ground idle setting. The airplane configuration for this test should be the same as that used for the all-engines-operating landing distance determination, except that the propeller reverse thrust position is used. The nose wheel should be free to caster, as in V_{MCG} tests, to simulate wet runway surface conditions. Differential braking may be used to maintain directional control. Procedures for using propeller reverse thrust during the landing must be developed and demonstrated. The procedures associated with the use of propeller reverse thrust, required by § 25.101(f), must meet the requirements of § 25.101(h). The criteria outlined below may be applied to derive the levels of propeller reverse thrust consistent with recommended landing procedures and provide an acceptable means of demonstrating compliance with these requirements. This testing should be conducted at the critical weight/CG position and landing speed. The propeller/engine rigging should be at the most adverse allowable tolerance. If the “compensating means” do not allow performance credit for the all-engines-operating ground idle drag, a minimum of three weights that cover the expected range of operational landing weights and speeds should be tested.

4.11.3.5.4 In accordance with § 25.101(f), procedures for using propeller reverse thrust during landing must be developed and demonstrated. These procedures should include all of the pilot actions necessary to obtain the recommended level of propeller reverse thrust, maintain directional control, ensure safe engine operating characteristics and cancel propeller reverse thrust.

4.11.3.5.5 It should be demonstrated that using propeller reverse thrust during a landing complies with the engine operating characteristics requirements of § 25.939. The propeller reverse thrust procedures may specify a speed at which the propeller reverse thrust is cancelled in order to maintain safe engine operating characteristics.

4.11.3.5.6 The time sequence for the actions necessary to obtain the recommended level of propeller reverse thrust should be demonstrated by flight test. The time sequence used to determine the landing distances should reflect the most critical case relative to the time needed to obtain selected propeller reverse thrust.

4.11.3.5.7 The response times of the affected airplane systems to pilot inputs should be taken into account, for example, delays in system operation, such as interlocks and power lever detents that prevent the pilot from immediately selecting propeller reverse thrust. The effects of transient response characteristics, such as propeller reverse thrust engine spin-up, should also be included.

4.11.3.5.8 To enable a pilot of average skill to consistently obtain the recommended level of propeller reverse thrust under typical in-service conditions, a lever position that incorporates tactile feedback (e.g., a detent or stop) should be provided. If tactile feedback is not provided, a conservative level of propeller reverse thrust should be assumed.

4.11.3.5.9 The applicant should demonstrate that exceptional skill is not required to maintain directional control on a wet runway. The propeller reverse thrust procedures may specify a speed at which the propeller reverse thrust is cancelled in order to maintain directional controllability.

4.11.3.5.10 Compliance with the requirements of §§ 25.901(b)(2), 25.901(c), 25.1309(b), and 25.1309(c) will be accepted as providing compliance with the “safe and reliable” requirements of §§ 25.101(h)(2) and 25.125(c)(3).

4.11.4 Instrumentation and Data.

Instrumentation should include a means to record the airplane’s glide path relative to the ground, and the ground roll against time, in a manner that permits determining the horizontal and vertical distance time-histories. The appropriate data to permit analysis of these time-histories should also be recorded.

4.11.5 Landing on Unpaved Runways.

Guidance material for evaluation of landing on unpaved runways is contained in chapter 42 of this AC.

4.11.6 Automatic Braking Systems.

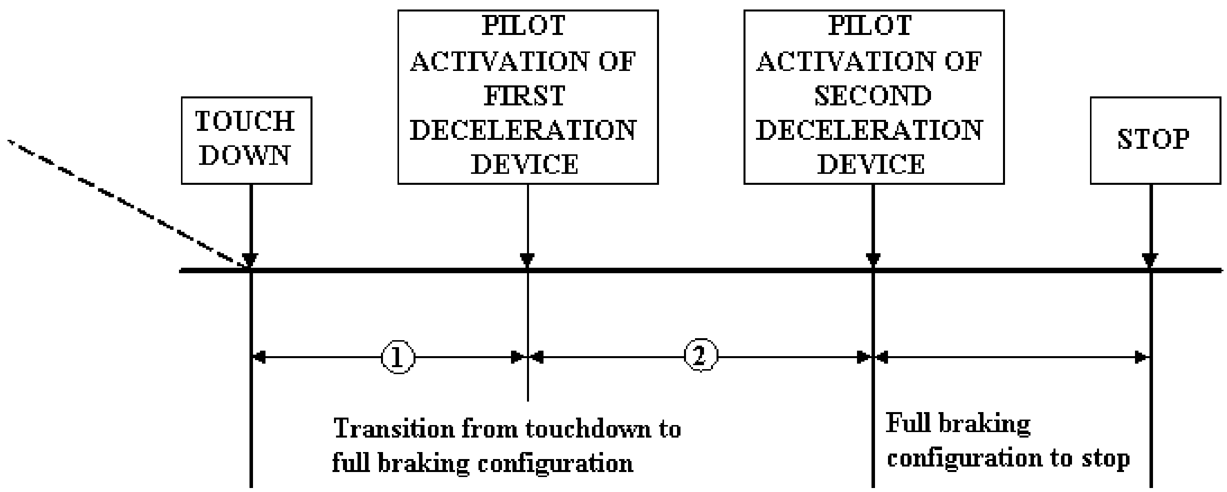
Guidance material relative to evaluation of auto-brake systems is provided in paragraph 15.4.9 of this AC.

4.11.7 AFM Landing Distances.

4.11.7.1 In accordance with § 25.101(i), AFM landing distances must be determined with all the airplane wheel brake assemblies at the fully worn limit of their allowable wear range. The brakes may be in any wear state during the flight tests used to determine the landing distances, as long as a suitable combination of airplane and dynamometer tests is used to determine the landing distances corresponding to fully worn brakes. Alternatively, the relationship between brake wear and stopping performance established during accelerate-stop testing may be used if it encompasses the brake wear conditions and energies achieved during the airplane flight tests used to establish the landing distances.

4.11.7.2 In deriving the scheduled distances, the time delays shown in figure 4-19 below should be assumed.

Figure 4-19. Landing Time Delays



4.11.7.2.1 Segment ① represents the flight test measured average time from touchdown to pilot activation of the first deceleration device. For AFM data expansion, use the longer of 1 second or the test time.

4.11.7.2.2 Segment ② represents the flight test measured average test time from pilot activation of the first deceleration device to pilot activation of the second deceleration device. For AFM data expansion, use the longer of 1 second or the test time.

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

4.11.7.3 For approved automatic deceleration devices (e.g., autobrakes or auto-spoilers, 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.

4.11.7.4 It has been considered acceptable to expand the airborne portion of the landing distance in terms of a fixed airborne time, independent of airplane weight or approach speed.

4.11.7.5 Assumptions to be made in assessing the effect of wind on landing distance are discussed in paragraph 3.1 of this AC.

4.11.8 Parametric Analysis Data Reduction.

The following is an acceptable method of converting the test data to a mathematical model for the parametric analysis method of air distance described in paragraph 4.11.2.3.

4.11.8.1 Test data for each test point:

$$R/S_{50} = Rate\ of\ sink\ at\ 50\ feet\ above\ landing\ surface\ (ft/sec)$$

$$R/S_{TD} = Rate\ of\ sink\ at\ touchdown\ (ft/sec)$$

$$V_{50} = True\ airspeed\ at\ 50\ feet\ above\ landing\ surface\ (ft/sec)$$

$$V_{TD} = True\ airspeed\ at\ touchdown\ (ft/sec)$$

$$t = Air\ time\ 50\ feet\ to\ touchdown\ (sec)$$

4.11.8.2 The multiple linear regression analysis as outlined below is used to solve for the constants in the following equation:

$$50/t = a + b(R/S_{50}) + c(R/S_{TD})$$

4.11.8.3 The form of the dependent variable being solved in the above equation is 50/t, rather than just t, in order to maintain the same units for all variables.

4.11.8.4 The test values of all the test points, 1 through n, are used to determine the constants a, b, and c in the above equation as follows, where n equals the number of test points and R1 through R13 are the regression coefficients:

$$R1 = \sum_{1}^{n} R/S_{50}$$

$$R2 = \sum_{1}^{n} (R/S_{50})^2$$

$$R3 = \sum_{1}^{n} R/S_{TD}$$

$$R4 = \sum_{1}^{n} (R/S_{TD})^2$$

$$R5 = \sum_{1}^{n} (R/S_{50})(R/S_{TD})$$

$$R6 = \sum_{1}^{n} (50/t)$$

$$R7 = \sum_{1}^{n} (R/S_{50})(50/t)$$

$$R8 = \sum_{1}^{n} (R/S_{STD})(50/t)$$

$$R9 = (n)(R2) - (R1)^2$$

$$R10 = (n)(R8) - (R3)(R6)$$

$$R11 = (n)(R5) - (R1)(R3)$$

$$R12 = (n)(R7) - (R1)(R6)$$

$$R13 = (n)(R4) - (R3)^2$$

$$a = [(R9)(R10) - (R11)(R12)]/[(R9)(R13) - (R11)^2]$$

$$b = [(R12) - (c)(R11)]/R9$$

$$c = [(R6) - (b)(R1) - (c)(R3)]/n$$

4.11.8.5 Using the same regression coefficient relationships, determine the values of the constants, a, b, and c, for the speed reduction between 50 feet and touchdown (V_{50}/V_{TD}) by using the value of (V_{50}/V_{TD}) for (50/t) for each test point.

4.11.8.6 After determining the values of the constants, use the above equation for (50/t) to calculate the time from 50 feet to touchdown for the target conditions of a -3.5° flight path angle and R/S_{TD} = 8 ft/sec. Use a value of (R/S_{50}) calculated from the approach path and V_{50}. Then, using the same equation, but substituting (V_{50}/V_{TD}) for (50/t) and using the constants determined for (V_{50}/V_{TD}), calculate (V_{50}/V_{TD}).

4.11.8.7 After V_{TD} is determined (from V_{50}/V_{TD} and V_{50}), the air distance may be determined for the average flare speed and air time.

Example

Test Data:

Run	R/S_{50}	R/S_{TD}	V_{50}	V_{TD}	t
1	13.4	6.1	219	214	5.6
2	10.9	1.8	223	218	8.5
3	7.9	5.8	209	201	7.4
4	8.3	2.3	213	206	9.6
5	9.8	4.1	218	212	7.5

Results:

$50/t = 1.0432 + 0.3647(R/S_{50}) + 0.4917(R/S_{TD})$

$V_{50}/V_{TD} = 1.05508 - 0.003198(R/S_{50}) + 0.001684(R/S_{TD})$

For conditions of V_{50} = 220 ft/sec; flight path = -3.5°; R/S_{TD} = 8.0 ft/sec; the results are:

R/S_{50} = 13.43 ft/sec

V_{50}/V_{TD} = 1.0256

t = 5.063 sec

Air distance = 1100 ft

CHAPTER 5. FLIGHT: CONTROLLABILITY AND MANEUVERABILITY

5.1 General—§ 25.143.

5.1.1 Explanation.

5.1.1.1 The purpose of § 25.143 is to verify that any operational maneuvers conducted within the operational envelope can be accomplished smoothly with average piloting skill and without encountering a stall warning or other characteristics that might interfere with normal maneuvering, or without exceeding any airplane structural limits. Control forces should not be so high that the pilot cannot safely maneuver the airplane. Also, the forces should not be so light that it would take exceptional skill to maneuver the airplane without over-stressing it or losing control. The airplane response to any control input should be predictable to the pilot.

5.1.1.2 The maximum forces given in the table in § 25.143(d) for pitch and roll control for short term application are applicable to maneuvers in which the control force is only needed for a short period. Where the maneuver is such that the pilot will need to use one hand to operate other controls (such as during the landing flare or a go-around, or during changes of configuration or power/thrust resulting in a change of control force that needs to be trimmed out) the single-handed maximum control forces will be applicable. In other cases (such as takeoff rotation, or maneuvering during en route flight), the two-handed maximum forces will apply.

5.1.1.3 Short-term and long-term forces should be interpreted as follows:

5.1.1.3.1 Short-term forces are the initial stabilized control forces that result from maintaining the intended flight path following configuration changes and normal transitions from one flight condition to another, or from regaining control following a failure. It is assumed that the pilot will take immediate action to reduce or eliminate such forces by re-trimming or changing configuration or flight conditions, and consequently short-term forces are not considered to exist for any significant duration. They do not include transient force peaks that may occur during the configuration change, change of flight conditions, or recovery of control following a failure.

5.1.1.3.2 Long-term forces are those control forces that result from normal or failure conditions that cannot readily be trimmed out or eliminated.

5.1.1.4 In conducting the controllability and maneuverability tests to show compliance with § 25.143 at speeds between V_{MO}/M_{MO} and V_{FC}/M_{FC}, the airplane should be trimmed at V_{MO}/M_{MO}.

5.1.1.5 Modern wing designs can exhibit a significant reduction in maximum lift capability with increasing Mach number. The magnitude of this Mach number effect depends on the design characteristics of the particular wing. For wing designs with a large Mach number effect, the maximum bank angle that can be achieved while retaining an acceptable stall margin can be significantly reduced. Because the effect of Mach number can be significant, and because it can also vary greatly for different wing designs, the multiplying factors applied to V_{SR} may be insufficient to ensure that adequate maneuvering capability exists at the minimum operating speeds. To address this issue, § 25.143(h) was added by amendment 25-108 to require a minimum bank angle capability in a coordinated turn without encountering stall warning or any other characteristic (including the envelope protection features of fly-by-wire flight control systems or automatic power or thrust increases) that might interfere with normal maneuvering. The maneuvering requirements consist of the minimum bank angle capability the FAA deems adequate for the specified regimes of flight combined with additional bank angle capability to provide a safety margin for various operational factors. These operational factors include both potential environmental conditions (e.g., turbulence, wind gusts) and an allowance for piloting imprecision (e.g., inadvertent overshoots). The FAA considers the automatic application of power or thrust by an envelope protection feature to be a feature that might interfere with normal maneuvering because it will result in a speed increase and flight path deviation, as well as potentially increasing crew workload due to the unexpected power or thrust increase.

5.1.2 General Test Requirements.

5.1.2.1 Compliance with § 25.143 (a) through (g) is primarily a qualitative determination by the pilot during the course of the flight test program. The control forces required and airplane response should be evaluated during changes from one flight condition to another and during maneuvering flight. The forces required should be appropriate to the flight condition being evaluated. For example, during an approach for landing, the forces should be light and the airplane responsive in order that adjustments in the flight path can be accomplished with a minimum of workload. In cruise flight, forces and airplane response should be such that inadvertent control input does not result in exceeding limits or in undesirable maneuvers. Longitudinal control forces should be evaluated during accelerated flight to ensure a positive stick force with increasing normal acceleration. Forces should be heavy enough at the limit load factor to prevent inadvertent excursions beyond the design limit. Sudden engine failures should be investigated during any flight condition or in any configuration considered critical, if not covered by another section of part 25. Control forces considered excessive should be measured to verify compliance with the maximum control force limits specified in § 25.143(d). Allowance should be made for delays in the initiation of recovery action appropriate to the situation.

5.1.2.2 Since § 25.143(h) involves a target speed, bank angle, and maximum value of thrust/power setting, not all flight test conditions to demonstrate compliance will necessarily result in a constant-altitude, thrust-limited turn. In cases with positive excess power or thrust, a climbing condition at the target bank and speed is acceptable. Alternately, if desired, the power or thrust may be reduced to less than the maximum allowed, so that compliance is shown with a completely stabilized, constant-altitude turn. With the airplane stabilized in a coordinated turn, holding power or thrust and speed, increase bank angle at constant airspeed until compliance is shown. For cases with negative excess power or thrust (e.g., the landing configuration case), a constant-altitude slow-down maneuver at the target bank angle has been shown to be a suitable technique. With the airplane descending at V_{REF} in wings-level flight on a 3° glide path, trim and throttle position are noted. The airplane is then accelerated to V_{REF} + 10 to 20 knots in level flight. The original trim and throttle conditions are reset as the airplane is rolled into a constant-altitude slow-down turn at the target bank angle. Throttles can be manipulated between idle and the marked position to vary slow-down rate as desired. Compliance is shown when the airplane decelerates through V_{REF} in the turn without encountering a stall warning or other characteristic that might interfere with normal maneuvering.

5.1.2.3 If stall warning is provided by an artificial stall warning system, the effect of production tolerances on the stall warning system should be considered when evaluating compliance with the maneuvering capability requirements of § 25.143(h). See paragraph 8.1.6.2.6 of this AC for more information.

5.1.3 <u>Controllability Following Engine Failure.</u>

Section 25.143(b)(1) requires the airplane to be controllable following the sudden failure of the critical engine. To show compliance with this requirement, the demonstrations described in paragraphs 5.1.3.1 and 5.1.3.2 below, should be made with engine failure (simulated by fuel cuts) occurring during straight, wings level flight. To allow for likely in-service delays in initiating recovery action, no action should be taken to recover control for two seconds following pilot recognition of engine failure. The recovery action should not necessitate movement of the engine, propeller, or trim controls, and should not result in excessive control forces. Additionally, the airplane will be considered to have reached an unacceptable attitude if the bank angle exceeds 45° during the recovery. These tests may be conducted using throttle slams to idle, with actual fuel cuts repeated only for those tests found to be critical.

5.1.3.1 At each takeoff flap setting at the initial all-engine climb speed (e.g., V_2 + 10 knots) with:

5.1.3.1.1 All engines operating at maximum takeoff power or thrust prior to failure of the critical engine;

5.1.3.1.2 All propeller controls (if applicable) in the takeoff position;

5.1.3.1.3 The landing gear retracted; and

5.1.3.1.4 The airplane trimmed at the prescribed initial flight condition.

5.1.3.2 With the wing flaps retracted at a speed of 1.23 V_{SR} with:

5.1.3.2.1 All engines operating at maximum continuous power or thrust prior to failure of the critical engine;

5.1.3.2.2 All propeller controls in the en route position;

5.1.3.2.3 The landing gear retracted; and

5.1.3.2.4 The airplane trimmed at the prescribed initial flight condition.

5.1.4 Pilot Induced Oscillations (PIO).

5.1.4.1 **Explanation.**

5.1.4.1.1 Section 25.143(a) and (b) require that the airplane be safely controllable and maneuverable without exceptional piloting skill and without danger of exceeding the airplane limiting load factor under any probable operating conditions. Service history events have indicated that modern transport category airplanes can be susceptible to airplane-pilot coupling under certain operating conditions and would not meet the intent of this requirement.

5.1.4.1.2 The classic PIO is considered to occur when an airplane's response is approximately 180° out of phase with the pilot's control input. However, PIO events with 180° phase relationships are not the only conditions in which the airplane may exhibit closed-loop (pilot-in-the-loop) characteristics that are unacceptable for operation within the normal, operational, or limit flight envelopes. Others include unpredictability of the airplane's response to the pilot's control input. This may be due to nonlinearities in the control system, actuator rate or position limiting not sensed by the pilot through the flight controls, or changing pitch response at high altitude as the airplane maneuvers into and out of Mach buffet. Artificial trim and feel systems which produce controllers with too small a displacement and light force gradients may also lead to severe over control. This is especially true in a dynamic environment of high altitude turbulence or upsets in which the autopilot disconnects. This places the airplane in the hands of the unsuspecting pilot in conditions of only a small g or airspeed margin to buffet onset and with very low aerodynamic damping. These characteristics, while not a classic 180° out of phase PIO per se, may be hazardous and should be considered under the more general description of airplane-pilot coupling tendencies.

5.1.4.1.3 Some of the PIO tendency characteristics described in paragraph 5.1.4.1.2 above are attributes of transport airplanes (e.g., low frequency short period, large response lags) that are recognized by part 25. Limits are placed on some of these individual attributes by part 25 (e.g., stick force per g, heavily damped short period) to assure satisfactory open-loop characteristics. However, service reports from recent years have indicated that certain operating envelope conditions, combined with triggering events, can result in airplane-pilot coupling incidents. Some of the conditions that have led to these PIOs include fuel management systems that permit extended operations with a CG at or near the aft limit, operating at weight/speed/altitude conditions that result in reduced margins to buffet onset combined with tracking tasks such as not exceeding speed limitations and severe buffet due to load factor following an upset, and control surface rate or position limiting.

5.1.4.1.4 This service experience has shown that compliance with only the quantitative, open-loop (pilot-out-of-the loop) requirements does not guarantee that the required levels of flying qualities are achieved. Therefore, in order to ensure that the airplane has achieved the flying qualities required by § 25.143(a) and (b), the airplane should be evaluated by test pilots conducting high-gain (wide-bandwidth), closed-loop tasks to determine that the potential of encountering adverse PIO tendencies is minimal.

5.1.4.1.5 For the most part, these tasks should be performed in actual flight. However, for conditions that are considered too dangerous to attempt in actual flight (i.e., certain flight conditions outside of the operational flight envelope, flight in severe atmospheric disturbances, flight with certain failure states, etc.), the closed loop evaluation tasks may be performed using a motion base high fidelity simulator if it can be validated for the flight conditions of interest.

5.1.4.2 **Special Considerations.**

5.1.4.2.1 The certification team should understand the flight control system and airplane design.

5.1.4.2.2 The applicant should explain why the design is not conducive to a PIO problem and how this is to be shown in both developmental and certification flight tests.

5.1.4.2.3 The applicant should explain what has been done during the development flight test experience and any design changes that were required for PIO problems.

5.1.4.2.4 The certification flight test program should be tailored to the specific airplane design and to evaluate the airplane in conditions that were found to be critical during its development program and PIO analytical assessment.

5.1.4.2.5 The FAA flight test pilots should also continuously evaluate the airplane for PIO tendencies during the certification program in both the airplane and simulator. This evaluation should include both normal and malfunction states; all certification flight test points; transitions between and recoveries from these flight test points; and normal, crosswind, and offset landing task evaluations.

5.1.4.2.6 Since the evaluation of flying qualities under § 25.143(a) and (b) is basically qualitative, especially evaluations of PIO susceptibility, the high-gain tasks discussed herein should be accomplished by at least three test pilots. Use of other pilots can provide additional insights into the airplane handling qualities, but for the purpose of demonstrating compliance with this requirement the evaluation pilots should be trained test pilots.

5.1.4.3 **Procedures: Flight Test.**

5.1.4.3.1 Evaluation of the actual task performance achieved, e.g., flight technical error, is not recommended as a measure of proof of compliance. Only the pilot's rating of the PIO characteristics is needed as described in paragraph 5.1.4.6. The tasks are used only to increase the pilot's gain, which is a prerequisite for exposing PIO tendencies. Although task performance is not used as proof of compliance, task performance should be recorded and analyzed to insure that all pilots seem to be attempting to achieve the same level of performance.

5.1.4.3.2 Tasks for a specific certification project should be based on operational situations, flight testing maneuvers, or service difficulties that have produced PIO events. Task requirements for a specific project will be dictated by the particular airplane and its specific areas of interest as determined by the tailored flight test program mentioned above. Some of these include high altitude upset maneuvers, encounters with turbulence at high altitude in which the autopilot disconnects, crosswind/crossed control landings with and without one engine inoperative, and offset landings to simulate the operational case in which the airplane breaks out of instrument meteorological conditions (IMC) offset from the glideslope and/or localizer beam and the pilot makes a rapid alignment correction. Tests should be conducted at or near the critical altitude/weight/CG combinations.

5.1.4.3.3 Tasks described here may be useful in any given evaluation and have proven to be operationally significant in the past. It is not intended that these are the only tasks that may be used or may be required depending on the scope and focus of the individual evaluation being conducted. Other tasks may be developed and used as appropriate. For example, some manufacturers have used formation tracking tasks successfully in the investigation of these tendencies. For all selected tasks, a build-up approach should be used and all end points should be approached with caution. Capture tasks and fine tracking tasks share many common characteristics but serve to highlight different aspects of any PIO problem areas that may exist. In some cases, depending on individual airplane characteristics, it may be prudent to look at capture tasks first and then proceed to fine tracking tasks or combined gross acquisition (capture) and fine tracking tasks as appropriate.

5.1.4.4 **Capture Tasks.**

5.1.4.4.1 Capture tasks are intended to evaluate handling qualities for gross acquisition as opposed to continuous tracking. A wide variety of captures can be done provided the necessary cues are available to the pilot. Pitch attitude, bank angle, heading, flight path angle, angle-of-attack, and g captures can be done to evaluate different aspects of the airplane response. These capture tasks can give the pilot a general impression of the handling qualities of the airplane, but because they do not involve closed-loop fine tracking, they do not expose all of the problems that may arise in fine tracking tasks. Capture tasks should not be used as the only evaluation tasks.

5.1.4.4.2 For pitch captures, the airplane is trimmed for a specified flight condition. The pilot aggressively captures 5° pitch attitude (or 10° if the airplane is already trimmed above 5°). The pilot then makes a series of aggressive pitch captures of 5° increments in both directions, and then continues this procedure with 10° increments in both directions. An airplane with more capability can continue the procedure with larger pitch excursions. If possible, the initial conditions for each maneuver should be such that the airplane will remain within ±1,000 feet and ±10 knots of the specified flight condition during the maneuver; however, large angle captures at high-speed conditions will inevitably produce larger speed and altitude changes. If the airplane should get too far from the specified condition during a task, it should be re-trimmed for the specified condition before starting the next maneuver.

5.1.4.4.3 The other kinds of captures are usually done in a similar manner, with some minor differences. G captures can be done from a constant-g turn or pull ups and pushovers using ±0.2 g and ±0.5 g. Heading captures can be used to evaluate the yaw controller alone (usually small heading changes of 5° or less).

5.1.4.4.4 Bank angle captures are also commonly done using bank-to-bank rolls. Starting from a 15° bank angle, the pilot aggressively rolls and captures the opposite 15° bank angle (total bank angle change of 30°). The pilot then rolls back and captures 15° bank in the original direction. This procedure should continue for a few cycles. The procedure is then repeated using 30° bank angles, and then repeated again using 45° bank angles. A variation of this is to capture wings-level from the initial bank condition.

5.1.4.4.5 Where suitable, combined conditions could be used as described in the task shown in paragraph 5.1.4.4.6 below, in which a target g and bank angle are tightly tracked until the target pitch attitude and heading are captured.

5.1.4.4.6 The following upset and/or collision avoidance maneuvers have been found to be effective in evaluating PIO susceptibility when the airplane is flying at high altitude under conditions of low g to buffet onset, typically 0.3 g. This emphasis on cruise susceptibility stems from operational experiences, but should not be interpreted as placing less emphasis on other flight phases.

1. Trim for level flight at long range cruise Mach number. Initiate a slight climb and slow the aircraft while leaving power/thrust set. Push the nose over and set up a descending turn with 30° to 40° of bank and approximately 10° nose below the horizon, or as appropriate, to accelerate to the initial trim speed. At the initial trim airspeed initiate a 1.5 g to 1.67 g (not to exceed deterrent buffet) pull up and establish a turn in the opposite direction to a heading which will intercept the initial course on which the airplane was trimmed. Establish a pitch attitude which will provide a stabilized climb back to the initial trim altitude. The pilot may use the throttles as desired during this maneuver and should pick a target g, bank angle, heading, and pitch attitude to be used prior to starting the maneuver. The target g and bank angle should be set and tightly tracked until the target pitch attitude and heading are obtained respectively. The stabilized steady heading climb should be tightly tracked for an adequate amount of time to allow the pilot to assess handling qualities, even through the initial trim altitude and course if required. The pilot should qualitatively evaluate the airplane during both the gross acquisition and fine tracking portions of this task while looking for any tendency towards PIO in accordance with the criteria in paragraph 5.1.4.6.
2. This maneuver should be repeated in the nose-down direction by accelerating to M_{MO} from the trim condition 10° nose down and then recover as above.
3. Trim for level flight as above. Initiate a 1.5 g to 1.67 g (not to exceed deterrent buffet) pull-up and approximately a 30° bank turn. Once the target g is set, transition the aircraft to approximately a 0.5 g pushover and reverse the turn to establish an intercept heading to the initial course. Using power or thrust as required, set up a stabilized steady

heading descent to intercept the initial course and altitude used for the trimmed condition. The pilot may continue the heading and descent through the initial conditions to allow more tracking time if needed. Attempt to precisely set and track bank angle, g, heading, and pitch attitude as appropriate. The pilot should qualitatively evaluate the airplane during both the gross acquisition and fine tracking portions of this task while looking for a PIO tendency in accordance with paragraph 5.1.4.6.

5.1.4.5 **Fine Tracking Tasks.**

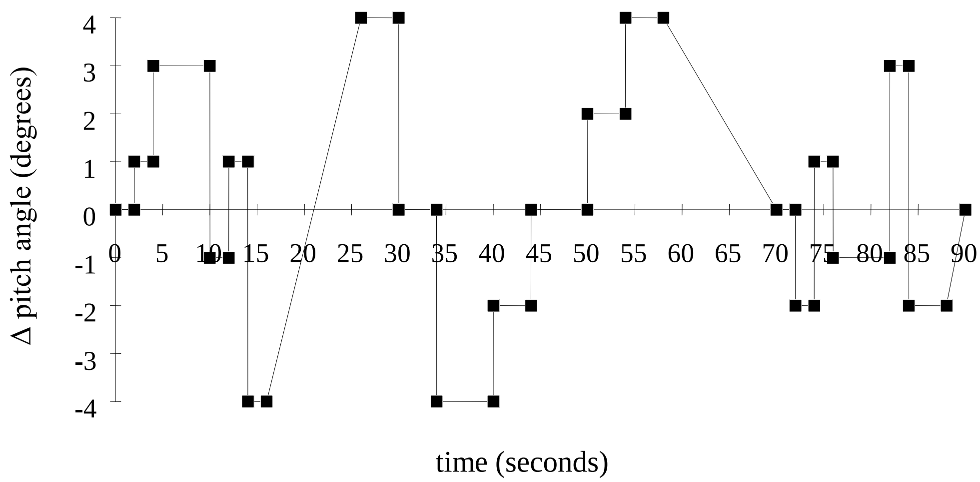
5.1.4.5.1 These tasks may be used to assess the airplane's PIO susceptibility when flying in turbulent atmospheric conditions. In this task, a tracking target is displayed which commands pitch and roll changes for the evaluation pilot to follow. Whatever visual cue is used (e.g., head up display (HUD), flight director, etc.), it should present the tracking task without filtering, smoothing, or bias. The pitch and roll commands should be combinations of steps and ramps. The sequence of pitch and roll commands should be designed so as to keep the airplane within ±1,000 feet of the test altitude and within ±10 knots of the test airspeed. The sequence should be long enough and complex enough that the pilot cannot learn to anticipate the commands. The unfamiliarity is intended to help keep the test pilot's gain high and to preclude inadvertent pilot compensation while accomplishing the task. Such compensation, along with reduced gains, could mask any PIO tendencies.

5.1.4.5.2 Even though these fine tracking tasks will provide insight into PIO susceptibility of a conventional airplane when flying in turbulence, other considerations apply to augmented airplane types. For example, structural load alleviation systems that use the same flight control surface as the pilot will limit the pilot's control authority in turbulent atmospheric conditions. Under these circumstances of rate or position limiting, PIO tendencies will be more critical as previously discussed. Therefore, specific evaluations for turbulent atmospheric conditions with these systems operating are necessary for these airplane types.

5.1.4.5.3 For single axis tasks, it has been found that aural commands given in a timed sequence provide an adequate cue in the event it is not possible to modify the flight director to display the pitch commands.

5.1.4.5.4 Based on PIO events seen in service, high altitude tracking tasks (with up to approximately ±4° pitch excursions from trim occurring at varying intervals of approximately 2 to 5 seconds) have been effective in evaluating PIO susceptibility. These tasks have been used where the airplane is flying under conditions of low g margin to buffet onset. The time history in figure 5-1 below is a pictorial representation of a sample task in MIL-STD-1797A that has the desired attributes for high altitude PIO evaluations.

Figure 5-1. Sample Pitch Tracking Task



5.1.4.6 **PIO Assessment Criteria.**

5.1.4.6.1 The evaluation of an airplane for PIO susceptibility will be conducted using the FAA handling qualities rating method (HQRM). (See appendix E of this AC for more information on the HQRM). Tasks should be designed to focus on any PIO tendencies that may exist. Table 5-1 below contains the descriptive material associated with PIO characteristics and its relationship to the PIO Rating Scale called out in the U.S. Military Standard.

Table 5-1. PIO Rating Criteria and Comparison to MIL Standard

FAA HQ Rating	PIO Characteristics Description	MIL-STD-1797A PIO Rating Scale
SAT	No tendency for pilot to induce undesirable motion.	1
	Undesirable motions (overshoots) *tend to occur* when pilot initiates abrupt maneuvers or attempts tight control. These motions can be prevented or eliminated by pilot technique. *(No more than minimal pilot compensation is required.)*	2
ADQ	Undesirable motions (unpredictability or over control) *easily induced* when pilot initiates abrupt maneuvers or attempts tight control. These motions can be prevented or eliminated but only at sacrifice to task performance or through considerable pilot attention and effort. *(No more than extensive pilot compensation is required.)*	3
CON	*Oscillations tend to develop* when pilot initiates abrupt maneuvers or attempts tight control. Adequate performance is not attainable and pilot has to reduce gain to recover. (Pilot can recover by merely reducing gain.)	4
UNSAT	*Divergent oscillations* tend to develop when pilot initiates *abrupt maneuvers* or attempts tight control. Pilot has to open control loop by releasing or freezing the controller.	5
	Disturbance or *normal pilot control* may cause divergent oscillation. Pilot has to open control loop by releasing or freezing the controller.	6

SAT = Satisfactory

ADQ = Adequate

CON = Controllable

UNSAT = Unsatisfactory or Failed

5.1.4.6.2 Table 5-1 above provides the FAA handling qualities (HQ) rating descriptions of airplane motions that may be seen during the conduct of specific PIO tasks or during tests throughout the entire certification flight test program. The italicized phrases highlight major differences between rating categories in the table.

5.1.4.6.3 The acceptable HQ ratings for PIO tendencies is shown in table E-2 of appendix E. As described in that appendix, the minimum HQ rating, and consequently the pass/fail criteria, varies with the flight envelope, atmospheric disturbance considered, and failure state. For example, table 5-2 below shows a handling qualities matrix for a tracking task with the airplane at aft CG trimmed in flight conditions giving 1.3 g to buffet onset.

Table 5-2. Example of Acceptable HQ Rating for PIO Tendencies

Airspeed	**MLRC**	**MLRC**	**MLRC**	**MLRC**
Load Factor Range	0.8 to 1.3	-1.0 to 2.5	0.8 to 1.3	-1.0 to 2.5
Buffet Level	Onset	Deterrent	Onset	Deterrent
Turbulence	Light	Light	Light	Light
Failure	None	None	Improbable failure of SAS	Improbable failure of SAS
Flight Envelope	NFE	LFE	NFE	LFE
Minimum Permitted HQ Rating	SAT	ADQ	ADQ	CON

SAT = Satisfactory ADQ = Adequate CON = Controllable

NFE = Normal flight envelope LFE = Limit flight envelope

SAS = Stability augmentation system MLRC = Long range cruise Mach number

5.1.5 Maneuvering Characteristics—§ 25.143(g).

5.1.5.1 **General.**

An acceptable means of compliance with the requirement that stick forces may not be excessive when maneuvering the airplane is to demonstrate that, in a turn for 0.5 g incremental normal acceleration (0.3 g above 20,000 ft) at speeds up to V_{FC}/M_{FC}, the average stick force gradient does not exceed 120 lbs per g.

5.1.5.2 **Interpretive Material.**

The objective of § 25.143(g) is to ensure that the limit strength of any critical component on the airplane would not be exceeded in maneuvering flight. In much of the structure, the load sustained in maneuvering flight can be assumed to be directly proportional to the load factor applied. However, this may not be the case for some parts of the structure (e.g., the tail and rear fuselage). Nevertheless, it is accepted that the airplane load factor will be a sufficient guide to the possibility of exceeding limit strength on any critical component if a structural investigation is undertaken whenever the design positive limit maneuvering load factor is closely approached. If flight testing indicates that the positive design limit maneuvering load factor could be exceeded in steady maneuvering flight with a 50-lb stick force, the airplane structure should be evaluated for the anticipated load at a 50-lb stick force. The airplane will be considered to have been overstressed if limit strength has been exceeded in any critical component. For the purposes of this evaluation, limit strength is defined as the lesser of either the limit design loads envelope increased by the available margins of safety, or the ultimate static test strength divided by 1.5.

5.1.5.3 **Minimum Stick Force to Reach Limit Strength.**

5.1.5.3.1 A stick force of at least 50 lbs to reach limit strength in steady maneuvers or wind-up turns is considered acceptable to demonstrate adequate minimum force at limit strength in the absence of deterrent buffeting. If heavy buffeting occurs before the limit strength condition is reached, a somewhat lower stick force at limit strength may be acceptable. The acceptability of a stick force of less than 50 lbs at the limit strength condition will depend upon the intensity of the buffet, the adequacy of the warning margin (i.e., the load factor increment between the heavy buffet and the limit strength condition), and the stick force characteristics. In determining the limit strength condition for each critical component, the contribution of buffet loads to the overall maneuvering loads should be taken into account.

5.1.5.3.2 This minimum stick force applies in the en route configuration with the airplane trimmed for straight flight, at all speeds above the minimum speed at which the limit strength condition can be achieved without stalling. No minimum stick force is specified for other configurations, but the requirements of § 25.143(g) are applicable in these conditions.

5.1.5.4 **Stick Force Characteristics.**

5.1.5.4.1 At all points within the buffet onset boundary determined in accordance with § 25.251(e), but not including speeds above V_{FC}/M_{FC}, the stick force should increase progressively with increasing load factor. Any reduction in stick force gradient with change of load factor should not be so large or abrupt as to impair significantly the ability of the pilot to maintain control over the load factor and pitch attitude of the airplane.

5.1.5.4.2 Beyond the buffet onset boundary, hazardous stick force characteristics should not be encountered within the permitted maneuvering envelope as limited by paragraph 5.1.5.4.3. It should be possible, by use of the primary longitudinal control alone, to rapidly pitch the airplane nose down so as to regain the initial trimmed conditions. The stick force characteristics demonstrated should comply with the following:

1. For normal acceleration increments of up to 0.3 g beyond buffet onset, where these can be achieved, local reversal of the stick force gradient may be acceptable, provided that any tendency to pitch up is mild and easily controllable.
2. For normal acceleration increments of more than 0.3 g beyond buffet onset, where these can be achieved, more marked reversals of the stick force gradient may be acceptable. It should be possible to contain any pitch-up tendency of the airplane within the allowable maneuvering limits, without applying push forces to the control column and without making a large and rapid forward movement of the control column.

5.1.5.4.3 In flight tests to satisfy paragraphs 5.1.5.4.1 and 5.1.5.4.2 above, the load factor should be increased until:

1. The level of buffet becomes sufficient to provide a strong and effective deterrent to any further increase of the load factor;
2. Further increase of the load factor requires a stick force in excess of 150 lbs (or in excess of 100 lbs when beyond the buffet onset boundary) or is impossible because of the limitations of the control system; or
3. The positive limit maneuvering load factor established in compliance with § 25.337(b) is achieved.

5.1.5.5 **Negative Load Factors.**

It is not intended that a detailed flight test assessment of the maneuvering characteristics under negative load factors should necessarily be made throughout the specified range of conditions. An assessment of the characteristics in the normal flight envelope involving normal accelerations from 1 g to zero g will normally be sufficient. Stick forces should also be assessed during other required flight testing involving negative load factors. Where these assessments reveal stick force gradients that are unusually low, or that are subject to significant variation, a more detailed assessment, in the most critical of the specified conditions, will be required. This may be based on calculations, provided they are supported by adequate flight test or wind tunnel data.

5.1.6 Thrust or Power Setting for Maneuver Capability Demonstrations.

The effect of thrust or power on maneuver capability is normally a function of only the thrust-to-weight ratio. Therefore, for those configurations in which the WAT-limited thrust or power setting is prescribed, it is usually acceptable to use the thrust or power setting that is consistent with a WAT-limited climb gradient at the test conditions of weight, altitude, and temperature. However, if the maneuver margin to stall warning (or other characteristic that might interfere with normal maneuvering) is reduced with increasing thrust or power, the critical conditions of both thrust or power and thrust-to-weight ratio should be taken into account when demonstrating the required maneuvering capabilities.

5.2 Longitudinal Control—§ 25.145.

5.2.1 Explanation.

5.2.1.1 Section 25.145(a) requires that there be adequate longitudinal control to promptly pitch the airplane nose down from at or near the stall to return to the original trim speed. The intent is to ensure that there is sufficient pitch control for a prompt recovery if inadvertently slowed to the point of stall. Although this requirement must be met with power off and at maximum continuous thrust or power, there is no intention to require stall demonstrations with thrust or power above that specified in § 25.201(a)(2). Instead of performing a full stall at maximum continuous power or thrust, compliance may be assessed by demonstrating sufficient static longitudinal stability and nose down control margin when the deceleration is ended at least one second past stall warning during a one knot per second deceleration. The static longitudinal stability during the maneuver and the nose down control power remaining at the end of the maneuver must be sufficient to assure compliance with the requirement.

5.2.1.2 Section 25.145(b) requires changes to be made in flap position, power or thrust, and speed without undue effort when re-trimming is impractical. The purpose is to ensure that any of these changes are possible assuming that the pilot finds it necessary to devote at least one hand to the initiation of the desired operation without being overpowered by the primary airplane controls. The objective is to show that an excessive change in trim does not result from the application or removal of power or thrust or the extension or retraction of wing flaps. The presence of gated positions on the flap control does not affect the requirement to demonstrate full flap extensions and retractions without changing the trim control. Compliance with § 25.145(b) also requires that the relation of control force to speed be such that reasonable changes in speed may be made without encountering very high control forces.

5.2.1.3 Section 25.145(c) contains requirements associated primarily with attempting a go-around maneuver from the landing configuration. Retraction of the high-lift devices from the landing configuration should not result in a loss of altitude if the power or thrust controls are moved to the go-around setting at the same time that flap/slat retraction is begun. The design features involved with this requirement are the rate of flap/slat retraction, the presence of any flap gates, and the go-around power or thrust setting. The go-around power or thrust setting should be the same as is used to comply with the approach and landing climb performance requirements of §§ 25.121(d) and 25.119, and the controllability requirements of §§ 25.145(b)(3), 25.145(b)(4), 25.145(b)(5), 25.149(f), and 25.149(g). The controllability requirements may limit the go-around power or thrust setting.

5.2.1.4 Section 25.145(d) provides requirements for demonstrating compliance with § 25.145(c) when gates are installed on the flap selector. Section 25.145(d) also specifies gate design requirements. Flap gates, which prevent the pilot from moving the flap selector through the gated position without a separate and distinct movement of the selector, allow compliance with these requirements to be demonstrated in segments. High lift device retraction must be demonstrated beginning from the maximum landing position to the first gated position, between gated positions, and from the last gated position to the fully retracted position.

5.2.1.4.1 If gates are provided, § 25.145(d) requires the first gate from the maximum landing position to be to be located at a position corresponding to a go-around configuration. If there are multiple go-around configurations, the following criteria should be considered when selecting the location of the gate:

1. The expected relative frequency of use of the available go-around configurations.
2. The effects of selecting the incorrect high-lift device control position.
3. The potential for the pilot to select the incorrect control position, considering the likely situations for use of the different go-around positions.
4. The extent to which the gate(s) aid the pilot in quickly and accurately selecting the correct position of the high-lift devices.

5.2.1.4.2 Regardless of the location of any gates, initiating a go-around from any of the approved landing positions should not result in a loss of altitude. Therefore, § 25.145(d) requires that compliance with § 25.145(c) be demonstrated for retraction of the high-lift devices from each approved landing position to the control position(s) associated with the high-lift device configuration(s) used to establish the go-around procedure(s) from that landing position. A separate demonstration of compliance with this requirement should only be necessary if there is a gate between an approved landing position and its associated go-around position(s). If there is more than one associated go-around position, conducting this test using the go-around configuration with the most retracted high-lift device position should suffice, unless there is a more critical case. If there are no gates between any of the landing flap positions and their associated go-around positions, the demonstrations discussed in paragraph 5.2.1.4 above should be sufficient to show compliance with this provision of § 25.145(d).

5.2.2 Procedures.

The following test procedures outline an acceptable means for demonstrating compliance with § 25.145. These tests may be conducted at an optional altitude in accordance with § 25.21(c). Where applicable, the conditions should be maintained on the engines throughout the maneuver.

5.2.2.1 **Longitudinal Control Recovery—§ 25.145(a).**

5.2.2.1.1 Configuration.

- Maximum weight, or a lighter weight if more critical.
- Critical CG position.
- Landing gear extended.
- Wing flaps retracted and extended to the maximum landing position.
- Engine power or thrust at idle and maximum continuous.

5.2.2.1.2 Test Procedure.

The airplane must be trimmed at the speed for each configuration as prescribed in § 25.103(b)(6). The airplane should then be decelerated at 1 knot per second with wings level. For tests at idle power or thrust, the applicant must demonstrate that the nose can be pitched down from any speed between the trim speed and the stall. Typically, the most critical point is at the stall when in stall buffet. The rate of speed increase during the recovery should be adequate to promptly return to the trim point. Data from the stall characteristics testing can be used to evaluate this capability at the stall. For tests at maximum continuous power or thrust, the maneuver need not be continued for more than one second beyond the onset of stall warning. However, the static longitudinal stability characteristics during the maneuver, and the nose down control power remaining at the end of the maneuver, must be sufficient to assure that a prompt recovery to the trim speed could be attained if the airplane is slowed to the point of stall.

5.2.2.2 **Longitudinal Control, Flap Extension—§ 25.145(b)(1).**

5.2.2.2.1 Configuration.

- Maximum landing weight or a lighter weight if considered more critical.
- Critical CG position.
- Wing flaps retracted.
- Landing gear extended.
- Engine power or thrust at flight idle.

5.2.2.2.2 Test procedure.

The airplane must be trimmed at a speed of 1.3 V_{SR}. The flaps must be extended to the maximum landing position as rapidly as possible while maintaining approximately 1.3 V_{SR} for the flap position existing at each instant throughout the maneuver. The control forces must not exceed 50 lbs (the maximum force for short term application that can be applied readily by one hand) throughout the maneuver without changing the trim control.

5.2.2.3 **Longitudinal Control, Flap Retraction—§ 25.145(b)(2) and (3).**

5.2.2.3.1 Configuration.

- Maximum landing weight or a lighter weight if considered more critical.
- Critical CG position.
- Wing flaps extended to the maximum landing position.
- Landing gear extended.
- Engine power or thrust at flight idle and the go-around power or thrust setting.

5.2.2.3.2 Test procedure.

With the airplane trimmed at 1.3 V_{SR}, the flaps must be retracted to the full up position while maintaining approximately 1.3 V_{SR} for the flap position existing at each instant throughout the maneuver. The longitudinal control force must not exceed 50 lbs throughout the maneuver without changing the trim control.

5.2.2.4 **Longitudinal Control, Power or Thrust Application—§ 25.145(b)(4) and (5).**

5.2.2.4.1 Configuration.

- Maximum landing weight or a lighter weight if considered more critical.
- Critical CG position.
- Wing flaps retracted and extended to the maximum landing position.
- Landing gear extended.
- Engine power or thrust at flight idle.

5.2.2.4.2 Test procedure.

The airplane must be trimmed at a speed of 1.3 V_{SR}. Quickly set go-around power or thrust while maintaining the speed of 1.3 V_{SR}. The longitudinal control force must not exceed 50 lbs throughout the maneuver without changing the trim control.

5.2.2.5 **Longitudinal Control, Airspeed Variation—§ 25.145(b)(6).**

5.2.2.5.1 Configuration.

- Maximum landing weight or a lighter weight if considered more critical.
- Most forward CG position.
- Wing flaps extended to the maximum landing position.
- Landing gear extended.
- Engine power or thrust at flight idle.

5.2.2.5.2 Test Procedure.

The airplane must be trimmed at a speed of 1.3 V_{SR}. The speed should then be reduced to V_{SW} and then increased to 1.6 V_{SR}, or the maximum flap extended speed, V_{FE}, whichever is lower. The longitudinal control force must not be greater than 50 lbs. Data from the static longitudinal stability tests in the landing configuration at forward CG, § 25.175(d), may be used to show compliance with this requirement.

5.2.2.6 **Longitudinal Control, Flap Retraction and Power or Thrust Application—§ 25.145(c).**

5.2.2.6.1 Configuration.

- Critical combinations of maximum landing weights and altitudes.
- Critical CG position.
- Wing flaps extended to the maximum landing position and gated position, if applicable.
- Landing gear extended.
- Engine power or thrust for level flight at a speed of 1.08 V_{SR} for propeller driven airplanes, or 1.13 V_{SR} for turbojet powered airplanes.

5.2.2.6.2 Test procedure.

With the airplane stable in level flight at a speed of 1.08 V_{SR} for propeller driven airplanes, or 1.13 V_{SR} for turbojet powered airplanes, retract the flaps to the full up position, or the next gated position, while simultaneously setting go-around power or thrust. Use the same power or thrust as is used to comply with the performance requirement of § 25.121(d), as limited by the applicable controllability requirements. It must be possible, without requiring exceptional piloting skill, to prevent losing altitude during the maneuver. Trimming is permissible at any time during the maneuver. If gates are provided, conduct this test beginning from the maximum landing flap position to the first gate, from gate to gate, and from the last gate to the fully retracted position. If there is a gate between any landing position and its associated go-around position(s), this test should also be conducted from that landing position through the gate to the associated go-around position. If there is more than one associated go-around position, this additional test should be conducted using the go-around position corresponding to the most retracted flap position, unless another position is more critical. Keep the landing gear extended throughout the test.

5.2.2.7 **Longitudinal Control, Out-of-Trim Takeoff Conditions—§§ 25.107(e)(4) and 25.143(a)(1).**

See paragraphs 4.2.8.3.3 and 4.2.8.3.4 of this AC.

5.3 Directional and Lateral Control—§ 25.147.

5.3.1 Explanation.

5.3.1.1 Sections 25.147(a) and (b) provide criteria to determine if the airplane may have dangerous characteristics such as rudder lock or loss of directional control if it is maneuvered only with the rudder, while maintaining wings level, when one or two critical engines are inoperative. Some yaw capability into the operating engine(s) should be possible. It should also be possible to make reasonably sudden heading changes of up to 15°, as limited by rudder force or deflection, toward the inoperative engine(s). The intention of the requirement is that the airplane can be yawed as prescribed without needing to bank the airplane. Small variations of bank angle that are inevitable in a realistic flight test demonstration are acceptable.

5.3.1.2 Sections 25.147(c) and (e) require an airplane to be easily controllable with the critical engine(s) inoperative. Section 25.147(d) further requires that lateral control be sufficient to provide a roll rate necessary for safety, without excessive control forces or travel, at the speeds likely to be used with one engine inoperative. Compliance can normally be demonstrated in the takeoff configuration at V_2 speed, because this condition is usually the most critical. Normal operation of a yaw stability augmentation system (SAS) should be considered in accordance with the normal operating procedures. Roll response with all engines operating, § 25.147(f), should be satisfactory for takeoff, approach, landing, and high speed configurations. Any permissible configuration that could affect roll response should be evaluated.

5.3.2 Procedures.

The following test procedures outline an acceptable means for demonstrating compliance with § 25.147.

5.3.2.1 **Directional Control: General—§ 25.147(a).**

5.3.2.1.1 Configuration.

- Maximum landing weight.
- Most aft CG position.
- Wing flaps extended to the approach position.
- Landing gear retracted.
- Yaw SAS on, and off if applicable.
- Operating engine(s) at the power or thrust for level flight at 1.3 V_{SR}, but not more than maximum continuous power or thrust.
- Inoperative engine that would be most critical for controllability, with the propeller (for propeller airplanes) feathered.

5.3.2.1.2 Test Procedure.

The airplane must be trimmed in level flight at the most critical altitude in accordance with § 25.21(c). Make heading changes into and away from the inoperative engine of up to 15° (not using more than 150 lbs rudder force), using the roll controls to maintain approximately wings level flight. The airplane should be controllable and free from any hazardous characteristics during this maneuver. For airplanes equipped with a rudder boost system, the evaluation should be done without rudder boost if the boost system can be inoperative.

5.3.2.2 **Directional Control: Four or More Engines—§ 25.147(b).**

5.3.2.2.1 Configuration.

- Maximum landing weight.
- Most forward CG position.
- Wing flaps in the most favorable climb position (normally retracted).
- Landing gear retracted.
- Yaw SAS on, and off, as applicable.
- Operating engines at the power or thrust required for level flight at 1.3 V_{SR1}, but not more than maximum continuous power or thrust.
- Two inoperative engines that would be most critical for controllability with (if applicable) propellers feathered.

5.3.2.2.2 Test Procedure.

The procedure outlined in paragraph 5.3.2.2.1 above is applicable to this test.

5.3.2.3 Lateral Control: General—§ 25.147(c).

5.3.2.3.1 Configuration.

- Maximum takeoff weight.
- Most aft CG position.
- Wing flaps in the most favorable climb position.
- Landing gear retracted and extended.
- Yaw SAS on, and off, as applicable.
- Operating engine(s) at maximum continuous power or thrust.
- The inoperative engine that would be most critical for controllability, with the propeller (for propeller airplanes) feathered.

5.3.2.3.2 Test Procedure.

With the airplane trimmed at 1.3 V_{SR1}, turns with a bank angle of 20° must be demonstrated with and against the inoperative engine from a steady climb at 1.3 V_{SR1}. It should not take exceptional piloting skill to make smooth, predictable turns.

5.3.2.4 Lateral Control: Roll Capability—§ 25.147(d).

5.3.2.4.1 Configuration.

- Maximum takeoff weight.
- Most aft CG position.
- Wing flaps in the most critical takeoff position.
- Landing gear retracted.
- Yaw SAS on, and off, as applicable.
- Operating engine(s) at maximum takeoff power or thrust.
- The inoperative engine that would be most critical for controllability, with propellers (for propeller airplanes) feathered.

5.3.2.4.2 Test Procedure.

With the airplane in trim, or as nearly as possible in trim, for straight flight at V_2, establish a steady 30° banked turn. Demonstrate that the airplane can be rolled to a 30° bank angle in the other direction in not more than 11 seconds. The rudder may be used to the extent necessary to minimize sideslip. Demonstrate this maneuver in the most adverse direction. The maneuver may be unchecked, that is, the pilot need not apply a control input to stop the roll until after the 30° bank angle is achieved. Care should be taken to prevent excessive sideslip and bank angle during the recovery.

5.3.2.5 **Lateral Control: Four or More Engines—§ 25.147(e).**

5.3.2.5.1 Configuration,

- Maximum takeoff weight.
- Most aft CG position.
- Wing flaps in the most favorable climb position.
- Landing gear retracted and extended.
- Yaw SAS on, and off, as applicable.
- Operating engines at maximum continuous power or thrust.
- Two inoperative engines most critical for controllability, with propellers (for propeller airplanes) feathered.

5.3.2.5.2 Test Procedure.

The procedure outlined in paragraph 5.3.2.1.2 is applicable to this test.

5.3.2.6 **Lateral Control: All Engines Operating—§ 25.147(f).**

5.3.2.6.1 Configuration.

All configurations within the flight envelope for normal operation.

5.3.2.6.2 Test Procedure.

This is primarily a qualitative evaluation that should be conducted throughout the test program. Roll performance should be investigated throughout the flight envelope, including speeds to V_{FC}/M_{FC}, to ensure adequate peak roll rates for safety, considering the flight condition, without excessive control force or travel. Roll response during sideslips expected in service should provide maneuvering capabilities adequate to recover from such conditions. Approach and landing configurations should be carefully evaluated to ensure adequate control to compensate for gusts and wake turbulence while in close proximity to the ground.

5.4 Minimum Control Speed—§ 25.149.

5.4.1 Explanation.

5.4.1.1 General.

Section 25.149 defines requirements for minimum control speeds during takeoff climb (V_{MC}), during takeoff ground roll (V_{MCG}), and during approach and landing (V_{MCL} and V_{MCL-2}). The V_{MC} (commonly referred to as V_{MCA}) requirements are specified in § 25.149(a), (b), (c) and (d); the V_{MCG} requirements are described in § 25.149(e); and the V_{MCL} and V_{MCL-2} requirements are covered in § 25.149(f), (g) and (h). Section 25.149(a) states, "...the method used to simulate critical engine failure must represent the most critical mode of powerplant failure with respect to controllability expected in service." That is, the power or thrust loss from the inoperative engine must be at the rate that would occur if an engine suddenly became inoperative in service. Prior to amendment 25-42 to § 25.149, the regulation required that rudder control forces must not exceed 180 lbs. With the adoption of amendment 25-42, rudder control forces became limited to 150 lbs. The relationships between V_{EF}, V_1, and V_{MCG} are discussed in paragraph 4.2, *Takeoff and Takeoff Speeds—§§ 25.105 and 25.107*, and paragraph 4.3, *Accelerate-Stop Distance—§ 25.109*.

5.4.1.2 Safety Concerns Addressed by V_{MCA}.

When flying with an inoperative engine, the asymmetric yawing moment must be compensated by aerodynamic forces created by rudder deflection and sideslip. When the speed decreases, sideslip increases rapidly in a non-linear manner. The purpose of the V_{MCA} requirement is to ensure the airplane remains safely controllable with the maximum power or thrust asymmetry at any speed down to V_{MCA}.

5.4.1.3 Weight Effect on V_{MCA}.

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

5.4.2 Procedures: General.

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

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

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

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

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

5.4.3 Procedures: Minimum Control Speeds—Air (V_{MCA}).

5.4.3.1 In showing compliance with the V_{MCA} requirements, the following two conditions should be satisfied:

5.4.3.1.1 The stabilized (static) condition where constant heading is maintained without exceeding a 5° bank angle, and

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

Note: Separate tests are usually conducted to show compliance with these two conditions.

5.4.3.2 **Static Test Procedure and Required Data.**

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

5.4.3.2.2 If the maximum asymmetric power or thrust that is permitted by the AFM operating limitations was maintained at the test day V_{MCA}, and the rudder pedal force did not exceed the limit specified in § 25.149(d), the resulting speed may be used as the single value of V_{MCA} for the airplane. If, at the option of the applicant, the AFM value of V_{MCA} is to vary with pressure altitude and temperature, the test day minimum control speed and the corresponding power or thrust should be used to calculate an equivalent yawing moment coefficient (C_N). This C_N value may then be used to calculate V_{MCA} as a function of takeoff power or thrust, thus permitting V_{MCA} to be scheduled as a function of pressure altitude and temperature for takeoff data expansion and presentation in the AFM. (See appendix F of this AC for further discussion of V_{MCA} correction.)

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

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

5.4.3.3 **Dynamic Test Procedures and Required Data.**

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

- Without deviating more than 20 degrees from the original heading,
- While maintaining the test airspeed, without reducing power/thrust on the operating engine(s), and
- Without exceeding the rudder pedal force limit of § 25.149(d).

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

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

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

5.4.4 <u>Procedures: Minimum Control Speed-Ground (V_{MCG})—§ 25.149(e).</u>

5.4.4.1 It must be demonstrated that, when the critical engine is suddenly made inoperative at V_{MCG} during the takeoff ground roll, the airplane is safely controllable if the takeoff is continued. During the demonstration, the airplane must not deviate more than 30 feet (25 feet prior to amendment 25-42) from the pre-engine-cut projected ground track. The critical engine) for ground minimum control speed testing should be determined during the takeoff ground run using techniques similar to these described in paragraph 5.4.2. If there is a significant difference in left and right rudder deflection, the loss of asymmetric propeller disc loading, due to near zero angle-of-attack during the takeoff roll, could result in the critical engine being on the opposite side of the airplane relative to the airborne minimum control speed tests.

5.4.4.2 Work up tests may be conducted by abruptly retarding the critical engine to idle to determine the airplane asymmetric control characteristics and provide data from which an estimate of V_{MCG} can be made. Due to the engine spindown characteristics with the critical engine retarded to idle, the speed will not, in general, be representative of the V_{MCG} speed that would be obtained with a fuel cut. Therefore, the certification tests for

V_{MCG} should be conducted using fuel cuts. Starting from a speed comfortably above the estimated V_{MCG} and with the maximum takeoff power or thrust level to be certified, several fuel cuts should be made at decreasing calibrated airspeeds to establish the minimum airspeed at which the lateral deviation is less than or equal to 30 feet. V_{MCG} is determined for zero crosswind conditions. However, in light crosswind test conditions the V_{MCG} value determined should be that which is appropriate to the adverse crosswind or, at the applicant's option, may be corrected to a zero crosswind value using runs made on reciprocal headings.

5.4.4.3 During determination of V_{MCG}, engine failure recognition should be provided by the pilot:

- Feeling a distinct change in the directional tracking characteristics of the airplane, or
- Seeing a directional divergence of the airplane with respect to the view outside the airplane.

5.4.4.4 Directional 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. Pilot input to controls to supplement the rudder effectiveness should not be used. Care should also be taken not to inadvertently apply brake pressure during large rudder deflections, as this will invalidate the test data.

5.4.4.5 V_{MCG} testing should be conducted at the most critical weight in the range where V_{MCG} may impact AFM V_1 speeds.

5.4.4.6 V_{MCG} testing should be conducted at aft CG and with the nose wheel free to caster, to minimize the stabilizing effect of the nose gear. If the nose wheel does not caster freely, the test may be conducted with enough nose up elevator applied to lift the nose wheel off the runway.

5.4.4.7 V_{MCG} testing should not be conducted on runways with excessive crowning (i.e., cross-runway slope) unless the effects of such crowning are determined to be conservative.

5.4.4.8 For airplanes with certification bases prior to amendment 25-42, V_{MCG} values may be demonstrated with nose wheel rudder pedal steering operative for dispatch on wet runways. The test should be conducted on an actual wet, smooth (i.e., not grooved or PFC) runway. The test(s) should include engine failure at or near a minimum V_{EF} associated with minimum V_R to demonstrate adequate controllability during rotation, liftoff, and the initial climbout. The V_{MCG} values obtained by this method are applicable for wet or dry runways only, not for icy runways.

5.4.5 Procedures: Minimum Control Speed during Approach and Landing (V_{MCL})—§ 25.149(f).

5.4.5.1 This section is intended to ensure that the airplane is safely controllable following an engine failure during an all-engines-operating approach and landing. From a controllability standpoint, the most critical case usually consists of an engine failing after the power or thrust has been increased to perform a go-around from an all-engines-operating approach. Section 25.149(f) requires the minimum control speed to be determined that allows a pilot of average skill and strength to retain control of the airplane after the critical engine becomes inoperative and to maintain straight flight with less than 5° of bank angle. Section 25.149(h) requires that sufficient lateral control be available at V_{MCL} to roll the airplane through an angle of 20°, in the direction necessary to initiate a turn away from the inoperative engine, in not more than five seconds when starting from a steady straight flight condition.

5.4.5.2 Conduct this test using the most critical of the all-engines-operating approach and landing configurations or, at the option of the applicant, each of the all-engines-operating approach and landing configurations. The procedures given in paragraphs 5.4.3.2 and 5.4.3.2.3 for V_{MCA} may be used to determine V_{MCL}, except that flap and trim settings should be appropriate to the approach and landing configurations, the power or thrust on the operating engine(s) should be set to the go-around power or thrust setting, and compliance with all V_{MCL} requirements of § 25.149(f) and (h) must be demonstrated.

5.4.5.3 In accordance with § 25.149(f)(5) for propeller driven airplanes, the propeller must be in the position it achieves without pilot action following engine failure, assuming the engine fails while at the power or thrust necessary to maintain a 3° approach path angle.

5.4.5.4 At the option of the applicant, a one-engine-inoperative landing minimum control speed, $V_{MCL(1\text{ out})}$, may be determined in the conditions appropriate to an approach and landing with one engine having failed before the start of the approach. In this case, only those configurations recommended for use during an approach and landing with one engine inoperative need be considered. The propeller of the inoperative engine, if applicable, may be feathered throughout. The resulting value of $V_{MCL(1\text{ out})}$ may be used in determining the recommended procedures and speeds for a one-engine-inoperative approach and landing.

5.4.6 Procedures: Minimum Control Speed with Two Inoperative Engines during Approach and Landing (V_{MCL-2})—§ 25.149(g).

5.4.6.1 For airplanes with three or more engines, V_{MCL-2} is the minimum speed for maintaining safe control during the power or thrust changes that are likely to be made following the failure of a second critical engine during an approach initiated with one engine inoperative.

5.4.6.2 In accordance with § 25.149(g)(5) for propeller driven airplanes, the propeller of the engine that is inoperative at the beginning of the approach may be in the feathered position. The propeller of the more critical engine must be in the position it automatically assumes following engine failure.

5.4.6.3 Conduct this test using the most critical approved one-engine-inoperative approach or landing configuration (usually the minimum flap deflection), or at the option of the applicant, each of the approved one-engine-inoperative approach and landing configurations. The following demonstrations should be conducted to determine V_{MCL-2}:

5.4.6.3.1 With the power or thrust on the operating engines set to maintain a -3° glideslope with one critical engine inoperative, the second critical engine is made inoperative and the remaining operating engine(s) are advanced to the go-around power or thrust setting. The V_{MCL-2} speed is established by the procedures presented in paragraphs 5.4.3.2 and 5.4.3.3 below for V_{MCA}, except that flap and trim settings should be appropriate to the approach and landing configurations, the power or thrust on the operating engine(s) should be set to the go-around power or thrust setting, and compliance with all V_{MCL-2} requirements of § 25.149(g) and (h) must be demonstrated.

5.4.6.3.2 With power or thrust on the operating engines set to maintain a -3° glideslope, with one critical engine inoperative:

1. Set the airspeed at the value determined in paragraph 5.4.6.3.1 above and, with zero bank angle, maintain a constant heading using trim to reduce the control force to zero. If full trim is insufficient to reduce the control force to zero, full trim should be used plus control deflection as required; and
2. Make the second critical engine inoperative and retard the remaining operating engine(s) to minimum available power or thrust without changing the directional trim. The V_{MCL-2} determined in paragraph 5.4.6.3.1 is acceptable if constant heading can be maintained without exceeding a 5° bank angle and the limiting conditions of § 25.149(h).
3. Starting from a steady straight flight condition, demonstrate that sufficient lateral control is available at V_{MCL-2} to roll the airplane through an angle of 20° in the direction necessary to initiate a turn away from the inoperative engines in not more than five seconds. This maneuver may be flown in a bank-to-bank roll through a wings level attitude.

5.4.6.4 At the option of the applicant, a two-engines-inoperative landing minimum control speed, $V_{MCL\text{-}2(2\ out)}$, may be determined in the conditions appropriate to an approach and landing with two engines having failed before the start of the approach. In this case, only those configurations recommended for use during an approach and landing with two engines inoperative need be considered. The propellers of the inoperative engines, if applicable, may be feathered throughout. The values of $V_{MCL\text{-}2}$ or $V_{MCL\text{-}2(2\ out)}$ should be used as guidance in determining the recommended procedures and speeds for a two-engines-inoperative approach and landing.

5.4.6.5 Autofeather Effects.

Where an autofeather or other drag limiting system is installed, and will be operative at approach power settings, its operation may be assumed in determining the propeller position achieved when the engine fails. Where automatic feathering is not available, the effects of subsequent movements of the engine and propeller controls should be considered, including fully closing the power lever of the failed engine in conjunction with maintaining the go-around power setting on the operating engine(s).

CHAPTER 6. FLIGHT: TRIM

6.1 **Trim—§ 25.161.**

6.1.1 Explanation.

Adequate trim capability should be provided for any flight condition that it is reasonable to assume will be maintained steadily for any appreciable time.

6.1.2 Procedures.

6.1.2.1 The trim requirements specify the ranges of speed and the airplane configurations at which the airplane must be able to maintain trim.

6.1.2.2 All weights, from the minimum in-flight weight to the maximum takeoff weight, should be considered. For airplanes with unpowered controls, the lowest weight may be more critical since this results in the lowest airspeed.

6.2 **[Reserved.]**

CHAPTER 7. FLIGHT: STABILITY

7.1 General—§ 25.171. [Reserved]

7.2 Static Longitudinal Stability and Demonstration of Static Longitudinal Stability—§§ 25.173 and 25.175.

7.2.1 Explanation.

7.2.1.1 Static Longitudinal Stability—§ 25.173.

7.2.1.1.1 Compliance with the general requirements of § 25.173 is determined from a demonstration of static longitudinal stability under the conditions specified in § 25.175.

7.2.1.1.2 The requirement is to have a pull force to obtain and maintain speeds lower than trim speed, and a push force to obtain and maintain speeds higher than trim speed. There may be no force reversal at any speed that can be obtained, except lower than the minimum for steady, unstalled flight or, higher than the landing gear or wing flap operating limit speed or V_{FC}/M_{FC}, whichever is appropriate for the test configuration. The required trim speeds are specified in § 25.175.

7.2.1.1.3 When the control force is slowly released from any speed within the required test speed range, the airspeed must return to within 10 percent of the original trim speed in the climb, approach, and landing conditions, and return to within 7.5 percent of the trim speed in the cruising condition specified in § 25.175 (free return).

7.2.1.1.4 The average gradient of the stick force versus speed curves for each test configuration may not be less than 1 lb for each 6 knots for the appropriate speed ranges specified in § 25.175. Therefore, after each curve is drawn, draw a straight line from the intersection of the curve and the required maximum speed to the trim point. Then draw a straight line from the intersection of the curve and the required minimum speed to the trim point. The slope of these lines must be at least 1 lb for each 6 knots. The local slope of the curve must remain stable for this range.

7.2.1.2 Demonstration of Static Longitudinal Stability—§ 25.175.

This section specifically defines the flight conditions, airplane configurations, trim speed, test speed ranges, and power or thrust settings to be used in demonstrating compliance with the longitudinal stability requirements.

7.2.2 Procedures.

7.2.2.1 **Stabilized Method.**

7.2.2.1.1 For the demonstration of static longitudinal stability, the airplane should be trimmed in smooth air at the conditions required by the regulation. Aft CG loadings are generally most critical. After stabilizing at the trim speed, apply a light pull force and stabilize at a slower speed. Continue this process in increments, the size of the speed increment being dependent on the speed spread being investigated, until reaching the minimum speed for steady, unstalled flight or the minimum speed appropriate for the configuration. A continuous pull force should be used from the trim speed on each series of test points to eliminate hysteresis effects. At the end of the required speed range, the force should be gradually relaxed to allow the airplane to return slowly toward the 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 normally be less than the original trim speed. The new speed, called the free return speed, must meet the requirements of § 25.173.

7.2.2.1.2 Starting again at the trim speed, and with the airplane in trim, push forces should be gradually applied and gradually relaxed in the same manner as described in paragraph 7.2.2.1.1 above.

7.2.2.1.3 The above techniques result in several problems in practice. One effect of changing airspeed is a change of altitude, with a corresponding change in Mach number and power or thrust output. Consequently, a reasonably small altitude band, limited to ±3,000 feet, should be used for the complete maneuver. If this altitude band is exceeded, regain the original trim altitude by changing the power or thrust setting and flap and gear position as necessary, but without changing the trim setting. Then continue the push or pull maneuver in the original configuration. Testing somewhat beyond the required speed limits in each direction assures that the resulting data covers at least the required speed ranges. It will also be noted in testing that while holding force constant at each data point, the airspeed and instantaneous vertical speed vary in a cyclic manner. This is due to the long period (phugoid) oscillation. Care should be exercised in defining and evaluating the data point, since it may be biased by this phugoid oscillation. Averaging these oscillating speeds at each data point is an acceptable method of eliminating this effect. Extremely smooth air improves the quality of the test data. In-bay and cross-bay wing fuel shift is another issue experienced in some airplanes. In-bay fuel shift occurs rapidly with pitch angle; therefore, consideration should be given to testing with fuel loadings that provide the maximum shift since it is generally destabilizing. Slower, cross-bay fuel shift, or burn from an aft tank, can influence the measured stability but usually only because of the time required to obtain the data points. This testing induced instability should be removed from the data before evaluating the slope of the stick force versus speed.

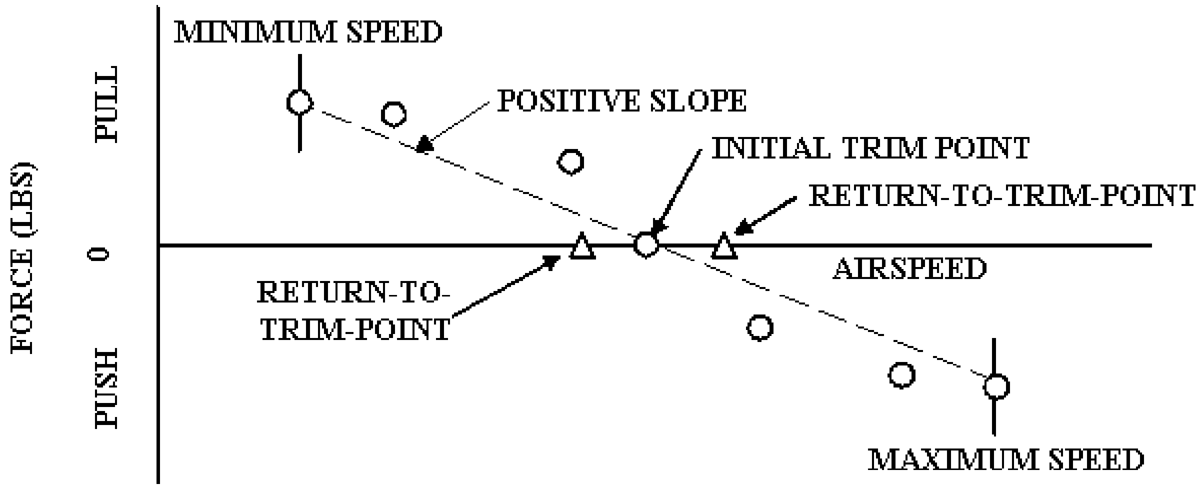
7.2.2.2 **Acceleration-Deceleration Method.**

7.2.2.2.1 Trim at the desired airspeed and note the power or thrust setting. Without changing pitch trim, increase power or thrust to accelerate the airplane to the extreme speed of the desired data band. Using elevator control as needed, maintain approximately a constant altitude. Then, without changing pitch trim, quickly reset the power or thrust to the original power setting and allow the airplane to decelerate at a constant altitude back to the original trim speed. Obtain longitudinal static stability data during the deceleration to trim speed with the power and the pitch trim position the same as the original trim data point.

7.2.2.2.2 Obtain data below the trim speed in a similar manner, by reducing power or thrust to decelerate the airplane to the lowest speed in the data band. Using elevator control as needed without changing pitch trim, maintain approximately a constant altitude. Then, without changing pitch trim, quickly reset the power to the original power setting, and record the data during the level flight acceleration back to trim speed. If, because of thrust/drag relationships, the airplane has difficulty returning to the trim conditions, small altitude changes within ±2,000 feet can also be used to coax an airplane back to trim speed. Level flight is preferred, if possible. Obtain speed and elevator stick force data approximately every 10 knots of speed change.

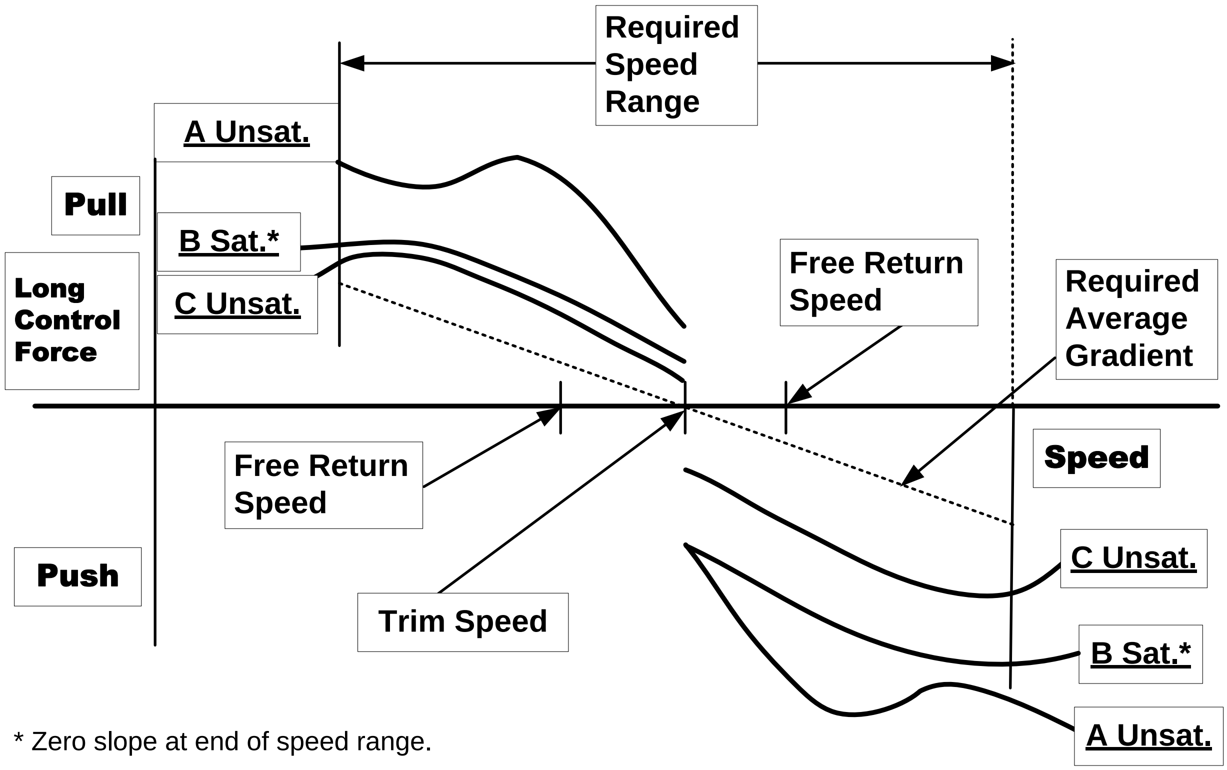
7.2.2.2.3 The resulting pilot longitudinal force test points should be plotted versus airspeed to show the positive stable gradient of static longitudinal stability and that there are no "local" reversals in the stick force versus airspeed relationship over the range of airspeeds tested. This plot should also show the initial trim point and the two return-to-trim points to evaluate the return-to-trim characteristics. (See figure 7-1 below.)

Figure 7-1. Longitudinal Static Stability



7.2.2.3 Examples of "local reversals" are given in figure 7-2 below. Curves A and C depict a local gradient reversal within the required speed range. Even though it might be argued that the "average gradient" meets the 1 lb in 6 knots criterion, the gradient reversals would render these characteristics unacceptable. Curve B depicts a situation in which the gradient reverses, but only outside the required speed range. In addition, Curve B demonstrates a situation in which the local gradient does not always meet the required 1 lb in 6 knots, even though the average gradient does.

Figure 7-2. Local Reversal



7.3 Static Directional and Lateral Stability—§ 25.177.

7.3.1 <u>Explanation.</u>

7.3.1.1 **Static Directional Stability.**

Positive static directional stability is defined as the tendency to recover from a skid with the rudder free. Positive static directional stability is required by § 25.177(a) for any landing gear and flap position and symmetrical power or thrust condition at speeds from 1.13 V_{SR1} up to V_{FE}, V_{LE}, or V_{FC}/M_{FC}, as appropriate for the airplane configuration.

7.3.1.2 **Static Lateral Stability.**

Positive static lateral stability is defined as the tendency to raise the low wing in a sideslip with hands off the roll controls. Section 25.177(b) requires that static lateral stability not be negative in any landing gear and flap position and symmetrical power or thrust condition at speeds from 1.13 V_{SR1} to V_{FE}, V_{LE}, or V_{MO}/M_{MO}, as appropriate for the airplane configuration. At speeds from V_{MO}/M_{MO} to V_{FC}/M_{FC}, negative static lateral stability is permitted by § 25.177(b), if the divergence is:

- Gradual,
- Easily recognizable by the pilot, and

- Easily controllable by the pilot.

7.3.1.3 **Steady Straight Sideslips.**

7.3.1.3.1 Section 25.177(c) requires, in steady, straight sideslips throughout the range of sideslip angles appropriate to the operation of the airplane, that the aileron and rudder control movements and forces be proportional to the angle of sideslip. Also, the factor of proportionality must lie between limits found necessary for safe operation. Section 25.177(c) also states that that the range of sideslip angles evaluated must include those sideslip angles resulting from the lesser of: (1) one-half of the available rudder control input; and (2) a rudder control force of 180 lbs. This means that if using one-half of the available rudder control input takes less than 180 lbs of force, then compliance must be based on using one-half of the available rudder control input. If application of 180 lbs of rudder control force results in using less than one-half of the available rudder control input, then compliance must be based on applying 180 lbs of rudder control force. By cross-reference to § 25.177(a), § 25.177(c) requires that these steady, straight sideslip criteria be met for all landing gear and flap positions and symmetrical power or thrust conditions at speeds from 1.13 V_{SR1} to V_{FE}, V_{LE}, or V_{FC}/M_{FC}, as appropriate for the configuration.

7.3.1.3.2 Experience has shown that an acceptable method for determining the appropriate sideslip angle for the operation of a transport category airplane is provided by the following equation:

$$\beta = arc\ sin(30/V)$$

Where:

$$\beta = Sideslip\ angle$$

$$V = Airspeed\ (KTAS)$$

7.3.1.3.3 Recognizing that smaller sideslip angles are appropriate as speed is increased, this equation provides sideslip angle as a function of airspeed. The equation is based on the theoretical sideslip value for a 30-knot crosswind, but has been shown to conservatively represent (i.e., exceed) the sideslip angles achieved in maximum crosswind takeoffs and landings and minimum static and dynamic control speed testing for a variety of transport category airplanes. Experience has also shown that a maximum sideslip angle of 15° is generally appropriate for most transport category airplanes even though the equation above may provide a higher sideslip angle. However, limiting the maximum sideslip angle to 15° may not be appropriate for airplanes with low approach speeds or high crosswind capability.

7.3.1.3.4 A lower sideslip angle than that provided in paragraph 7.3.1.3.2 above may be used if it is substantiated that the lower value conservatively covers all crosswind conditions, engine failure scenarios, and other conditions where sideslip may be experienced within the approved operating envelope. Conversely, a higher value should be used for airplanes where test evidence indicates that a higher value would be appropriate to the operation of the airplane.

7.3.1.3.5 For the purpose of showing compliance with the requirement out to sideslip angles associated with the lesser of (1) one half of the available rudder control input; and (2) a rudder control force of 180 lbs; there is no need to consider a rudder control input beyond that corresponding to full available rudder surface travel. Some rudder control system designs may limit the available rudder surface deflection such that full deflection for the particular flight condition, or the maximum commanded sideslip angle for the flight condition, is reached before the rudder control reaches one-half of its available travel. In such cases, further rudder control input is unnecessary as it would not result in a higher sideslip angle, and therefore would not affect compliance with the rule.

7.3.1.4 **Full Rudder Sideslips.**

7.3.1.4.1 At sideslip angles greater than those appropriate for normal operation of the airplane, up to the sideslip angle at which full rudder control input is used or a rudder control force of 180 lbs is obtained, § 25.177(d) requires that the rudder pedal control may not reverse and increased rudder deflection must be needed for increased angles of sideslip. The goals of this higher-than-normal sideslip angle test are to show that at full rudder control input, or at maximum expected pilot effort (1) the rudder control force does not reverse, and (2) increased rudder deflection must be needed for increased angles of sideslip, thus demonstrating freedom from rudder lock or fin stall, and adequate directional stability for maneuvers involving large rudder inputs.

7.3.1.4.2 Compliance with this requirement should be shown using straight, steady sideslips. However, if full lateral control input is reached before full rudder control travel or a rudder control force of 180 lbs is reached, the maneuver may be continued in a non-steady heading (i.e., rolling and yawing) maneuver. Care should be taken to prevent excessive bank angles that may occur during this maneuver.

7.3.1.4.3 Section 25.177(d) states that the criteria listed in paragraph 7.3.1.4.1 above must be met at all approved landing gear and flap positions for the range of operating speeds and power conditions appropriate to each landing gear and flap position with all engines operating. The range of operating speeds and power conditions appropriate to each landing gear and flap position with all engines operating should be consistent with the following:

1. For takeoff configurations, speeds from V_2+xx (airspeed approved for all-engines-operating initial climb) to V_{FE} or V_{LE}, as appropriate, and takeoff power/thrust;
2. For flaps up configurations, speeds from 1.23 V_{SR} to V_{LE} or V_{MO}/M_{MO}, as appropriate, and power from idle to maximum continuous power/thrust;
3. For approach configurations, speeds from 1.23 V_{SR} to V_{FE} or V_{LE}, as appropriate, and power from idle to go-around power/thrust; and
4. For landing configurations, speeds from V_{REF}-5 knots to V_{FE} or V_{LE}, as appropriate, with power from idle to go-around power/thrust at speeds from V_{REF} to V_{FE}/V_{LE}, and idle power at V_{REF}-5 knots (to cover the landing flare).

7.3.2 Procedures.

The test conditions should include each flap and landing gear configuration as described in paragraphs 7.3.1.1 through 7.3.1.4 of this AC at an altitude appropriate to each configuration.

7.3.2.1 **Basic Tests for Static Directional and Lateral Stability.**

7.3.2.1.1 Static Directional Stability.

To check static directional stability with the airplane in the desired configuration and stabilized at the trim speed, the airplane is slowly yawed in both directions while maintaining the wings level with the roll controls. When the rudder is released, the airplane should tend to return to straight flight.

7.3.2.1.2 Static Lateral Stability.

To check lateral stability with a particular configuration and trim speed, conduct steady, straight sideslips at the trim speed by maintaining the airplane heading with rudder and banking with the roll controls. When the roll controls are released, with the rudder held fixed, the low wing should tend to return to level. Initial bank angle should be appropriate to type; however, it is recommended that it should not be less than 10° or that necessary to maintain the steady, straight sideslip with one-half rudder deflection, whichever occurs first. Roll control centering by the pilot should not be permitted during this evaluation. The intent of this testing is to evaluate the short-term response of the airplane; therefore, long-term effects, such as those due to spanwise fuel movement, need not be taken into account.

7.3.2.1.3 Steady, Straight Sideslips.

Steady, straight sideslips should be conducted in each direction to show that the aileron and rudder control movements and forces are substantially proportional to the angle of sideslip in a stable sense, and that the factor of proportionality is within the limits found necessary for safe operation. These tests should be conducted at progressively greater sideslip angles up to the sideslip angle appropriate to the operation of the airplane (see paragraph 7.3.1.3.2) or the sideslip angle associated with one-half of the available rudder control input (as limited by a rudder control force of 180 lbs), whichever is greater.

7.3.2.1.4 When determining the rudder and aileron control forces, the controls should be relaxed at each point to find the minimum force needed to maintain the control surface deflection. If excessive friction is present, the resulting low forces will indicate the airplane does not have acceptable stability characteristics.

7.3.2.1.5 Instead of conducting each of the separate qualitative tests described in paragraph 7.3.2.1, the applicant may use recorded quantitative data showing aileron and rudder control force and position versus sideslip (left and right) to the appropriate limits in the steady heading sideslips conducted to show compliance with § 25.177(c). If the control force and position versus sideslip indicates positive dihedral effect and positive directional stability, compliance with § 25.177(a) and (b) will have been successfully demonstrated.

7.3.2.2 **Full Rudder Sideslips.**

7.3.2.2.1 Rudder lock is that condition where the rudder over-balances aerodynamically and either deflects fully with no additional pilot input or does not tend to return to neutral when the pilot input is released. It is indicated by a reversal in the rudder control force as sideslip angle is increased. Full rudder sideslips are conducted to determine the rudder control forces and deflections out to sideslip angles associated with full rudder control input (or as limited by a rudder control force of 180 lbs) to investigate the potential for rudder lock and lack of directional stability.

7.3.2.2.2 To check for positive directional stability and for the absence of rudder lock, conduct steady heading sideslips at increasing sideslip angles until obtaining full rudder control input or a rudder control force of 180 lbs. If full lateral control is reached before reaching the rudder control limit or 180 lbs of rudder control force, continue the test to the rudder limiting condition in a non-steady heading sideslip maneuver.

7.3.2.3 **Control Limits.**

The control limits approved for the airplane should not be exceeded when conducting the flight tests required by § 25.177.

7.3.2.4 **Flight Test Safety Concerns.**

In planning for and conducting the full rudder sideslips, items relevant to flight test safety should be considered, including:

- Inadvertent stalls,
- Effects of sideslip on stall protection systems,
- Actuation of stick pusher, including the effects of sideslip on angle-of-attack sensor vanes,
- Heavy buffet,
- Exceeding flap loads or other structural limits,
- Extreme bank angles,
- Propulsion system behavior (e.g., propeller stress, fuel and oil supply, and inlet stability),
- Minimum altitude for recovery,
- Resulting roll rates when the aileron limit is exceeded,
- Position errors and effects on electronic or augmented flight control systems, especially when using the airplane's production airspeed system, and
- Rudder loads, particularly those that may occur with dynamic rudder inputs.

7.4 Dynamic Stability—§ 25.181.

7.4.1 Explanation.

The dynamic stability tests described in this section should be conducted over the speed range of 1.13 V_{SR} to V_{FE}, V_{LE} or V_{FC}/M_{FC}, as appropriate.

7.4.1.1 Dynamic Longitudinal Stability.

7.4.1.1.1 The short period oscillation is the first oscillation the pilot sees after disturbing the airplane from its trim condition with the pitch control (as opposed to the long period (phugoid)). Care should be taken that the control movement used to excite the motion is not too abrupt.

7.4.1.1.2 Heavily damped means that the oscillation has decreased to 1/10 the initial amplitude within approximately two cycles after completion of the control input.

7.4.1.1.3 Short period oscillations must be heavily damped, both with controls free and controls fixed.

7.4.1.2 Dynamic Lateral-Directional Stability.

The evaluation of the dynamic lateral-directional stability should include any combined lateral-directional oscillation ("Dutch roll") occurring over the speed range appropriate to the airplane configuration. This oscillation must be positively damped with controls free and must be controllable with normal use of the primary controls without requiring exceptional piloting skill.

7.4.2 Procedures.

7.4.2.1 **Dynamic Longitudinal Stability.**

7.4.2.1.1 The test for longitudinal dynamic stability is accomplished by a rapid movement or pulse of the longitudinal control in a nose up and nose down direction at a rate and degree necessary to obtain a short period pitch response from the airplane.

7.4.2.1.2 Dynamic longitudinal stability should be checked at a sufficient number of points in each configuration to assure compliance at all operational speeds.

7.4.2.2 **Dynamic Lateral-Directional Stability.**

7.4.2.2.1 A typical test for lateral-directional dynamic stability is accomplished by a rudder doublet input at a rate and amplitude that will excite the lateral-directional response (i.e., Dutch roll). The control input should be in phase with the airplane's oscillatory response.

7.4.2.2.2 Dynamic lateral-directional stability should be checked under all conditions and configurations. If critical, special emphasis should be placed on adverse wing fuel loading conditions.

7.4.2.3 **Airplanes Equipped with Stability Augmentation Systems (SAS).**

7.4.2.3.1 In the event a SAS is required for the airplane to show compliance with § 25.181(a) or (b), it must meet the requirements of §§ 25.671 and 25.672. Additionally:

7.4.2.3.2 If the airplane is equipped with only one SAS (i.e., a single strand system), in accordance with § 25.672, compliance with the dynamic stability requirements of § 25.181(a) or (b), as applicable, must be shown throughout the normal operating flight envelope to be certificated with the SAS operating, and in a reduced, practical operating flight envelope that will permit continued safe flight and landing with the SAS inoperative.

7.4.2.3.3 If the airplane is equipped with more than one SAS, the resulting effects of SAS failure should be considered when determining whether or not the primary and any redundant SAS should be operating simultaneously for showing compliance with the dynamic stability requirements of § 25.181(a) or (b). If the primary and redundant SAS are dissimilar, the functional capability (i.e., control authority) of the redundant SAS should be considered with regard to restricting the operating envelope after failure of the primary SAS. At the applicant's option, however, compliance with

§ 25.181(a) or (b) may still be demonstrated to a reduced flight envelope with no SAS operating as described in paragraph 7.4.2.3.2 above.

7.4.2.3.4 Regardless of the SAS redundancy, the airplane should be safely controllable at the point of system failure or malfunction anywhere in the approved operating flight envelope of the airplane. Accordingly, it should be demonstrated that the airplane remains controllable during transition from the operating SAS to any redundant SAS, and during transition from anywhere in the normal operating envelope to the reduced practical operating envelope of § 25.672(c), if applicable. Airplane controllability should be demonstrated to meet the following levels as defined by the FAA HQRM. (The FAA HQRM is described in appendix E of this AC.)

1. In the normal operating flight envelope with the SAS operating, the handling qualities should be “satisfactory” (SAT) as defined by the FAA HQRM.
2. At the point of SAS failure in the normal operating envelope, the airplane should be “controllable” (CON), as defined by the FAA HQRM, during the short term transitory period required to attain a speed and configuration that will permit compliance with paragraph 3 below.
3. During transition from the primary SAS to a redundant SAS, or from the normal operating envelope to a reduced, practical operating envelope (where applicable), the handling qualities should be “adequate” (ADQ) as defined by the HQRM.
4. In the reduced, practical operating flight envelope that will permit continued safe flight and landing, the handling qualities should be “satisfactory” (SAT) as defined by the HQRM.

CHAPTER 8. FLIGHT: STALLS

8.1 Stall Testing.

8.1.1 Applicable 14 CFR Regulations.

- Section 25.21(c), *Proof of compliance*.
- Section 25.103, *Stall speed*.
- Section 25.143, *Controllability and maneuverability—General*.
- Section 25.201, *Stall demonstration*.
- Section 25.203, *Stall characteristics*.
- Section 25.207, *Stall warning*.

8.1.2 Explanation.

8.1.2.1 The purpose of stall testing is threefold:

8.1.2.1.1 To define the reference stall speeds and how they vary with weight, altitude, and airplane configuration.

8.1.2.1.2 To demonstrate that handling qualities are adequate to allow a safe recovery from the highest angle-of-attack attainable in normal flight (stall characteristics).

8.1.2.1.3 To determine that there is adequate pre-stall warning (either aerodynamic or artificial) to allow the pilot time to recover from any probable high angle-of-attack condition without inadvertently stalling the airplane.

8.1.2.2 During this testing, the angle-of-attack should be increased at least to the point where the behavior of the airplane gives the pilot a clear and distinctive indication through the inherent flight characteristics or the characteristics resulting from the operation of a stall identification device (e.g., a stick pusher) that the airplane is stalled.

8.1.3 Stall Demonstration—§ 25.201.

8.1.3.1 The airplane is considered to be fully stalled when any one or a combination of the characteristics listed below occurs to give the pilot a clear and distinctive indication to cease any further increase in angle-of-attack, at which time recovery should be initiated using normal techniques.

8.1.3.1.1 The pitch control reaches the aft stop and is held full aft for two seconds, or until the pitch attitude stops increasing, whichever occurs later. In the case of turning flight stalls, recovery may be initiated once the pitch control reaches the aft stop when accompanied by a rolling motion that is not immediately controllable (provided the rolling motion complies with § 25.203(c)).

8.1.3.1.2 An uncommanded, distinctive, and easily recognizable nose down pitch that cannot be readily arrested. This nose down pitch may be accompanied by a rolling motion that is not immediately controllable, provided that the rolling motion complies with § 25.203(b) or (c), as appropriate.

8.1.3.1.3 The airplane demonstrates an unmistakable, inherent aerodynamic warning of a magnitude and severity that is a strong and effective deterrent to further speed reduction. This deterrent level of aerodynamic warning (i.e., buffet) should be of a much greater magnitude than the initial buffet ordinarily associated with stall warning. An example is a large transport airplane that exhibits "deterrent buffet" with flaps up and is characterized by an intensity that inhibits reading cockpit instruments and would require a strong determined effort by the pilot to increase the angle-of-attack any further.

8.1.3.1.4 The activation point of a stall identification device that provides one of the characteristics listed above. See paragraph 42.1 of this AC for additional guidance material on demonstrating compliance with the regulatory requirements of part 25 for stall identification systems.

8.1.3.2 It should be recognized that the point at which the airplane is considered stalled may vary, depending on the airplane configuration (e.g., flaps, gear, CG, and gross weight). In any case, the angle-of-attack should be increased until one or more of these characteristics is reached for all likely combinations of variables.

8.1.4 Stall Speeds.

8.1.4.1 **Background.**

Since many of the regulations pertaining to performance and handling qualities specify trim speeds and other variables that are functions of stall speeds, it is desirable to accomplish the stall speed testing early in the program, so the data are available for subsequent testing. Because of this interrelationship between the stall speeds and other critical performance parameters, it is essential that accurate measurement methods be used. Most standard airplane pitot-static systems are unacceptable for stall speed determination. These tests require the use of properly calibrated instruments and usually require a separate test airspeed system.

8.1.4.2 **Configuration.**

8.1.4.2.1 Stall speeds should be determined for all aerodynamic configurations to be certificated for use in the takeoff, en route, approach, and landing configurations.

8.1.4.2.2 The CG positions to be used should be those that result in the highest stall speeds for each weight (forward CG in most cases).

8.1.4.2.3 Sufficient testing should be conducted to determine the effects of weight on stall speed. Altitude effects (compressibility, Reynolds Number) may also be considered if credit for variations in these parameters is sought by the applicant. If stall speeds are not to be defined as a function of altitude, then all stall speed testing should be conducted at a nominal altitude no lower than 1,500 feet above the maximum approved takeoff and landing altitude. (See paragraph 8.1.4.5.7 of this AC.)

8.1.4.3 **Procedures.**

8.1.4.3.1 The airplane should be trimmed for hands-off flight at a speed 13 percent to 30 percent above the anticipated V_{SR}, with the engines at idle and the airplane in the configuration for which the stall speed is being determined. Then, using only the primary longitudinal control for speed reduction, maintain a constant deceleration (entry rate) until the airplane is stalled, as defined in § 25.201(d) and paragraph 8.1.3.1 of this AC. Following the stall, engine power or thrust may be used as desired to expedite recovery.

8.1.4.3.2 A sufficient number of stalls (normally four to eight) should be accomplished at each critical combination of weight, altitude, CG, and external configuration. The intent is to obtain enough data to determine the stall speed at an entry rate not exceeding 1.0 knot/second. During the maneuver for determining stall speeds, the flight controls should be operated smoothly in order to achieve good data quality rather than trying to maintain a constant entry rate because experience has shown that adjusting the flight controls to maintain a constant entry rate leads to fluctuations in load factor and significant data scatter.

8.1.4.3.3 During the stall speed testing, the stall characteristics of the airplane must also satisfy the requirements of § 25.203(a) and (b).

8.1.4.3.4 For airplanes that have stall identification devices for which the angle-of-attack for activation is biased by angle-of-attack rate, some additional considerations are necessary. The stall speeds are normalized against an average airspeed deceleration rate, as described in paragraph 8.1.4.5.5. However, stall identification systems generally activate at a specific angle-of-attack, biased by an instantaneous angle-of-attack rate. Therefore, longitudinal control manipulation by the pilot during the stall maneuver, close to the stall identification system activation point, can advance or delay its activation without appreciably affecting the average stall entry airspeed rate. To minimize scatter in the stall speed versus entry rate data, the pilot should attempt to maintain a stable angle-of-attack rate or pitch rate (not necessarily a fixed airspeed deceleration rate), until the stall identification system activates. The resulting time-history of angle-of-attack data should be smooth and without discontinuities. A cross plot of airspeed deceleration rate, as defined in paragraph 8.1.4.5.5, versus angle-of-attack rate for all related test points, will show the general trend of this relationship for each flap setting. Any points that do not follow this general trend should not be used in establishing the stall speed.

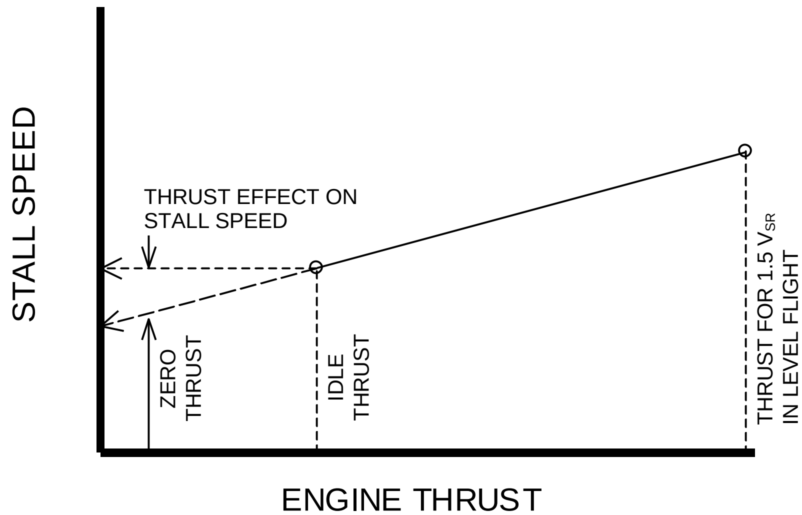
8.1.4.4 **Thrust Effects on Stall Speed.**

8.1.4.4.1 Stall speeds are typically determined with the thrust levers at idle; however, it is necessary to verify by test or analysis that engine idle thrust does not result in appreciably lower stall speeds than would be obtained at zero thrust. Prior to amendment 25-108, a negative idle thrust at the stall, which slightly increases stall speeds, was considered acceptable, but applicants were not required to base stall speeds on idle thrust. With the adoption of amendment 25-108, it became a requirement to base stall speeds on idle thrust, except where that thrust level results in a significant decrease in stall speeds. If idle thrust results in a significant decrease in stall speeds, then stall speeds cannot be based on more than zero thrust.

8.1.4.4.2 To determine whether thrust effects on stall speed are significant, at least three stalls should be conducted at one flap setting, with thrust set to approximately the value required to maintain level flight at 1.5 V_{SR} in the selected configuration.

8.1.4.4.3 These data may then be extrapolated to a zero thrust condition to determine the effects of idle thrust on stall speeds. (See figure 8-1 below.) If the difference between idle thrust and zero thrust stall speed is 0.5 knots or less, the effect may be considered insignificant.

Figure 8-1. Thrust Effect on Stall Speed



8.1.4.4.4 The effects of engine power on stall speeds for a turbopropeller airplane can be evaluated in a similar manner. Stall speed flight tests should be accomplished with engines idling and the propellers in the takeoff position. Engine torque, engine RPM, and estimated propeller efficiency can be used to predict the thrust associated with this configuration.

8.1.4.5 **Data Reduction and Presentation.**

The following is an example of how the data obtained during the stall speed testing may be reduced to standard conditions. Other methods may be found acceptable.

8.1.4.5.1 Record the indicated airspeed from the flight test airspeed system throughout the stall, and correct these values to equivalent airspeed. Also record load factor normal to the flight path. Typically, the load factor data would be obtained from a sufficient number of accelerometers capable of resolving the flight path load factor. It *may* be possible to obtain acceptable data using one accelerometer aligned along the expected 1-g stall pitch angle. More likely, it will take at least two accelerometers, one aligned along the fuselage longitudinal axis and one aligned at 90° to that axis, as well as a means to determine the angle between the flight path and the fuselage longitudinal axis.

8.1.4.5.2 Calculate the airplane lift coefficient (C_L) from the equation given below and plot it as a time history throughout the stall maneuver:

$$C_L = \frac{n_{zw}W}{qS} = \frac{295.37 n_{zw}W}{V_e^2 S}$$

Where:

$$n_{ZW} = Airplane\ load\ factor\ normal\ to\ the\ flight\ path$$

$$W = Airplane\ test\ weight\ (lbs)$$

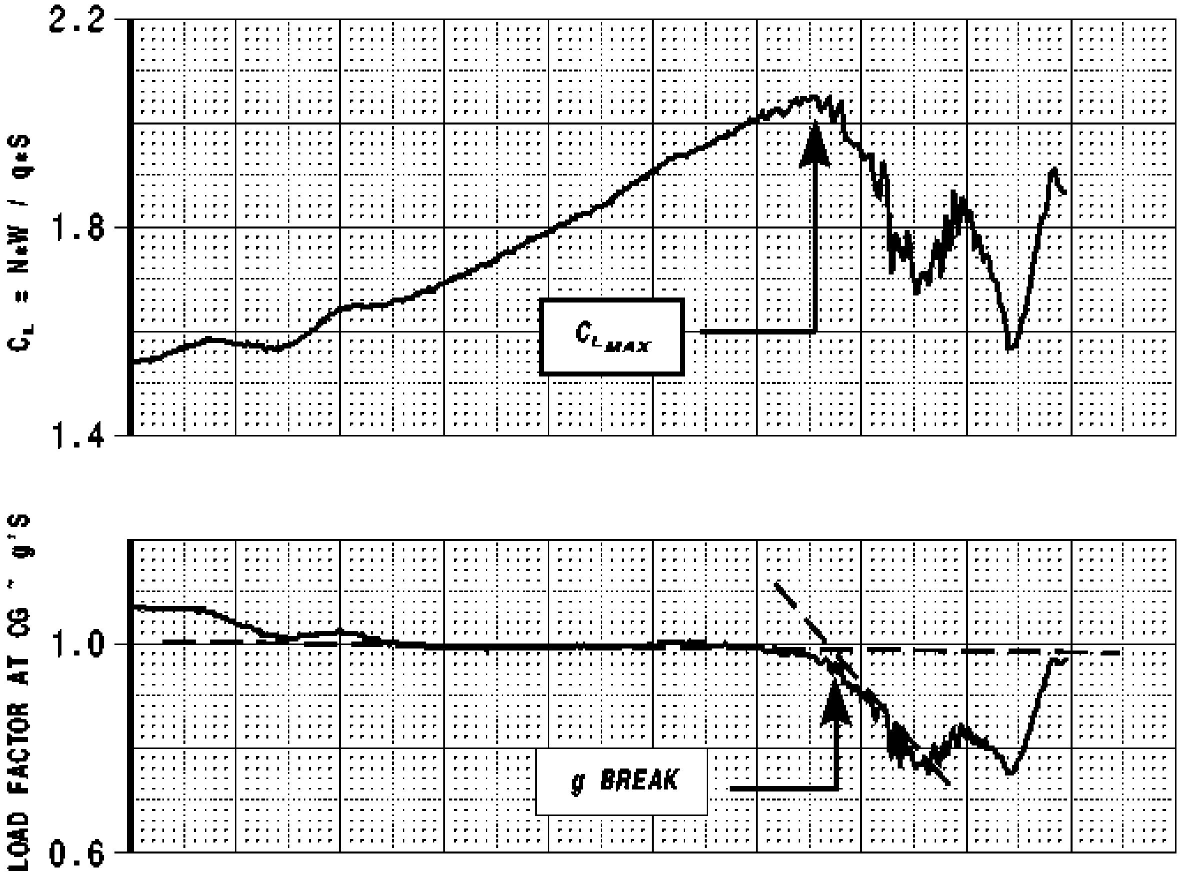
$$q = Dynamic\ pressure\ (lbs/ft^2)$$

$$S = Reference\ wing\ area\ (ft^2)$$

$$V_e = knots\ equivalent\ airspeed$$

8.1.4.5.3 The maximum lift coefficient $C_{L_{MAX}}$ is defined as the maximum value of C_L achieved during the stall test. Where the time history plot of C_L exhibits multiple peak values, $C_{L_{MAX}}$ normally corresponds to the first maximum. However, the peak corresponding to the highest C_L achieved may be used for $C_{L_{MAX}}$, provided it represents usable lift, meaning that it does not occur after deterrent buffet or other stall identification cue (ref. § 25.201(d)). There should also typically be a noticeable break in a plot of the load factor normal to the flight path near the point at which $C_{L_{MAX}}$ is reached. The analysis to determine $C_{L_{MAX}}$should disregard any transient or dynamic increases in recorded load factor, such as might be generated by abrupt control inputs that do not reflect the lift capability of the airplane. The load factor normal to the flight path should be maintained at nominally 1.0 until $C_{L_{MAX}}$ is reached. (See figure 8-2 below.)

Figure 8-2. $C_{L_{MAX}}$ and Load Factor



8.1.4.5.4 Correct the $C_{L_{MAX}}$ obtained for each stall, if necessary, from the test CG position to the targeted CG position, and for any thrust effects, using the equation:

$$C_{L_{MAX}} = C_{L_{MAX\,(test\,CG\,position)}}[1 + (MAC/l_t)(CG_{std} - CG_{test})] - \Delta C_{L_T}$$

Where:

$$MAC = Wing\ mean\ aerodynamic\ chord\ length\ (inches)$$

$$l_t = Effective\ tail\ length, measured\ between\ the\ wing\ 25\ percent\ MAC\ and\ the\ stabilizer\ 25\ percent\ MAC\ (inches)$$

$$CG_{std} = CG\ position\ resulting\ in\ the\ highest\ value\ of\ reference\ stall\ speed, normally\ the\ forward\ CG\ limit\ at\ the\ pertinent\ weight\ (percent\ MAC/100)$$

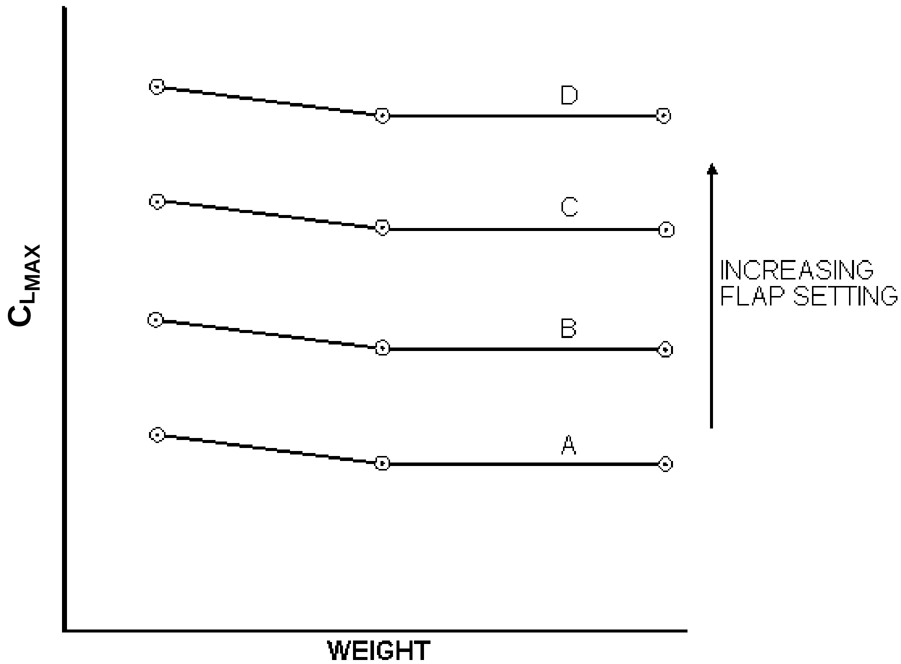
$$CG_{test} = Actual\ test\ CG\ position\ (percent\ MAC/100)$$

$$\Delta C_{L_T} = Change\ in\ C_L\ due\ to\ engine\ thrust\ (if\ effect\ of\ idle\ thrust\ is\ greater\ thatn\ 0.5\ knots\ in\ stall\ speed$$

8.1.4.5.5 Determine the stall entry rate, which is defined as the slope of a straight line connecting the stall speed and an airspeed 10 percent above the stall speed, for each stall test. Because $C_{L_{MAX}}$ is relatively insensitive to stall entry rate, a rigorous investigation of entry rate effects should not be necessary.

8.1.4.5.6 For each approved configuration, construct a plot of $C_{L_{MAX}}$ versus weight. (See figure 8-3 below.)

Figure 8-3. $C_{L_{MAX}}$ versus Weight and Flap Setting



8.1.4.5.7 Flight test safety concerns usually dictate the lowest test altitude for determining stall speeds. The test data should then be expanded to lower altitudes, and hence lower Mach numbers, to cover the operational envelope of the airplane. Since $C_{L_{MAX}}$ usually increases as the Mach number is reduced, simple expansion of the flight test data could result in extrapolating to a higher $C_{L_{MAX}}$ than tested. The expansion of $C_{L_{MAX}}$ versus Mach number data is only permitted up to the highest $C_{L_{MAX}}$ demonstrated within the range of W/δ's tested, unless the continuation of the trend of higher $C_{L_{MAX}}$ with decreasing Mach number is substantiated with other test data. For example, data obtained at a more aft CG position or with power on can be used for this purpose if CG and thrust effects can be accounted for. Data from another airplane in the same family with the same wing and showing the same general trend of $C_{L_{MAX}}$ versus Mach (e.g., a lighter weight variant) may also be used if shown to be applicable.

8.1.4.5.8 The reference stall speed, V_{SR}, is a calibrated airspeed defined by the applicant. V_{SR} may not be less than the 1-g stall speed and is expressed as:

$$V_{SR} \geq \frac{V_{C_{L_{MAX}}}}{\sqrt{n_{zw}}}$$

Where:

$$C_{L_{MAX}} = \sqrt{295.37(n_{zw})(W)/C_{L_{MAX}}S} + \Delta V_C,$$

$$if\ the\ stalling\ maneuver\ is\ limited\ by\ a\ device\ that\ commands\ an\ abrupt\ nose\ down\ pitch\ (e.g., a\ stick\ pusher), C_{L_{MAX}}\ may\ not\ be\ less\ than\ the\ speed\ existing\ at\ the\ instant\ the\ instant\ the\ device\ operates.$$

$$\Delta V_C = Compressibility\ correction\ (i.e., the\ difference\ between\ \textit{equivalent airspeed and calibrated airspeed})$$

$$W = Airplane\ weight\ (lbs)$$

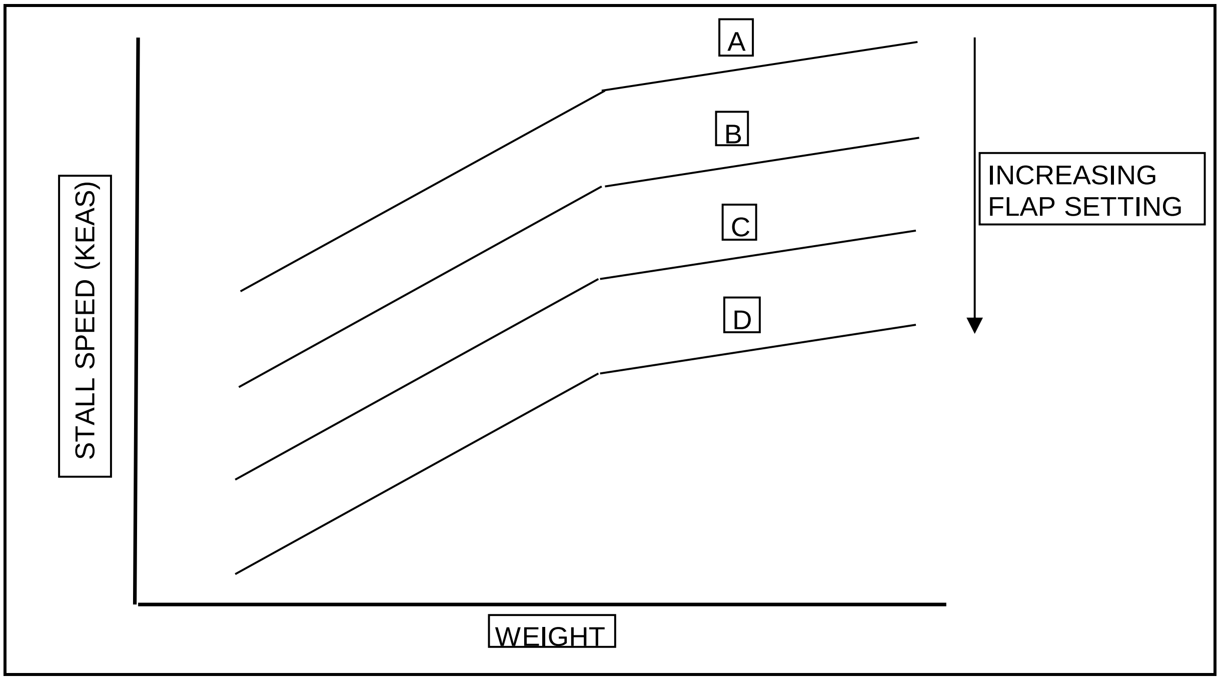
$$n_{zw} = Airplane\ load\ factor\ normal\ to\ the\ flight\ path$$

$$C_{L_{MAX}} = Value\ of\ C_{L_{MAX}}\ corresponding\ to\ the\ chosen\ weight\ (see\ \textit{Figure 8-4 below})$$

$$S = Reference\ wing\ area\ (ft^2)$$

8.1.4.5.9 Construct a plot of reference stall speed versus weight for each flap/gear configuration. (See figure 8-4 below).

Figure 8-4. Stall Speed versus Weight and Flap Setting



8.1.4.5.10 For airplanes equipped with a device that abruptly pushes the nose down at a selected angle-of-attack (e.g., a stick pusher), V_{SR} must not be less than the greater of 2 knots or 2 percent above the speed at which the device activates (§ 25.103(d)).

8.1.4.5.11 In showing compliance with § 25.103(d) for airplanes equipped a device that abruptly pushes the nose down at a selected angle-of-attack (e.g., a stick pusher), the speed at which the device operates need not be corrected to 1 g. Requiring a load factor correction of the device activation speed to the 1-g condition would unnecessarily increase the stringency of § 25.103(d). For example, it would be possible for the device activation speed to be assessed as higher than V_{SR} (or at least closer to V_{SR} than would be obtained without correcting to the 1 g condition). Test procedures should be in accordance with paragraph 8.1.4.3.1 to ensure that no abnormal or unusual pilot control input is used to obtain an artificially low speed at which the device first activates.

8.1.5 <u>Stall Characteristics—§ 25.203.</u>

8.1.5.1 **Background.**

To assure a safe and expeditious recovery from an unintentional stall, it should not require any unusual piloting technique to successfully demonstrate compliance with § 25.203, nor should it require exceptional skill or repeated practice by the test pilot. The behavior of the airplane during the stall and recovery must be easily controllable using normally expected pilot reactions.

8.1.5.2 **Configuration.**

8.1.5.2.1 Stall characteristics should be investigated with wings level and in a 30° banked turn, with both power or thrust on and power or thrust off in all configurations approved for normal operations.

8.1.5.2.2 The test configurations for stall characteristics should include deployed deceleration devices for all flap positions, unless limitations against the use of those devices with particular flap positions are imposed. Deceleration devices include spoilers used as airbrakes, and thrust reversers approved for inflight use. Stall demonstrations with deceleration devices deployed should normally be carried out with power or thrust off, except where deployment of the deceleration devices with power or thrust on would likely occur in normal operations (e.g., extended spoilers during landing approach).

8.1.5.2.3 Stall characteristics should be investigated with any systems or devices that may alter the stalling behavior of the airplane in their normal functioning mode. Unless the design of the airplane's automatic flight control system precludes its ability to operate beyond the stall warning angle-of-attack, stall characteristics and the adequacy of stall warning should be evaluated when the airplane is stalled under the control of the automatic flight control system.

8.1.5.2.4 Power-off stalls should be conducted at flight idle for the appropriate configuration. For propeller-driven airplanes, the propeller should be set in the normal low pitch (high RPM) position.

8.1.5.2.5 For power-on stalls, power or thrust should be set to the value required to maintain level flight at a speed of 1.5 V_{SR} at the maximum landing weight with flaps in the approach position, and the landing gear retracted. The approach flap position referred to is the maximum flap deflection used to show compliance with § 25.121(d), which specifies a configuration in which the reference stall speed does not exceed 110 percent of the reference stall speed for the related landing configuration.

8.1.5.2.6 Stall characteristics testing is normally done at the aft CG limit, which is typically the most adverse; however, if the stall speed tests at forward CG indicate that marginal stall recovery characteristics may exist at forward CG, compliance with § 25.203 should be shown for the most critical loading.

8.1.5.2.7 In accordance with § 25.21(c), stalls must be demonstrated up to the maximum approved operating altitude to determine if there are any adverse compressibility effects on stall characteristics. These tests should be flown with gear and flaps up at the most adverse CG. Power or thrust may be set, as required, to maintain approximately level flight and a 1 knot/second deceleration. A slight descent rate is permissible as long as the stall occurs at approximately the maximum approved altitude. Characteristics should be checked during a wings level stall and in a 30° banked turn.

8.1.5.2.8 For abnormal aerodynamic configurations covered by AFM procedures, high angle-of-attack characteristics should be evaluated down to the speed reached one second after stall warning in a one knot/second deceleration with the wings level and at idle power or thrust. If there are no adverse characteristics and there is adequate controllability, it is not necessary to stall the airplane. Adequate controllability means that it is possible to produce and to correct pitch, roll, and yaw by unreversed use of the flight controls, and that there are no uncommanded airplane motions due to aerodynamic flow breakdown. The applicant should also demonstrate that the airplane is safely controllable and maneuverable when flown at the recommended operating speed.

8.1.5.2.9 Stall characteristics should also be demonstrated with the maximum allowable asymmetric fuel loading. Requirements are as specified in § 25.203(a) and (c).

8.1.5.3 **Procedures.**

8.1.5.3.1 The airplane should be trimmed for hands-off flight at a speed 13 percent to 30 percent above the reference stall speed, with the appropriate power or thrust setting and configuration. Then, using only the primary longitudinal control, establish and maintain a deceleration (stall entry rate) consistent with that specified in § 25.201(c)(1) or (c)(2), as appropriate, until the airplane is stalled. Both power/thrust and pilot selectable trim should remain constant throughout the stall and recovery (to where the angle-of-attack has decreased to the point of no stall warning).

8.1.5.3.2 The same trim reference (for example, 1.23 V_{SR}) should be used for both the stall speeds and characteristics testing. For all stall testing, the trim speed is based on the stall speeds provided in the AFM.

8.1.5.3.3 During the approach to the stall, the longitudinal control pull force should increase continuously as speed is reduced from the trimmed speed to the onset of stall warning. Below that speed some reduction in longitudinal control force is acceptable, provided it is not sudden or excessive.

8.1.5.3.4 Section 25.203(b) states that “the roll occurring between the stall and the completion of the recovery may not exceed approximately 20 degrees” for level wing stalls. In level wing stalls the bank angle may exceed 20° occasionally, provided that lateral control is effective during recovery.

8.1.5.3.5 Section 25.203(c) requires the action of the airplane, following the 30° bank turning stalls, "not be so violent or extreme" such that a prompt recovery would be difficult and require more than normal piloting skill. The maximum bank angle that occurs during the recovery should not exceed approximately 60° in the original direction of the turn, or 30° in the opposite direction.

8.1.5.3.6 The intent of evaluating the 3 knot per second deceleration rate required under § 25.201(c)(2) is to demonstrate safe characteristics at higher rates of increase in angle-of-attack than are obtained from the 1 knot per second stalls. The specified airspeed deceleration rate, and associated angle-of-attack rate, should be maintained up to the point at which the airplane stalls. The maximum bank angle that occurs during the recovery should not exceed approximately 90° in the original direction of the turn, or 60° in the opposite direction.

8.1.5.3.7 For those airplanes where stall is defined by full nose-up longitudinal control for both forward and aft CG, the time at full aft stick during characteristics testing should be not less than that used for stall speed determination. For turning flight stalls, however, recovery may be initiated once the pitch control reaches the aft stop when accompanied by a rolling motion that is not immediately controllable (provided the rolling motion complies with § 25.203(c)).

8.1.5.3.8 As required by § 25.203(a), normal use of the lateral control must produce (or correct) a roll, and normal use of the directional control must produce (or correct) a yaw in the applied direction up to the point where the airplane is considered stalled. It must be possible to prevent or recover from a stall by normal use of the controls.

8.1.5.3.9 If wind tunnel tests have indicated an airplane may be susceptible to deep stall penetration (i.e., that area beyond the stall angle-of-attack from which recovery may be difficult or impossible), substantiation should be provided that there is adequate recovery control available at, and sufficiently beyond, the stall angle-of-attack.

8.1.6 Stall Warning—§ 25.207.

8.1.6.1 **Explanation.**

The purpose of these stall warning requirements is to provide an adequate spread between warning and stall to allow the pilot time to recover without inadvertently stalling the airplane.

8.1.6.2 **Background.**

To be acceptable, a stall warning must have the following features:

8.1.6.2.1 Distinctiveness.

The stall warning indication must be clear and distinct to a degree that will ensure positive pilot recognition of an impending stall.

8.1.6.2.2 Timeliness.

For one knot per second entry rate stalls, the stall warning must begin at a speed, V_{SW}, not less than five knots or five percent (whichever is greater) above the speed at which the stall is identified in accordance with § 25.201(d). For straight flight stalls, at idle power or thrust and with the CG at the position specified in § 25.103(b)(5), the stall warning must begin at a speed not less than three knots or three percent (whichever is greater) above the reference stall speed. These speed margins should be in terms of the same units of measurement as V_{SR} (i.e., calibrated airspeed).

8.1.6.2.3 Consistency.

The stall warning should be reliable and repeatable. The warning must occur with flaps and gear in all normally used positions in both straight and turning flight (§ 25.207(a)) and must continue throughout the stall demonstration until the angle-of-attack is reduced to approximately that at which the stall warning was initiated (§ 25.207(c)). The warning may be furnished naturally through the inherent aerodynamic characteristics of the airplane, or artificially by a system designed for this purpose. If artificial stall warning is provided for any airplane configuration, it must be provided for all configurations (§ 25.207(b)).

8.1.6.2.4 An artificial stall warning indication that is a solely visual device which requires attention in the cockpit, inhibits cockpit conversation or, in the event of malfunction, causes distraction that would interfere with safe operation of the airplane, is not acceptable.

8.1.6.2.5 For airplanes that use artificial stall warning systems, paragraph 42.1 of this AC presents guidance material for demonstrating compliance with the regulatory requirements of part 25.

8.1.6.2.6 If the stall warning required by § 25.207 is provided by an artificial stall warning system (e.g., a stick shaker), the effect of production tolerances on the stall warning system should be considered when evaluating the stall warning margin required by § 25.207(c) through (f) and the maneuver capabilities required by § 25.143(h).

8.1.6.2.7 The stall warning margin required by § 25.207(c) through (f) should be available with the stall warning system set to the most critical setting expected in production. Unless another setting would provide a lesser margin, the stall warning system should be operating at its high angle-of-attack limit. For airplanes where V_{SR} is set by a device that abruptly pushes the nose down at a selected angle-of-attack (e.g., a stick pusher), the stall warning margin may be evaluated with both the stall warning and stall identification (e.g., stick pusher) systems at their nominal angle-of-attack settings unless a lesser margin can result from the various system tolerances.

8.1.6.2.8 The maneuver capabilities required by § 25.143(h) should be available assuming the stall warning system is operating on its nominal setting. When the stall warning system is operating at its low angle-of-attack limit, the maneuver capabilities should not be reduced by more than 2° of bank angle from those specified in § 25.143(h). A flight test, an acceptable analysis, or simulation can be used to make this assessment.

8.1.6.2.9 The stall warning margin and maneuver capabilities may be demonstrated by flight testing at the most critical settings specified above for the stall warning and, if so equipped, stall identification systems. Alternatively, compliance may be shown by applying adjustments to flight test data obtained at a different system setting if an acceptable method is used that takes into account all of the relevant variables.

8.1.6.3 **Procedures.**

Stall warning tests are normally conducted in conjunction with the stall testing required by § 25.103 (stall speeds), § 25.201 (stall demonstration), and § 25.203 (stall characteristics), including consideration of the prescribed bank angles, power or thrust settings, and CG position. The pilot technique in stalling the airplane should be consistent between the onset of stall warning and the point at which the stall is identified. That is, there should not be any deliberate attempt to reduce the load factor, change the deceleration, or use any other means to increase the stall warning margin. In addition, if the stall warning margin may be affected by a system (e.g., a stall warning or stick pusher system that modifies the stall warning or stall identification speed as a function of power or thrust, bank angle, angle-of-attack rate, etc.), compliance with § 25.207(c) should be demonstrated at the most critical conditions in terms of stall warning margin. However, for this case, bank angles greater than 40° and power or thrust exceeding maximum continuous power or thrust need not be demonstrated. If the effect of the stall identification or stall warning system compensation is to increase the stall warning margin relative to the nominal values demonstrated during the testing required by §§ 25.103, 25.201, and 25.203, these additional stall warning margin demonstrations need not be done.

8.1.6.4 **Data Acquisition and Reduction.**

The stall warning speed and type and quality of warning should be noted. To determine if the required margin exits, compare the speed at which acceptable stall warning begins with (1) the stall identification speed, and (2) V_{SR} (for the conditions under which V_{SR} is defined). The stall warning margin comparisons should be made at a constant 1-g load factor when showing compliance with § 25.207(d).

8.1.7 Accelerated Stall Warning.

8.1.7.1 **Explanation.**

Section 25.207(f) requires that, in slow-down turns with at least a 1.5 g load factor normal to the flight path and an airspeed deceleration rate greater than 2 knots per second, sufficient stall warning is provided to prevent stalling when the pilot takes recovery action not less than one second after recognition of stall warning. The purpose of the requirement is to ensure that adequate stall warning exists to prevent an inadvertent stall under the most demanding conditions that are likely to occur in normal flight. The elevated load factor will emphasize any adverse stall characteristics, such as wing drop or asymmetric wing flow breakdown, while also investigating Mach and potential aeroelastic effects on available lift.

8.1.7.2 **Procedures.**

8.1.7.2.1 Trim at 1.3 V_{SR}. Once trimmed, accelerate to a speed that will allow enough time to set up and complete the maneuver at the specified load factor and airspeed deceleration rate. Set power or thrust appropriate to the power or thrust for level flight at 1.3 V_{SR} and do not adjust it during the maneuver. In a level flight maneuver, 1.5 g equates to a bank angle of 48°. To prevent an excessive deceleration rate (e.g., greater than 3 knots per second), a descent may be used. Conversely, if the deceleration rate is too low, the maneuver should be conducted in a climbing turn.

8.1.7.2.2 After the onset of stall warning, continue the maneuver without releasing stick force for one second before attempting recovery. Normal low speed recovery techniques should be used. If any of the indications of a stall prescribed in § 25.201(d) (see paragraph 8.1.3.1 of this AC) occur during the accelerated stall warning demonstration, compliance with § 25.207(f) will not have been demonstrated.

8.1.8 Maneuver Margins.

See paragraph 5.1 of this AC for guidance material associated with demonstrating compliance to the maneuvering capability requirements of § 25.143(h).

8.1.9 Additional Considerations for Airplanes Equipped with Stall Identification Systems.

A stall identification system is any system that is used to show compliance with § 25.201(d), which requires the airplane to give the pilot a clear and distinctive indication of stall. The stall identification system consists of everything from the sensing devices that supply inputs to the system to the activation of the system response that provides stall identification to the flightcrew. Section 25.1309(a) requires that such a system, when it is needed to show compliance with the stall-related requirements, be designed to perform its intended function under any foreseeable operating condition.

8.1.9.1 The applicant should verify that the stall identification system, considering system design features (e.g., filtering, phase advancing) and airplane and system production tolerances will not result in an unsafe diminishing of the margin between stall warning and stall identification, or between stall identification and any hazardous airplane flight characteristic in any foreseeable operating condition. This verification may be provided by a combination of analysis, simulation, and flight test. The following operating conditions should not result in unwanted activation of the stall identification system or in aerodynamic stall prior to, or close to, activation of the stall warning system: dynamic and accelerated stall entries, the effects of atmospheric turbulence, any foreseeable type of wing contamination (e.g., ice, frost, insects, dirt, anti-icing fluids), or wing leading edge damage within prescribed maintenance limits. Operation in windshear environments where the airplane will be flown at, or very near, stall warning, should also be considered, although, depending on the severity of the windshear, it may be impossible to ensure that there is no possibility of stall indication system operation. For wing contamination, the applicant should substantiate the critical height and density of the contaminant. Carborundum sandpaper No. 40 (that is, 40-grit carborundum sandpaper) has been used in past certification programs to represent residual ice or frost contamination.

8.1.9.2 Stall characteristics testing should be performed with the following airplane and stall identification system production tolerances set to achieve the most adverse stall identification system activation condition for stall characteristics:

8.1.9.2.1 Airframe build tolerances—the impact of wing angle of incidence variation relative to stall identification system vane angle; and

8.1.9.2.2 Stall identification system tolerances (e.g., activation vane angles).

8.1.9.3 If the combined root-sum-square (square root of the sum of the squares of each tolerance) effect of the tolerances identified above is less than ±1 knot, stall speeds testing can be performed and the stall speeds determined with the tolerances at their nominal values. If the combined root-sum-square effect is ±1 knot or greater, stall speed testing should be performed with the tolerances at the values that would result in the highest stall speeds.

8.1.10 Reliability of Artificial Stall Warning and Stall Identification Systems.

Additional guidance material related to the testing and approval of artificial stall warning and stall identification systems is presented in paragraph 42.1 of this AC.

CHAPTER 9. FLIGHT: GROUND AND WATER HANDLING CHARACTERISTICS

9.1 Part 25 Regulations.

The applicable regulations are §§ 25.231, 25.233, 25.235, 25.237, and 25.239.

9.2 Longitudinal Stability and Control—§ 25.231.

9.2.1 Explanation.

Test program objectives would not be expected to demonstrate taxiing over rough surfaces at speeds high enough to approach structural design limits, nor is it expected that in the test program the airplane be landed harder or at higher sink rates than it will ever encounter in service. However, new or modified landing gear systems should be evaluated on rough surfaces that are representative of normal service, and landings should be conducted at various sink rates sufficient to identify any dangerous characteristics or tendencies. Variables to be considered are CG and taxi speed. The cockpit motion dynamics during ground handling should not impede control of the airplane, and pitching motion during bounce should not create static pitch control problems or pilot induced oscillation tendencies.

9.2.2 Procedures.

Ground handling tests at speeds normally expected in service should be conducted on smooth and rough surfaces that are likely to be encountered under normal operating conditions. Particular attention should be paid to the following:

9.2.2.1 Brakes.

The adequacy of the brakes when maneuvering on the ground and the tendency of the brakes to cause nosing-over should be investigated. Any bad tendency will normally be exaggerated when taxiing in a strong cross or tail wind.

9.2.2.2 Seaplanes and Amphibians.

The most adverse water conditions safe for taxiing, takeoff, and landing must be established per § 25.231(b). Procedure and limitations for using reverse thrust should be determined.

9.3 Directional Stability and Control—§ 25.233.

9.3.1 Explanation.

None.

9.3.2 Procedures.

Taxi, takeoff, and landing should be conducted in all configurations under normal operating conditions.

9.3.2.1 There may be no uncontrollable ground-looping tendency in 90° crosswinds, up to a wind velocity of 20 knots or 0.2 V_{SR0}, whichever is greater (except that the wind velocity need not exceed 25 knots) at any speed at which the airplane may be expected to be operated on the ground. This may be shown while establishing the 90° crosswind component required by § 25.237.

9.3.2.2 Landplanes must be satisfactorily controllable, without exceptional piloting skill or alertness in power-off landings at normal landing speed, without using brakes or engine power or thrust to maintain a straight path. This may be shown during power-off landings made in conjunction with other tests.

9.3.2.3 The airplane must have adequate directional control during taxiing. This may be shown during taxiing prior to takeoffs made in conjunction with other tests.

9.4 Taxiing Condition—§ 25.235. [Reserved]

9.5 Wind Velocities—§ 25.237.

9.5.1 Explanation.

9.5.1.1 **Landplanes.**

9.5.1.1.1 There must be a 90° crosswind component established that is shown to be safe for takeoff and landing on dry runways.

9.5.1.1.2 The airplane must exhibit satisfactory controllability and handling characteristics in 90° crosswinds at any ground speed at which the airplane is expected to operate.

9.5.1.2 **Seaplanes and Amphibians.**

9.5.1.2.1 There must be a 90° crosswind component established that is shown to be safe for takeoff and landing in all water conditions that may reasonably be expected in normal operation.

9.5.1.2.2 There must be a wind velocity established for which taxiing is safe in any direction under all water conditions that may reasonably be expected in normal operation.

9.5.1.3 **Crosswind Demonstration.**

A 90° crosswind component at 10 meters (as required by § 25.21(f)) of at least 20 knots or 0.2 V_{SR0} (where V_{SR0} is for the maximum design landing weight), whichever is greater, except that it need not exceed 25 knots, must be demonstrated during type certification tests. There are two results possible:

9.5.1.3.1 A crosswind component value may be established that meets the minimum requirements but is not considered to be a limiting value for airplane handling characteristics. This demonstrated value should be included as information in the AFM.

9.5.1.3.2 A crosswind component value may be established that is considered to be a maximum limiting value up to which it is safe to operate for takeoff and landing. This limiting value should be shown in the operating limitations section of the AFM.

9.5.2 Procedures.

9.5.2.1 **Configuration.**

These tests should be conducted in the following configurations:

9.5.2.1.1 At light weight and aft CG. (This is desirable; however, flexibility should be permitted.)

9.5.2.1.2 Normal takeoff and landing flap configurations using the recommended procedures.

9.5.2.1.3 Normal usage of thrust reversers. Particular attention should be paid to any degradation of rudder effectiveness due to thrust reverser airflow effects.

9.5.2.1.4 Yaw dampers/turn coordinator On, or Off, whichever is applicable.

9.5.2.2 **Test Procedures.**

Three takeoffs and three landings, with at least one landing to a full stop, should be conducted in a 90° crosswind component of at least 20 knots or 0.2 V_{SR0}, whichever is greater, except that it need not exceed 25 knots. For each test condition, a qualitative evaluation by the pilot of airplane control capability, forces, airplane dynamic reaction in gusty crosswinds (if available), and general handling characteristics should be conducted. The airplane should be satisfactorily controllable without requiring exceptional piloting skill or strength. If thrust reversers are installed, these landings should be conducted with the thrust reversers deployed as per normal procedures and additional landings should be conducted at the critical reverse thrust/power level to verify that there are no unsatisfactory handling characteristics.

9.5.2.3 **Test data.**

Crosswind data may be obtained from a calibrated flight test wind measurement station, from an airfield wind reporting device, or from any other method acceptable to the FAA.

9.5.2.3.1 A calibrated flight test wind measurement station located in the vicinity of the liftoff or touchdown point generally provides the most accurate data and is preferable.

9.5.2.3.2 An airport wind reporting device may also be acceptable provided the device has been calibrated and is located near the runway being used for testing.

9.5.2.3.3 Crosswind data taken directly from a commercially available inertial or differential GPS based reference system may not be accurate in sideslips and is not accurate on the ground. During landing, filtering may introduce lags making the data incorrect due to wind shear with altitude (i.e., a higher wind value at altitude is "remembered"). Hence this method is considered unsuitable for accurately determining the crosswind during takeoff and landing.

9.5.2.3.4 Other methods based on the computation of the actual crosswind encountered by the airplane based on on-board measurements are also acceptable. For example, the crosswind can be computed by resolving the difference between true airspeed (from an ADC) and an accurate ground speed measurement (e.g., derived from IRS groundspeed) into the along-runway and across-runway heading taking into account the airplane heading, track angle and sideslip.

9.5.2.3.5 No matter which method is used, the wind should be continuously time-recorded throughout the takeoff from brake release (or any low speed above which all data necessary to the computation are available and of sufficient accuracy) to a height of 50 feet, and throughout the landing from a height of 50 feet to termination of the test event (e.g., full stop, touch-and-go, go-around) or any low speed above which all data necessary to the computation are available and of sufficient accuracy. The measured crosswind component should be corrected from the height of the measurement device to a height of 10 meters. The average crosswind at 90° to the runway heading should then be calculated for the above time span. The maximum gust could also be derived during this process, based on the same time span.

9.5.2.3.6 With prior agreement from the FAA, it may also be permissible to obtain crosswind data from tower wind reports. However, the use of this method should be carefully reviewed to ensure that the measurement sensor is properly calibrated to establish the measurement sensor reference height, to establish that the smoothing characteristics do not produce unacceptable filtering, and that the location of the measurement sensor is appropriate for the takeoff and landing runway(s). Such a method has the disadvantage of not being able to provide the gust value during takeoff and landing.

9.6 Spray Characteristics, Control, and Stability on Water—§ 25.239.

9.6.1 Explanation.

These characteristics should be investigated at the most adverse weight/CG combinations.

9.6.2 Procedures.

9.6.2.1 The spray characteristics and, in particular, the pilot view during the initial takeoff run, should allow sufficient view in order to maintain a reasonable track over the water. Since not all seaplane operations are on open lakes or bays, but can be on rivers or channels, the directional control and view should be sufficient enough to stay within the channel confines.

9.6.2.2 The tendency of the wing floats or sponsons to submerge and/or cause waterloops should be evaluated during the crosswind testing. During the step taxiing evaluations, the floats should also be evaluated for any tendency to bury and either cause waterlooping or damage. The procedures used to avoid undesirable characteristics should be included in the AFM.

9.6.2.3 During low speed taxi, the effectiveness of the water rudders and/or asymmetric power or thrust should be evaluated in view of the types of maneuvering to be expected in service. If reverse thrust is to be used, it too should be evaluated in terms of ease of accomplishment and crew coordination.

9.6.2.4 If an amphibian is intended to be “beached” or run up a ramp, the handling characteristics and ability to maneuver onto the ramp should be evaluated. Forward CG is generally more critical. The procedures should be included in the AFM. There should be no undue tendency to damage the bow or other structure.

9.6.2.5 Engine failure of the critical engine at any time during the takeoff run should be evaluated. No dangerous porpoising, swerving, or waterlooping should result.

9.6.2.6 There should be no undue tendency to porpoise and no extraordinary skill or alertness should be required to control porpoising.

9.6.2.7 Spray impingement on the airframe (control surfaces, etc.) should be evaluated to assure the resulting loads are within acceptable limits.

9.6.2.8 The above evaluations should be performed in the airplane on the water rather than by analysis or model testing. Analysis and/or model testing may be used to point out the problem areas but should not be substituted for actual testing.

CHAPTER 10. FLIGHT: MISCELLANEOUS REQUIREMENTS

10.1 Vibration and Buffeting—§ 25.251.

10.1.1 Explanation.

10.1.1.1 The testing required by subpart C of part 25 covers the vibration extremes expected in service. The applicant's flight tests should assure that the regulatory limits are not exceeded. Flight testing should not be conducted beyond where structural (subpart C) tests and calculations have been completed.

10.1.1.2 For § 25.251(b) and (c), vibration and buffeting is considered excessive when it is determined that it:

10.1.1.2.1 May cause structural damage or, if sustained over an extended period of time, could lead to structural fatigue;

10.1.1.2.2 May cause pilot fatigue or annoyance that interferes with operation of the airplane or management of the airplane systems; or

10.1.1.2.3 Interferes with flight instrument readability.

10.1.1.3 No perceptible buffeting is permitted in the cruise configuration as required by § 25.251(d). Weight and/or altitude AFM limitations may need to be imposed to comply with this criterion. Reasonable buffet during the deployment of spoilers and other high drag devices is permitted to the extent allowed under § 25.251(b) and (c), as described in paragraph 10.1.1.2 above.

10.1.1.4 For airplanes with M_D greater than 0.6 or with a maximum operating altitude greater than 25,000 feet, the buffet onset envelope must be established for the ranges of airspeed and/or Mach number, weight, altitude, and load factor for which the airplane is to be certificated. This envelope must be provided in the AFM in accordance with § 25.1585(d). These AFM data should be valid criteria for forward CG conditions or correctable to forward CG by the use of AFM procedures. This boundary should be established by pilot qualitative evaluation or by correlation with pilot qualitative evaluation, as there is no predetermined criterion for buffet level at the pilot station. A normal acceleration of ±0.05 g has been used in some cases; however, the appropriate acceleration level will vary from airplane to airplane and may also be affected by the dynamic response of the accelerometer. If a measured normal acceleration is to be used, the acceleration level and specific accelerometer should first be correlated against a pilot's assessment of the onset of buffet.

10.1.1.5 Modifications to airplanes, particularly modifications that may affect airflow about the wing, should be evaluated for their effect on vibration and buffeting characteristics, changes in the speeds for onset of buffet, and maneuvering characteristics beyond buffet onset. This change may not only impact the buffet boundary envelope, but may change the acceptability of the V_{MO}/M_{MO} or V_{DF}/M_{DF} speeds established on the unmodified airplane. If this occurs, the maximum operating speed and demonstrated flight diving speed may need to be reduced. However, the regulations concerning the speed spread margin between $V_{MO}M_{MO}$ and V_{DF}/M_{DF} remain in effect. Systems and flight characteristics affected by the reduced maximum speeds should also be reevaluated. Indicator markings, overspeed horns, etc. must be reset, as necessary, to remain in compliance with the applicable regulations.

10.1.1.6 On swept-wing airplanes, undesirable pitch-up maneuvering characteristics can occur as the center of lift moves inboard and forward with increasing g, due to shock-wave induced separation and/or as wing load alleviation systems unload the wingtips. Straight-wing airplanes can also exhibit similar characteristics; therefore, new airplanes and those modified in a manner that may affect the spanwise lift distribution or produce undesirable pitching moment as a function of g, or increase the exposure to high altitude buffet encounters, should be evaluated as described herein.

10.1.1.7 Section 25.251(e) requires that "probable inadvertent excursions beyond the boundaries of buffet" may not result in "unsafe conditions." In order to assure that no unsafe conditions are encountered in maneuvering flight, maneuvering flight evaluations to demonstrate satisfactory maneuvering stability are described below. A determination of the longitudinal maneuvering characteristics should be made to assure the airplane is safely controllable and maneuverable in the cruise configuration to assure there is no danger of exceeding the airplane limit load factor, and that the airplane's pitch response to the primary longitudinal control is predictable to the pilot.

10.1.2 Procedures.

10.1.2.1 **Section 25.251(a).**

The test procedures outlined below will provide the necessary flight demonstrations for compliance with § 25.251(a).

10.1.2.2 **Section 25.251(b).**

The airplane should be flown at V_{DF}/M_{DF} at several altitudes from the highest practicable cruise altitude to the lowest practicable altitude. The test should be flown starting from trimmed flight at V_{MO}/M_{MO} at a power or thrust setting not exceeding maximum continuous power or thrust. The airplane gross weight should be as high as practicable for the cruise condition, with the CG at or near the forward limit. In addition, compliance with § 25.251(b) should be demonstrated with high drag devices (i.e., speed brakes) deployed at V_{DF}/M_{DF}. Thrust reversers, if designed for inflight deployment, should be deployed at their limit speed conditions.

10.1.2.3 **Section 25.251(c).**

The weight of the airplane should be as heavy as practical, commensurate with achieving the maximum certificated altitude.

10.1.2.4 **Section 25.251(d).**

It should be demonstrated in flight tests that perceptible buffeting does not occur in straight flight in the cruise configuration, at any speed up to V_{MO}/M_{MO}, to show compliance with § 25.251(d). This should be met from initial combinations of critical weight and altitude, if achievable, where the airplane has a 0.3 g margin to the buffet onset boundary developed under § 25.251(e). These initial conditions should be established using a nominal cruise Mach number (typically long-range cruise Mach, M_{LRC}) with the CG at the forward limit. This flight condition is representative of practical operating criteria imposed by most operators. From these initial conditions, the airplane should be accelerated in 1 g flight to V_{MO}/M_{MO} using maximum continuous power or thrust. Descending flight is acceptable if needed to achieve V_{MO}/M_{MO}.

10.1.2.5 **Section 25.251(e).**

Section 25.251(e) requires the determination of the buffet onset envelope, in the cruise configuration, for airplanes with M_D greater than 0.6 or maximum operating altitudes greater than 25,000 feet. This requirement also provides criteria for evaluation of maneuvering stability in cruise flight under load factor conditions up to and beyond the onset of buffet.

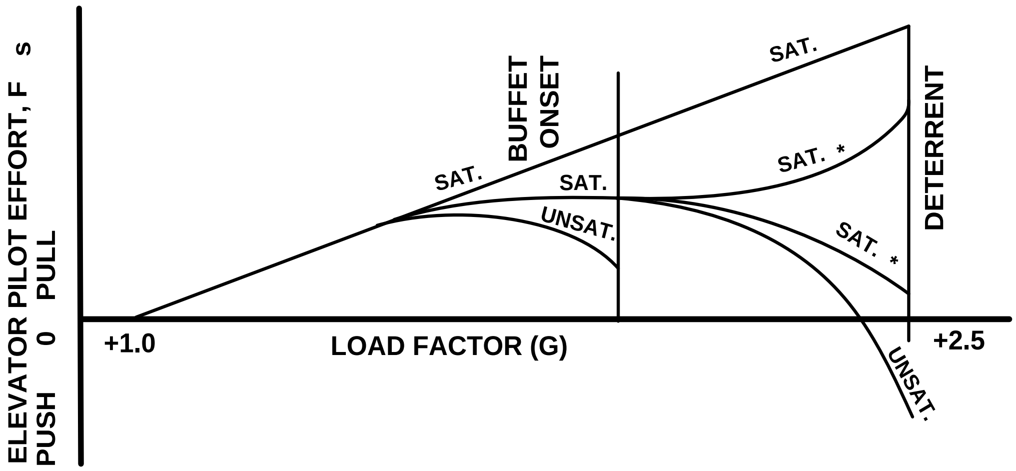
10.1.2.6 The determination of compliance with § 25.251(e), using flight test data from maneuvers conducted well into buffet, is extremely difficult due to the dynamics of this type of maneuver and the establishment of the F_S/g relationship from such data. The pilot flying the airplane needs to evaluate the airplane characteristics under such conditions. Figure 31-1 provides guidance on stick force per g (F_S/g) characteristics that would be considered acceptable or unacceptable.

10.1.2.7 For determination of the buffet onset envelope, the flight tests should be conducted at forward CG. For maneuvering characteristics, airplanes should be evaluated at the most aft CG in accordance with the following criteria:

10.1.2.7.1 For all weight/altitude combinations where buffet onset occurs at various load factors between approximately +1 g and +2 g, the longitudinal control force (F_S) characteristics of § 25.255(b)(1) and (2) apply prior to encountering that buffet onset. See figure 10-1 of this AC.

Note: The characteristics shown in figure 10-1 are satisfactory only in accordance with paragraphs 10.1.2.7.1 above and 10.1.2.7.2 below.

Figure 10-1. Maneuvering Characteristics at Speeds up to V_{MO}/M_{MO}



10.1.2.7.2 Under the airplane weight/altitude combinations of paragraph 10.1.2.7.1 above, but at load factors beyond buffet onset, the following F_S characteristics apply (see figure 10-1):

1. The evaluation should proceed to a g level that will allow recovery to be accomplished near +2.5 g, unless sufficient buffet or other phenomena (natural, artificial, or a combination) of such intensity exists that is a strong and effective deterrent to further pilot application of nose-up longitudinal control force (as in § 25.201(d)(2)) so that there is no danger of exceeding the airplane limit load factor. (See § 25.143(b)).

Note: A strong and effective deterrent is analogous to that required for stall identification; stick shaker or stall warning buffet are not considered to be an adequate end point for these tests.

2. Any pitching tendency (uncommanded changes in load factor) should be mild and readily controllable.
3. Sufficient control should be available to the pilot, through unreversed use of only the primary longitudinal control, to affect a prompt recovery to +1 g flight from the load factors described herein.
4. The airplane's pitch response to primary longitudinal control should be predictable to the pilot.

10.1.2.7.3 Experience has shown that maneuvering evaluations conducted at the highest Mach and the highest weight and altitude (W/δ) combination may not necessarily produce the most critical results. Equally important is the character of the buffet buildup (e.g., slowly increasing or rapid rise, and the g at which it starts). Conditions associated with buffet onset near 2 g at Mach numbers below M_{MO} have sometimes yielded the most critical characteristics. Therefore, a sufficient spread of conditions should be evaluated.

10.2 **High Speed Characteristics—§ 25.253.**

10.2.1 Explanation.

10.2.1.1 The maximum flight demonstrated dive speed, V_{DF}/M_{DF}, selected by the applicant, is used along with V_D/M_D when establishing V_{MO}/M_{MO} in accordance with the associated speed margins under the provisions of § 25.1505. Both V_{MO}/M_{MO} and V_{DF}/M_{DF} are then evaluated during flight tests for showing compliance with § 25.253.

10.2.1.2 The pitch upset defined in § 25.335(b), as amended by amendment 25-23, or defined in § 25.1505, prior to amendment 25-23, provides a means for determining the required speed margin between V_{MO}/M_{MO} and both V_D/M_D and V_{DF}/M_{DF}. The operational upsets expected to occur in service for pitch, roll, yaw, and combined axis upsets are evaluated when showing compliance to § 25.253 and must not result in exceeding V_D/M_D or V_{DF}/M_{DF}.

10.2.1.3 In general, the same maneuvers should be accomplished in both the dynamic pressure and Mach critical ranges. All maneuvers in either range should be accomplished at power/thrust and trim points appropriate for the specific range. Some maneuvers in the Mach range may be more critical for some airplanes due to drag rise characteristics, and at high altitudes a lower gross weight may be required to achieve the maximum approved operating altitude and Mach/airspeed conditions.

10.2.1.4 The airplane’s handling characteristics in the high speed range should be investigated in terms of anticipated action on the part of the flightcrew during normal and emergency conditions.

10.2.1.5 At least the following factors should be considered in determining the necessary flight tests:

10.2.1.5.1 Effectiveness of longitudinal control at V_{MO}/M_{MO} and up to V_{DF}/M_{DF}.

10.2.1.5.2 Effect of any reasonably probable mistrim on upset and recovery.

10.2.1.5.3 Dynamic and static stability.

10.2.1.5.4 The speed increase resulting from likely passenger movement when trimmed at any cruise speed to V_{MO}/M_{MO}.

10.2.1.5.5 Trim changes resulting from compressibility effects.

10.2.1.5.6 Characteristics exhibited during recovery from inadvertent speed increase.

10.2.1.5.7 Upsets due to vertical and horizontal gusts (turbulence).

10.2.1.5.8 Speed increases due to horizontal gusts and temperature inversions.

10.2.1.5.9 Effective and unmistakable aural speed warning at V_{MO} plus 6 knots, or M_{MO} plus 0.01 M.

10.2.1.5.10 Speed and flight path control during application of deceleration devices.

10.2.1.5.11 Control forces resulting from the application of deceleration devices.

10.2.1.6 Section 25.1505 states that the speed margin between V_{MO}/M_{MO}, and V_D/M_D or V_{DF}/M_{DF}, as applicable, "may not be less than that determined under § 25.335(b) or found necessary during the flight tests conducted under § 25.253." Note that one speed margin must be established that complies with both § 25.335(b) and § 25.253. Therefore, if the applicant chooses a V_{DF}/M_{DF} that is less than V_D/M_D, then V_{MO}/M_{MO} must be reduced by the same amount (i.e., compared to what it could be if V_{DF}/M_{DF} were equal to V_D/M_D) in order to provide the required speed margin to V_{DF}/M_{DF}. In determining the speed margin between V_{MO}/M_{MO} and V_{DF}/M_{DF} during type certification programs, the factors outlined in paragraph 10.2.1.5 above should also be considered in addition to the items listed below:

10.2.1.6.1 Increment for production tolerances in airspeed systems (0.005 M), unless larger differences are found to exist.

10.2.1.6.2 Increment for production tolerances of overspeed warning error (0.0l M).

10.2.1.6.3 Increment ΔM due to speed overshoot from M_{MO}, established during flight tests in accordance with § 25.253, should be added to the values for production differences and equipment tolerances. The value of M_{MO} may not be greater than the lowest value obtained from each of the following equations, which reflect the requirements of §§ 25.253 and 25.1505:

$$M_{MO} \leq M_{DF} - \Delta M - 0.005M - 0.01M$$

Or

$$M_{MO} \leq M_{DF} - 0.01M$$

Note: The combined minimum increment may be reduced from 0.07 M to as small as 0.05 M if justified by the rational analysis used to show compliance with § 25.335(b)(2).

10.2.1.6.4 At altitudes where V_{MO} is limiting, the increment 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.

10.2.1.6.5 Increment ΔV due to speed overshoot from V_{MO}, established during flight tests in accordance with § 25.253, 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 equation, and from § 25.1505:

$$V_{MO} \leq V_{DF} - \Delta V - 3\ knots - 6\ knots$$

Where:

$$3\ knots = Production\ differences$$

$$6\ knots = Equipment\ tolerances$$

10.2.1.6.6 For an airplane with digital interface between the airspeed system and the overspeed warning system, the production tolerance for the warning system may be deleted when adequately substantiated.

10.2.2 Affected Regulations.

These criteria refer to certain provisions of part 25. They may also be used in showing compliance with the corresponding provisions of the former Civil Air Regulations (CARs) in the case of airplanes for which these regulations apply. Other affected CFR are as follows:

- Section 25.175(b)regarding demonstration of static longitudinal stability in cruise condition.
- Section 25.251, *Vibration and buffeting*.
- Section 25.253, *High-speed characteristics*.
- Section 25.335(b) regarding design dive speed (V_D).
- Section 25.1303(b)(1) and (c) regarding required flight and navigation instruments.
- Section 25.1505, *Maximum operating limit speed*.

10.2.3 Procedures.

Using the speeds V_{MO}/M_{MO} and V_{DF}/M_{DF} determined in accordance with §§ 25.1505 and 25.251, respectively, and the associated speed margins, the airplane should be shown to comply with the high-speed characteristics of § 25.253. Unless otherwise stated, the airplane characteristics should be investigated beginning at the most critical speed up to and including V_{MO}/M_{MO}, and the recovery procedures used should be those selected by the applicant, except that the normal acceleration during recovery should be no more than 1.5 g (total). Testing should be conducted with the CG at the critical position and generally perpendicular to local wind aloft.

10.2.3.1 **CG Shift.**

The airplane should be upset by the CG shift corresponding to the forward movement of a representative number of passengers (and/or serving carts) depending upon the airplane interior configuration. The airplane should be permitted to accelerate until 3 seconds after V_{MO}/M_{MO}.

10.2.3.2 **Inadvertent Speed Increase.**

Simulate an evasive control application when trimmed at V_{MO}/M_{MO}, by applying sufficient forward force to the pitch control to produce 0.5 g (total) for a period of 5 seconds, after which recovery should be initiated at not more than 1.5 g (total).

10.2.3.3 **Gust Upset.**

In the following three upset tests, 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.

10.2.3.3.1 With the airplane trimmed in wings-level flight, simulate a transient gust by rapidly rolling to the maximum bank angle appropriate for the airplane, but not less than 45° nor more than 60°. The rudder and longitudinal control should be held fixed during the time that the required bank is being attained. The rolling velocity should be arrested at this bank angle. Following this, the controls should be abandoned for a minimum of 3 seconds after V_{MO}/M_{MO} or 10 seconds, whichever occurs first.

10.2.3.3.2 Perform a longitudinal upset from normal cruise. Airplane trim is determined at V_{MO}/M_{MO} using power/thrust required for level flight but with not more than maximum continuous power/thrust. (If V_{MO}/M_{MO} cannot be reached in level flight with maximum continuous power or thrust, then the airplane should be trimmed at V_{MO}/M_{MO} in as shallow a descent as practicable that allows V_{MO}/M_{MO} to be reached.) This is followed by a decrease in speed, after which a pitch attitude of 6-12° nose down, as appropriate for the airplane type, is attained using the same power/thrust and trim. The airplane is permitted to accelerate until 3 seconds after V_{MO}/M_{MO}. The force limits of § 25.143(d) for short term application apply.

10.2.3.3.3 Perform a two-axis upset, consisting of combined longitudinal and lateral upsets. Perform the longitudinal upset, as in paragraph 10.2.3.3.2 above, and when the pitch attitude is set, but before reaching V_{MO}/M_{MO}, roll the airplane 15-25°. The established attitude should be maintained until 3 seconds after V_{MO}/M_{MO}.

10.2.3.4 **Leveling Off from Climb.**

Perform transition from climb to level flight without reducing power or thrust below the maximum value permitted for climb until 3 seconds after V_{MO}/M_{MO}. Recovery should be accomplished by applying not more than 1.5 g (total).

10.2.3.5 **Descent from Mach Airspeed Limit Altitude.**

A descent should be performed at the airspeed schedule defined by M_{MO} and continued until 3 seconds after V_{MO}/M_{MO} occurs, at which time recovery should be accomplished without exceeding 1.5 g (total).

10.2.3.6 **Roll Capability, § 25.253(a)(4).**

10.2.3.6.1 Configuration.

- Wing flaps retracted.
- Speedbrakes retracted and extended.
- Landing gear retracted.
- Trim: The airplane trimmed for straight flight at V_{MO}/M_{MO}. The trimming controls should not be moved during the maneuver.
- Power: (1) All engines operating at the power required to maintain level flight at V_{MO}/M_{MO}, except that maximum continuous power need not be exceeded; and (2) if the effect of power is significant, with the throttles closed.

10.2.3.6.2 Test Procedure.

An acceptable method of demonstrating that roll capability is adequate to assure prompt recovery from a lateral upset condition is as follows:

1. Establish a steady 20° banked turn at a speed close to V_{DF}/M_{DF} limited to the extent necessary to accomplish the following maneuver and recovery without exceeding V_{DF}/M_{DF}. Using lateral control alone, it should be demonstrated that the airplane can be rolled to a 20° bank angle in the opposite direction in not more than 8 seconds. The demonstration should be made in the most adverse direction. The maneuver may be unchecked.
2. For airplanes that exhibit an adverse effect on roll rate when rudder is used, it should also be demonstrated that use of rudder to pick up the low wing in combination with the lateral control will not result in a roll capability significantly below that specified above.

10.2.3.7 **Extension of Speedbrakes.**

10.2.3.7.1 The following guidance is provided to clarify the meaning of the words "the available range of movements of the pilot's control" in § 25.253(a)(5) and to provide guidance for demonstrating compliance with this requirement. Normally, the available range of movements of the pilot's control includes the full physical range of movements of the speedbrake control (i.e., from stop to stop). Under some circumstances, however, the available range of the pilot's control may be restricted to a lesser range associated with in-flight use of the speedbrakes. A means to limit the available range of movement to an in-flight range may be acceptable if it provides an unmistakable tactile cue to the pilot when the control reaches the maximum allowable in-flight position and compliance with § 25.697(b) is shown for positions beyond the in-flight range. Additionally, the applicant's recommended procedures and training must be consistent with the intent to limit the in-flight range of movements of the speedbrake control.

10.2.3.7.2 Section 25.697(b) requires that lift and drag devices intended only for ground operation have means to prevent the inadvertent operation of their controls in flight if that operation could be hazardous. If speedbrake operation is limited to an in-flight range, operation beyond the in-flight range of available movement of the speedbrake control must be shown to be not hazardous. Two examples of acceptable, unmistakable tactile cues for limiting the in-flight range are designs incorporating either a gate or both a detent and a substantial increase in force to move the control beyond the detent. It is not an acceptable means of compliance to restrict the use of or available range of the pilot's control solely by means of an AFM limitation or procedural means.

10.2.3.7.3 The effect of extension of speedbrakes may be evaluated during other high speed testing (for example, paragraph 10.1.2.2 and paragraphs 10.2.3.1 through 10.2.3.5 of this AC) and during the development of emergency descent procedures. It may be possible to infer compliance with § 25.253(a)(5) by means of this testing. To aid in determining compliance with the qualitative requirements of this rule, the following quantitative values may be used as a generally acceptable means of compliance. A positive load factor should be regarded as excessive if it exceeds 2 g. A nose-down pitching moment may be regarded as small if it necessitates an incremental force of less than 20 lbs to maintain 1 g flight. These values may not be appropriate for all airplanes, and will depend on the characteristics of the particular airplane design in high speed flight. Other means of compliance may be acceptable, provided that compliance has been shown to the qualitative requirements specified in § 25.253(a)(5).

10.3 Out-of-Trim Characteristics—§ 25.255.

10.3.1 Explanation.

Certain early, trimmable stabilizer equipped jet transports experienced “jet upsets” that resulted in high speed dives. When the airplane was mistrimmed in the nose-down direction and allowed to accelerate to a high airspeed, it was found that there was insufficient elevator power to recover. Also, the stabilizer could not be trimmed in the nose-up direction, because the stabilizer motor stalled due to excessive airloads imposed on the horizontal stabilizer. As a result, a special condition was developed and applied to most part 25 airplanes with trimmable stabilizers. With certain substantive changes, it was adopted as § 25.255, effective with amendment 25-2. While these earlier problems seem to be generally associated with airplanes having trimmable stabilizers, it is clear from the preamble discussions to amendment 25-42 that § 25.255 applies “regardless of the type of trim system used in the airplane.” Section 25.255 is structured to give protection against the following unsatisfactory characteristics during mistrimmed flight in the higher speed regimes:

10.3.1.1 Changes in maneuvering stability leading to overcontrolling in pitch.

10.3.1.2 Inability to achieve at least 1.5 g for recovery from upset due to excessive control forces.

10.3.1.3 Inability of the flightcrew to apply the control forces necessary to achieve recovery.

10.3.1.4 Inability of the pitch-trim system to provide necessary control force relief when high control force inputs are present.

10.3.2 Discussion of § 25.255.

10.3.2.1 Section 25.255(a) is the general statement of purpose. Maneuvering stability may be shown by a plot of applied control force versus normal acceleration at the airplane CG. Mistrim must be set to the greater of the following:

10.3.2.1.1 Section 25.255(a)(l).

A 3-second movement of the longitudinal trim system at its normal rate for the particular flight condition with no aerodynamic load. Since many modern trim systems are variable rate systems, this subsection requires that the maneuver condition be defined and that the no-load trim rate for that condition be used to set the degree of mistrim required. For airplanes that do not have power-operated trim systems, experience has shown a suitable amount of longitudinal mistrim to be applied is that necessary to produce a 30-lb control force, or reach the trim limit, whichever occurs first.

10.3.2.1.2 Section 25.255(a)(2).

The maximum mistrim that can be sustained by the autopilot while maintaining level flight in the high speed cruising condition. The high speed cruising condition corresponds to the speed resulting from maximum continuous power or thrust, or V_{MO}/M_{MO}, whichever occurs first. Maximum autopilot mistrim may be a function of several variables, and the degree of mistrim should therefore correspond to the conditions of test. In establishing the maximum mistrim that can be sustained by the autopilot, the normal operation of the autopilot and associated systems should be taken into consideration. If the autopilot is equipped with an auto-trim function, then the amount of mistrim that can be sustained, if any, will generally be small. If there is no auto-trim function, consideration should be given to the maximum amount of out-of-trim that can be sustained by the elevator servo without causing autopilot disconnect.

10.3.2.2 Section 25.255(b) establishes the basic requirement to show positive maneuvering stability throughout a specified acceleration envelope at all speeds to V_{FC}/M_{FC}, and the absence of longitudinal control force reversals throughout that acceleration envelope at speeds between V_{FC}/M_{FC} and V_{DF}/M_{DF}. (Later subsections (d) and (e) recognize that buffet boundary and control force limits will limit the acceleration actually reached; this does not account for Mach trim gain, etc.)

10.3.2.2.1 The out-of-trim condition for which compliance must be shown with § 25.255(b) is specified in § 25.255(a). For the initial trimmed condition before applying the mistrim criteria, the airplane should be trimmed at:

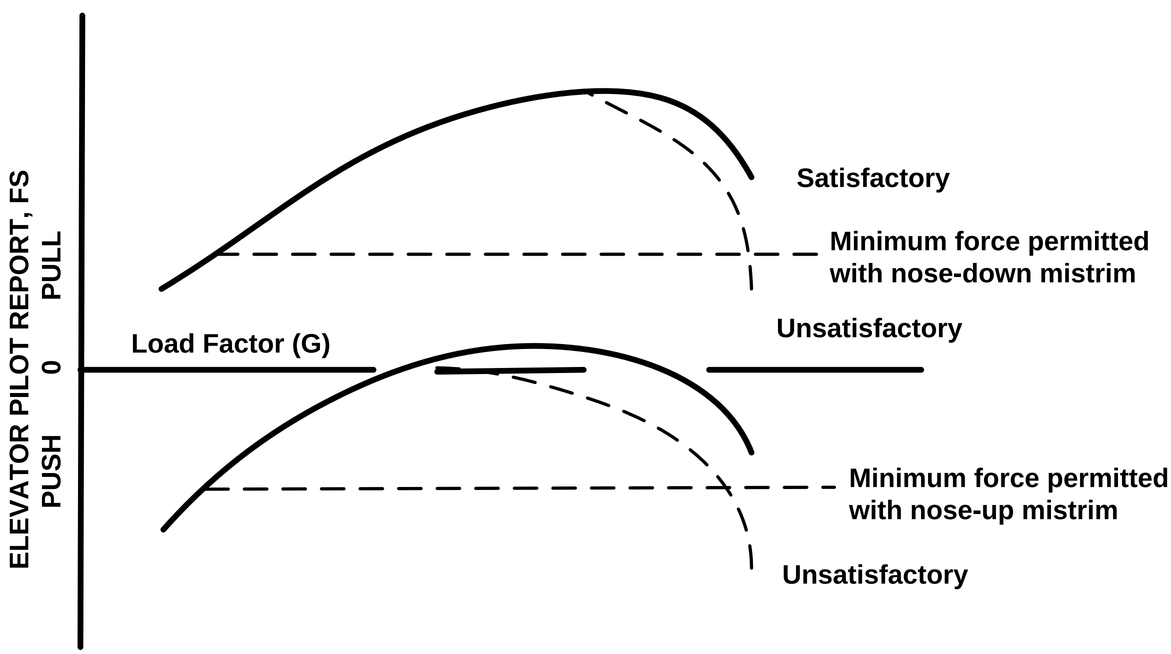
- For speeds up to V_{MO}/M_{MO}, the particular speed at which the demonstration is being made; and
- For speeds higher than V_{MO}/M_{MO}, V_{MO}/M_{MO}.

10.3.2.2.2 Section 25.255(b)(2) appears to indicate that unstable airplane characteristics would be satisfactory, regardless of the character of the primary longitudinal control force as load factor is increased, as long as the force did not reverse (e.g., from a pull to a push). While such criteria may have merit for evaluating airplanes when starting the maneuver from a trimmed condition, it can be shown that this provides a poor specification for evaluating an airplane's maneuvering characteristics when starting the test from the specified mistrimmed condition. For example, an airplane would be deemed to have unacceptable characteristics with a nose-up mistrim, if while relaxing the large initial elevator push force to increase the load factor to the specified value, the elevator force just happened to cross through zero to a slight pull force at one load factor, and then back through zero to a push force at a higher load factor. Such an airplane's characteristics are clearly superior to one that has a severe elevator force slope reversal, during the same maneuver, but never reaches a zero elevator force condition as the load factor is increased. A literal interpretation of § 25.255(b)(2) would find this airplane to be compliant, while finding the preceding airplane non-compliant because it had a slight reversal of the primary longitudinal control force.

10.3.2.2.3 Section 25.255(b)(2) should be interpreted to mean that the primary longitudinal control force, for load factors greater than 1.0, may not be less than that used to obtain the initial 1 g flight condition. This is illustrated in figure 10-2 below. Slight control force reversals, as discussed in paragraph 10.3.2.2.1 above will be permitted for speeds between V_{FC}/M_{FC} and V_{DF}/M_{DF} only if:

- No severe longitudinal control force slope reversals exist;
- Any pitching tendency (uncommanded changes in load factor) should be mild and readily controllable; and
- The airplane's pitch response to primary longitudinal control should be predictable to the pilot.

Figure 10-2. Mistrimmed Maneuvering Characteristics: Speeds Between V_{FC}/M_{FC} and V_{DF}/M_{DF}



10.3.2.3 Section 25.255(c) requires that the investigation of maneuvering stability (§ 25.255(b)) include all attainable acceleration values between –l g and +2.5 g. Sections 25.333(b) and 25.337, to which it refers, limit the negative g maximum to 0 g at V_D. Section 25.251 further limits the g to that occurring in probable inadvertent excursions beyond the buffet onset boundary at those altitudes where buffet is a factor.

10.3.2.4 Section 25.255(c)(2) allows for extrapolation of flight test data by an acceptable method. For example, if the stick force gradient between 0 and +2 g agrees with predicted data, extrapolation to -1 g and 2.5 g should be allowed.

10.3.2.5 Section 25.255(d) requires flight tests to be accomplished from the normal acceleration at which any marginal stick force reversal conditions are found to exist to the applicable limits of § 25.255(b)(1). This requirement takes precedence over the extrapolation allowance described in paragraph 10.3.2.4 above.

10.3.2.6 Section 25.255(e), limits the investigation to the required structural strength limits of the airplane and maneuvering load factors associated with probable inadvertent excursions beyond the boundary of the buffet onset envelope. It also accounts for the fact that speed may increase substantially during test conditions in the -1 g to +1 g range. It limits the entry speed to avoid exceeding V_{DF}/M_{DF}.

10.3.2.7 Section 25.255(f) requires that, in the out-of-trim condition specified in § 25.255(a), it be possible to produce at least 1.5 g during recovery from the overspeed condition of V_{DF}/M_{DF}. If adverse flight characteristics preclude the attainment of this load factor at the highest altitude reasonably expected for recovery to be initiated at V_{DF}/M_{DF} following an upset at high altitude, the flight envelope (CG, V_{DF}/M_{DF}, altitude, etc.) of the airplane should be restricted to a value where 1.5 g is attainable. If trim must be used for the purpose of obtaining 1.5 g, it must be shown to operate with the primary control surface loaded to the least of three specified values.

10.3.2.7.1 The force resulting from application of the pilot limit loads of § 25.397 (300 lbs).

10.3.2.7.2 The control force required to produce 1.5 g (between 125 and 300 lbs).

10.3.2.7.3 The control force corresponding to buffeting or other phenomena of such intensity that it is a strong deterrent to further application of primary longitudinal control force.

10.3.3 Procedures.

10.3.3.1 Compliance is determined by the characteristics of F_S/g (normally a plot). Any standard flight test procedure that yields an accurate evaluation of F_S/g data in the specified range of speeds and acceleration should be considered for acceptance. Bounds of investigation and acceptability are set forth in the rule and in discussion material above, and broad pilot discretion is allowed in the selection of maneuvers.

10.3.3.2 **Investigation Range.**

Out-of-trim testing should be done at the most adverse loading for both high and low control forces. Testing should be accomplished both at the dynamic pressure (q) and Mach limits.

10.3.3.3 The ability to move the primary controls (including trim), when loaded, should be considered prior to the tests.

CHAPTER 11. STRUCTURE [RESERVED]

CHAPTER 12. DESIGN AND CONSTRUCTION: GENERAL [RESERVED]

CHAPTER 13. DESIGN AND CONSTRUCTION: CONTROL SURFACES [RESERVED]

CHAPTER 14. DESIGN AND CONSTRUCTION: CONTROL SYSTEMS

14.1 General—§ 25.671.

14.1.1 Explanation.

This material deals with the all-engines out case of § 25.671(d). The intent of this rule is to assure that in the event of failure of all engines, the airplane will be controllable, and an approach and landing flare possible. This may be done by analysis where the method is considered reliable.

14.1.2 Procedures.

14.1.2.1 In accordance with § 25.671(d), the airplane must be controllable when all engines fail. Compliance should be shown for each approved configuration. The airplane should remain controllable following the failure of the engines. Reconfiguration, if possible with all engines failed, is permitted. Any such reconfiguration should be included in the AFM operating procedures for an all engines failed condition.

14.1.2.2 The effectiveness of the emergency power to drive the airplane control system, whether generated from a windmilling engine or an auxiliary power supply, should be demonstrated in flight.

14.1.2.3 Past approaches to showing compliance with § 25.671(d) have been to show that the airplane is controllable following the failure of all engines in the climb, cruise, descent, approach, and holding configurations and can be flared to a landing attitude from a reasonable approach speed.

14.1.2.4 For airplanes with fully powered or electronic flight control systems, the non-normal procedures section of the approved AFM should contain appropriate operating procedures and a statement similar to the following:

“The airplane has a fully powered (or electronic) control system that is dependent upon engine windmill RPM, or an auxiliary power supply, to provide the necessary source of control system power in the event all engines fail in flight. A minimum airspeed of XXX knots IAS will provide adequate hydraulic or electrical power for airplane controllability in this emergency condition.”

14.2 Flap and Slat Interconnections—§ 25.701.

14.2.1 Explanation.

In accordance with § 25.701(a), if the wing flaps are not mechanically interconnected, tests or analysis should be conducted to show that the airplane has safe flight characteristics with asymmetric flap or slat deployment.

14.2.2 Reference.

See AC 25-22 for additional guidance.

14.2.3 Procedures.

Simulate appropriate flap and slat malfunctioning during takeoffs, approaches, and landings to demonstrate that the airplane is safe under these conditions. To be considered safe, adequate stall margins and controllability should be retained without requiring exceptional piloting skill or strength. Additionally, there should be no hazardous change in altitude or attitude during transition to the asymmetric condition considering likely transition rates.

14.3 Takeoff Warning System—§ 25.703. [Reserved]

CHAPTER 15. DESIGN AND CONSTRUCTION: LANDING GEAR

15.1 Retracting Mechanism—§ 25.729.

15.1.1 Explanation.

None.

15.1.2 Procedures.

15.1.2.1 In accordance with the provisions of § 25.729, flight tests should be conducted to demonstrate the ability of the landing gear and associated components, in their heaviest configuration, to properly extend and retract at:

15.1.2.1.1 V_{LO} (the placard airspeed) in the cruise configuration at near 1 g flight and normal yaw angles; and

15.1.2.1.2 Airspeeds and flap settings corresponding to typical landings. The landing gear operating placard airspeed, V_{LO}, established in accordance with § 25.1515(a), should not exceed the 1.6 V_{S1} design value of § 25.729(a)(1)(ii).

Note: "Normal" yaw angles are those associated with engine-out flight and counteracting crosswinds of up to 20 knots.

15.1.2.2 The alternate extend system should be demonstrated at airspeeds up to V_{LO} at near 1 g flight and normal yaw angles. An envelope of emergency extension capability should be established and presented in the emergency operating procedures section of the AFM. (Refer to the note under paragraph 15.1.2.1.2 above.)

15.1.2.3 **Operation Test—§ 25.729(d).**

15.1.2.3.1 The engine-out gear retraction time should be determined from flight tests with one engine at idle power or thrust and the operating engine(s) adjusted to provide the lowest thrust-to-weight ratio to be certificated. The hydraulic system should be in the critical configuration corresponding to an actual engine failure condition. The airplane should be stabilized on a steady heading before gear retraction is initiated. The resulting gear retraction time will be used in developing AFM takeoff flight path performance information in accordance with § 25.111.

15.1.2.3.2 Gear retraction time is the time from landing gear lever movement to the "UP" position until the last landing gear, including doors, is in the retracted configuration. Allowance should be made for any delays associated with the landing gear indication system.

15.1.2.4 Position indication and aural warning, § 25.729(e): It should be confirmed that the actual landing gear position agrees with the position indicated on the landing gear indicator. Landing gear aural warning should meet the intent of § 25.729(e)(2) through (e)(4). A combination of flight tests, ground tests, and analysis may be used to show compliance with these requirements.

15.2 **Wheels—§ 25.731.**

15.2.1 References.

- TSO-C135a, *Transport Airplane Wheels and Wheel and Brake Assemblies*, dated July 1, 2009.
- Paragraph 15.4.2.5 of this AC, *Wheel Fuse Plugs*.
- Paragraph 15.4.10 of this AC, *Wheel Fuse Plug Integrity*.
- AC 21-29D.

15.2.2 Explanation.

15.2.2.1 Original guidelines for wheels in § 4b.335 of the Civil Air Regulations (CAR) were superseded by TSO-C26 and subsequent revisions. Early versions of TSO-C26 referred to minimum standard requirements in versions of Society of Automotive Engineers (SAE) Aeronautical Standard (AS) 227. Minimum standards were subsequently specified in TSO-C26b and later revisions. For braked wheels, wheels and brakes must be approved under § 25.735(a) as an assembly in recognition of design and safety interdependencies associated with thermal control, vibration control, structural stresses, etc. Paragraphs 15.4.2.5 and 15.4.10 of this AC provide insight into the criticality of proper fuse function to support airworthiness. As demands increased for longer life wheels and more robust designs, changes were introduced such as the addition of combined vertical and side loads for a portion of roll testing; an increase in roll miles at maximum static load from 1,000 to 2,000 miles; and addition of a roll-on-rim requirement to increase robustness in wheel flange areas.

15.2.2.2 In most cases, wheels are usually removed from service based upon condition. Typically, inspection frequency will increase as life on a particular wheel is accumulated in accordance with the wheel and brake supplier’s component maintenance manual (CMM). If wheel failures occur on the airplane, they typically occur when the airplane is on the ground with wheel and tire assembly loaded.

15.2.2.3 The trend in certain airplane manufacturer specifications is to place additional longevity and safety focused test requirements on wheel and brake suppliers. Added requirements, such as fail safe design verification(s), testing to failure of uncorroded and corroded wheels, and mandated use of over pressurization protection devices (in addition to fuses) have been incorporated. With the introduction of longer life tires, the demands on wheels and components, such as wheel bearings, have further intensified as landings between inspections at tire overhauls have increased. In addition, airplane manufacturers should be involved in wheel design, test, and manufacturer approvals to ensure that airplane specific needs have been addressed. For example, at least one airplane manufacturer specifies a missing wheel tie bolt requirement so that minimum equipment list (MEL) dispatch relief can be provided for a limited number of cycles. As a second example, individual airplane manufacturers may specify intensified wheel load and/or test requirements to account for various tire failure modes on multi-wheeled landing gear truck and other airplane landing gear configurations. Therefore, continued airworthiness of a particular wheel/tire or wheel/brake/tire assembly is usually demonstrated by compliance with airplane manufacturer requirements and not TSO minimum standards.

15.2.2.4 Separate wheel applicable TSO and (if applicable) airplane manufacturer tests are performed with radial and bias tires due to different tire-to-wheel interface loading and resultant wheel stress pattern and deflection/clearance differences. For braked wheels, separate wheel and brake assembly tests are performed with radial and bias tires due to differences in tire energy absorption that may be encountered. Some significant differences in wheel life have been reported by one wheel and brake supplier in one case using bias tires from different tire manufacturers. Typically, however, wheel/tire, or wheel/brake/tire assembly tests using different manufacturer bias tires have not been shown to be necessary.

15.2.2.5 Wheel bearings in transport category airplane wheels should be qualified as part of the wheel assembly. Industry experience indicates that qualification of a specific manufacturer’s bearing(s) in a given wheel assembly is required to assure proper performance and airworthiness. Standard part bearing assemblies are not acceptable unless performance can be demonstrated during wheel qualification testing. It has been reported that roller end scoring is the most common mechanism leading to bearing failures on the airplane.

15.2.2.6 Improved wheel bearing grease and bearing preload retention means have also been introduced on some recent airplanes to increase wheel bearing longevity in the severe landing gear system environments and account for longer tire lives/ increased intervals between tire changes and inspections. Bearing wheel grease recommendations are usually specified in wheel and brake supplier CMMs. Intermixing of bearing cups/rollers/cones from different bearing manufacturers is not recommended on some large transport category airplane wheels due to different roller end scoring resistance capabilities and other often subtle differences.

15.2.3 Procedures/Method of Compliance.

Due to the unique and critical nature of wheel, and wheel and brake designs, and historical airplane and personnel safety problems that have been experienced, compliance should only be approved upon successful completion of all applicable tests. We recommend guidance be solicited from the original wheel and brake supplier(s) (e.g., technical standard order authorization (TSOA) or letter of design approval (LODA) holder) on any replacement part(s) to assure that continued airworthiness is not degraded.

15.3 Tires—§ 25.733.

[Reserved]

15.4 Brakes—§ 25.735.

15.4.1 References.

- TSO-C135a, *Transport Airplane Wheels and Wheel and Brake Assemblies,* dated July 1, 2009.
- AC 25-22.
- AC 25.735-1.

15.4.2 Explanation.

15.4.2.1 **Background.**

15.4.2.1.1 The original objective of § 25.735 (formerly § 4b.337) developed from a study to define a reasonable brake life for operational landings. This element is still retained in current § 25.735(f)(1), which requires substantiation that the wheel, brake, and tire assembly have the ability to absorb the energy resulting from an operational landing stop at maximum landing weight. Compliance with this requirement is shown through dynamometer testing.

15.4.2.1.2 It later became evident that a rejected takeoff could be critical in determining overall brake capability, and the maximum RTO energy absorption capability by the brakes could limit the aircraft maximum allowable gross weight for dispatch.

15.4.2.1.3 Investigation of an RTO overrun accident, in which 80 percent of the brakes on the subject airplane were at or very near their completely worn state, brought about the need to consider the effect of brake wear state on energy absorption capability, and stopping capability. As a result, the FAA issued a series of specific airworthiness directives for the existing fleet of transport category airplanes to establish brake wear limits such that the brakes would be capable of absorbing a maximum energy absorption RTO in the fully worn state. The FAA also initiated rulemaking to address energy absorption capability and stopping distance with fully worn brake for future airplane types. The resulting rule, amendment 25-92, added:

1. A requirement for the maximum rejected takeoff kinetic energy capacity rating of the aircraft brakes to be determined with the brakes at 100 percent of the allowable wear limit;
2. A new requirement for the maximum kinetic energy rejected takeoff flight test demonstration to be conducted using brakes that have not more than 10 percent of their allowable wear range remaining; and
3. A general performance requirement under § 25.101(i) that requires the accelerate-stop and landing distances of §§ 25.109 and 25.125, respectively, to be determined with all wheel brake assemblies at the fully worn limit of their allowable wear range.

15.4.2.1.4 ACs 25-22 and 25.735-1 provide guidance and policy on how to show compliance with § 25.735. Additional information is provided in the following paragraphs pertaining to flight test evaluations performed in connection with showing compliance.

15.4.2.2 **Brake Controls—§ 25.735(c).**

General brake control force and operation should be noted throughout the flight test program to determine that they are satisfactory.

15.4.2.3 **Brake Control Valves.**

The brake valves in the normal brake system should allow the pilots to modulate pressure to the brakes. The foregoing provision need not necessarily apply to an alternate or emergency brake system, although obviously such a provision would be desirable. Flight tests should be conducted to determine that the normal and alternate/emergency brake systems fulfill the requirements of § 25.231.

15.4.2.4 **Parking Brake—§ 25.735(d).**

A demonstration should be made to determine that sufficient braking is provided with the parking brake to prevent the airplane from rolling on a paved, dry, level runway (or any suitable level hard surface) while maximum takeoff power or thrust is applied on the most critical engine and up to maximum ground idle power or thrust is applied to all other engines. The airplane should be loaded to the maximum ramp weight at aft CG (or a weight-CG combination that prevents the wheels from sliding). In the case of propeller-driven airplanes, the effects of propeller wash and engine/propeller torque should also be considered in determining the critical engine. Because the resultant thrust vector can be at an angle to a propeller's axis of rotation, one engine/propeller may be more critical than its counterpart on the opposite wing, particularly if all propellers turn in the same direction.

15.4.2.5 **Wheel Fuse Plugs.**

15.4.2.5.1 The hazardous condition of exploding tires and wheels associated with high energy emergency stopping conditions has been greatly alleviated by the installation of wheel fuse plugs. These plugs relieve the tire pressure when the wheel temperatures approach a dangerous limit. The effectiveness of these plugs in preventing hazardous tire blowouts should be demonstrated during an RTO test where the brake energy to be absorbed exceeds the maximum landing energy, but not the RTO energy, and the fuse plug releases, thereby deflating the tire(s) before blowout.

15.4.2.5.2 An improperly designed blowout plug that allows premature or unwanted release of tire pressure during takeoff or landing could also constitute a hazardous condition. Such a situation would most probably arise during a takeoff from a quick turn-around type of airline operation. Fuse plug integrity should be demonstrated by conducting a maximum landing brake energy test, which should not result in a fuse plug release.

15.4.2.5.3 Most turbojet transport airplanes have been able to demonstrate wheel blowout plug integrity at a maximum energy level in accordance with the procedures outlined in this section. More restrictive operational limitations (e.g., runway slope and tailwind values) have been imposed to stay within this maximum energy level demonstrated for wheel blowout plug integrity. With the advent of requests to increase the maximum landing weights, and to eliminate these restrictive operational limits, it has been considered acceptable to remove the pertinent restrictions and operational limitations and substitute in their place a chase-around chart as a limitation in the AFM. This chart will permit determining whether or not a critical energy level has been exceeded for the operating conditions of altitude, temperature, runway slope, tailwind, and landing weight. When the critical value is exceeded, a statement should be placed in the limitations section of the AFM to require that following a landing under such operating conditions, the airplane must remain on the ground a certain length of time prior to taxiing out for takeoff. This length of time will be the time to reach peak wheel temperatures (appropriate to the blowout plug location), plus 15 minutes. In lieu of the AFM fuse plug limitation chart, an alternate method for determining limit operational landing energy, such as a brake temperature limit, can be considered for approval.

15.4.2.5.4 The wear level of the brakes used for the chase-around chart discussed in the preceding paragraph should be selected by the applicant. Service experience indicates that the conservatism contained in the method of determining the turnaround time limits is adequate to allow these limits to be determined using new brakes.

15.4.2.5.5 In the case where it is possible to demonstrate wheel blowout plug integrity at a maximum energy level in accordance with the procedures in this section and without imposing certain restrictions on the operational limitations (e.g., runway slope and tailwind values), it is not considered necessary to incorporate the chase-around chart and pertinent statement in the limitations section of the AFM. Where restrictions are necessary, a pertinent statement and reference to the chase-around chart could be included in the limitations section of the AFM.

15.4.2.6 **Replacement and Modified Brakes.**

15.4.2.6.1 In order to establish aircraft landing and RTO certification performance levels for a replacement brake or a modified brake, measured accelerate-stop tests, and functional flight tests (landing distance), may be required, depending upon an evaluation of the individual merits of each brake system change. The type and magnitude of flight tests required will depend on whether or not a requested change involves a corresponding change of heat sink and/or torque requirements of the original certificated brake. A review of the change by the cognizant aircraft certification office (ACO) for the type certificate holder is necessary, since original landing gear designs are based on structural analysis, which could be adversely affected by a brake system change. In addition, such tests will also depend on whether or not an improvement in the FAA certificated performance is desired by the applicant.

15.4.2.6.2 Changes to the friction couple elements (rotors and stators) are generally considered to be a major change, requiring the testing described in paragraph 15.4.4, unless it can be shown that the change cannot affect the airplane stopping performance, brake energy absorption characteristics, or continued airworthiness. Historically, continued airworthiness considerations include such items as landing gear system/airplane vibration control, braking feel, landing gear system compatibilities etc.

15.4.2.6.3 Changes to a brake by a manufacturer other than the original TSO holder might be considered to be a minor change, as long as the changes are not to the friction couple elements, and the proposed change(s) cannot affect the airplane stopping performance, brake energy absorption, vibration, and/or thermal control characteristics, and continued airworthiness of the airplane. In certain circumstances, the change to a steel rotor by a manufacturer other than the original TSO holder may be considered to be a minor change, as discussed in paragraph 15.4.8.2.

15.4.3 Procedures.

The extent of the flight test requirements, except new airplane certification, may vary depending upon an evaluation of the individual merits of each airplane brake system change, and whether an increase in the FAA certificated performance level is desired by the applicant. Past experience has proven that dynamometer tests alone are not considered adequate in determining compliance with this requirement. Flight test procedures for new, replacement, and modified brakes are categorized as follows:

15.4.4 New Airplane Certification.

This is a complete new design where no airplane performance data exist.

15.4.4.1 **Required Tests.**

15.4.4.1.1 For complete analysis, at least six rejected takeoffs and six landings will normally be necessary.

1. Landings should be conducted on the same wheels, tires, and brakes.
2. All tests should be conducted with engines trimmed to the high side of the normal idle range (if applicable).
3. For airplanes whose certification basis includes amendment 25-92, § 25.101(i) requires the stopping distance portions of the accelerate-stop and landing distances to be determined with all the aircraft brake assemblies in the fully worn state. An acceptable means of compliance with this requirement is to accomplish the flight test braking tests with less than fully worn brakes, and then correct the test results using dynamometer test data determined with fully worn brakes. It should be substantiated that the dynamometer test methodology employed, and analytical modeling of the airplane/runway system, are representative of actual conditions.

15.4.4.1.2 Additional tests may be necessary for each airplane configuration change (i.e., takeoff and/or landing flaps, nose wheel brakes, anti-skid devices inoperative, deactivation of wheel brakes, etc.).

15.4.4.1.3 Brake system response evaluation including braking during taxiing (see paragraph 9.2.2.1.)

15.4.4.1.4 Parking brake adequacy. (See paragraph 15.4.4.3.)

15.4.4.1.5 Alternate braking system stops.

15.4.4.1.6 Wheel fuse plug evaluation. (See paragraph 15.4.10.)

15.4.4.1.7 Anti-skid compatibility on a wet runway.

15.4.4.1.8 Automatic gear retraction braking system on airplanes so equipped.

15.4.4.2 Maximum RTO energy will be established by conducting an RTO at the maximum brake energy level for which the airplane will be certified. Fires on or around the landing gear are acceptable if the fires can be allowed to burn during the first 5 minutes after the airplane comes to a stop, before extinguishers are required to maintain the safety of the airplane. The condition of the tires, wheels, and brakes can be such that the airplane would require maintenance prior to removal from the runway. A deceleration rate should be maintained during this test that is consistent with the values used by performance scheduling. Tire or wheel explosions are not acceptable. Tire fuse plug releases may occur late in the RTO run, provided directional control is not compromised. The resulting distance (with fuse plugs blown during the RTO run) is to be included in the data used to establish AFM performance, only if it is longer than the data obtained with normal full braking configuration.

15.4.4.2.1 For airplanes whose certification basis includes amendment 25-92, the maximum brake energy absorption level must be determined, according to § 25.101(i), for an airplane with all wheel brake assemblies in the fully worn state. In accordance with § 25.109(i), the flight test maximum energy RTO demonstration must be accomplished with all brake assemblies within 10 percent of their allowable wear limit (i.e., at least 90 percent worn). Dynamometer testing, when used to extend the flight test results to determine the maximum energy absorption capability of the brakes in the fully worn state (i.e., 100 percent worn), should be substantiated as being representative of actual airplane and runway conditions. The fully worn limit is defined as the amount of wear allowed before the brake needs to be removed from the airplane for overhaul. The allowable wear should be defined in terms of a linear dimension in the axial direction, which is typically determined by measuring the wear pin extension.

15.4.4.2.2 The maximum energy RTO demonstration should be preceded by at least a three-mile taxi, with at least three intermediate full stops, using normal braking and with all engines operating.

15.4.4.2.3 Landings are not an acceptable means to conduct maximum energy RTO demonstrations. Though permitted in the past, service experience has shown that methods used to predict brake and tire temperature increases that would have occurred during taxi and acceleration were not able to account accurately for the associated energy increments.

15.4.4.3 The ability of the parking brake to prevent the airplane from rolling should be demonstrated on a paved, dry, level runway (or any suitable level hard surface) with takeoff power or thrust applied on the critical engine and up to maximum ground idle power or thrust is applied to all other engines using the following test procedure:

15.4.4.3.1 The airplane should be loaded to its maximum takeoff weight (or a weight-CG combination that prevents the wheels from sliding) with the tires inflated to the normal pressure for that weight, the flaps should be retracted, the control surfaces centered, and the parking brake set.

15.4.4.3.2 Apply takeoff power or thrust to the critical engine with the other engine(s) at maximum ground idle power or thrust.

15.4.4.3.3 Compliance with the requirements of § 25.735(d) is shown if the wheels do not rotate; this is best observed by painting a white radial stripe(s) on the wheels. The airplane may skip, tire tread may shear, or the tire may slip on the wheel, but the parking brake must prevent the wheels from rotating. Skidding of the tires is acceptable.

15.4.5 Addition of New or Modified Brake Design.

15.4.5.1 This item concerns the addition of a new or highly modified brake design to an existing type certificated airplane for which FAA-approved braking performance test data exists, either for performance credit, or to the existing performance level. A highly modified brake is defined as one that contains new or modified parts that may cause a significant variance in brake kinetic energy absorption characteristics, airplane stopping performance, or continued airworthiness of the airplane. Examples are: significant change in rotor and/or stator lining compound or area, number of stages, piston area, reduction in heat sink weight, changes in total number of friction faces and elements, change in brake geometry (friction, radius, friction area), fuse plug relocation or change in release temperature, heat shield changes that would affect the temperature profile of the wheel and/or fuse plugs, or seal changes.

15.4.5.2 **Required Tests.**

15.4.5.2.1 For improved performance, all applicable portions of paragraph 15.4.4.

15.4.5.2.2 For equivalent performance, a sufficient number of conditions to verify the existing approved performance levels (RTO and landing). Consideration should be given to verification of fuse plugs, performance verification at appropriate energy levels, and configuration differences, including antis-kid on and off. Taxi tests to ensure that ground handling, maneuvering, and brake sensitivity are satisfactory should be conducted. At least two braking stops, one at heavy weight and one at light weight, should be conducted on a wet runway to verify brake and anti-skid system compatibility.

15.4.5.2.3 For extended performance, a sufficient number of conditions to define the extended line and determine equivalency to the existing performance levels. Consideration should be given to the items in paragraph 15.4.5.2.2 above.

15.4.5.3 **Definitions.**

15.4.5.3.1 Improved performance implies an increase in the mu versus energy level for the desired operation(s) and may be requested for landing, RTOs, or a specific configuration such as anti-skid "on" only.

15.4.5.3.2 Equivalent performance implies that sufficient data will be obtained to verify that the performance level for the desired change is equal to or better than the existing performance levels. The change may be for the purpose of changing the CG envelope, or for airplane configuration changes (such as flap angles), and may apply to specific operations (such as landings).

15.4.5.3.3 Extended performance implies that the existing certification mu versus energy line will be extended to establish the braking force level for a proposed change, such as gross weight or the maximum desired energy level, and may be applied to a specific operation (such as landing only).

15.4.6 Addition of New, or Changes to, Anti-skid Systems that may Affect Airplane Performance.

(For example, new anti-skid system, or a change from coupled to individual wheel control.) A sufficient number of airplane performance tests and/or functional tests should be conducted to verify existing approved performance anti-skid "on" levels. In the event an increase of braking performance is desired, full airplane performance testing is required.

15.4.7 Fuse Plug Modification.

15.4.7.1 Airplane tests for changes to the fuse plugs should be evaluated on a case-by-case basis. While airplane tests are required to establish the initial fuse-plug-no-melt energy, minor changes to fuse plugs or wheel designs may be validated by a back-to-back dynamometer comparison of old versus new designs, provided it is acceptable to the cognizant FAA ACO.

15.4.7.2 Airplane tests should be conducted when a significant change of wheel design and/or redesign or relocation of thermal or pressure fuse plugs is made. One airplane test should be conducted to show that the fuse plugs will release when excessive energies are absorbed. Another airplane test should be conducted to verify the maximum kinetic energy at which fuse plugs will not release (fuse plug substantiation). Dynamometer tests are not considered adequate for this test.

15.4.8 Minor/Major Changes.

15.4.8.1 Minor brake changes that do not affect airplane braking performance may require functional landings. This may be required to verify airplane-pilot-brake-anti-skid combination compatibility. Normally, five non-instrumented, functional landings are considered sufficient to verify this compatibility. Examples of minor changes might include structural improvements (increased fatigue life), adjuster/retractor modifications, material and process specifications changes for structural components, and modified heat-sink relief slots (steel brakes). Examples of other minor changes that do not require functional landings are paint/corrosion changes, changes to bleed ports or lube fittings, revised over inflation devices, metal repair, and salvage procedure.

15.4.8.2 Changes to heat sink friction couple elements are to be considered major changes, unless the applicant can provide evidence that changes are minor. Based upon experience, thicker friction material or heavier heatsink elements are usually acceptable as minor changes in steel brakes. Thicker or heavier heat sink elements in carbon brakes may require additional laboratory and/or airplane testing to assess brake performances and continued airworthiness. Major changes are subject to extensive airplane testing, unless it can be shown that the change cannot affect the airplane stopping performance, brake energy absorption characteristics, and continued airworthiness. In this regard, the original manufacturer of the wheel/brake assembly, who holds the TSO authorization and the type certificate holder, who is knowledgeable with respect to such items as landing gear design assumptions and airplane braking system history, may possess data sufficient to show that such changes could be considered to be minor (i.e., performance would not be affected). In contrast, an applicant other than the original manufacturer who wishes to produce replacement rotors or stators may not have access to or have established developmental or other test data required to show that performance, braking energy capacities, braking system compatibilities, or overall continued airworthiness safeguards have been addressed. Due to the complex nature of the friction surfaces and airplane braking system interfaces, proposed replacement stators/rotors by an applicant other than the original manufacturer(s) should always be considered a major change.

15.4.8.3 It is considered very difficult to determine 100 percent identicality. This is particularly true for brake friction rubbing components (e.g., linings in cups, linings sintered to plates, steels used in steel brakes, and carbon discs in carbon brakes). A finding of equivalence based upon physical documentation and dynamometer testing may not be possible or practical due to friction material complexities and/or the extent of dynamometer testing required.

15.4.8.4 Due to the complexities associated with aircraft brake friction couples, industry and authorities have generally discouraged mixing of friction components from various suppliers within the same brake or mixing wheel and brake assemblies from different manufacturers on the same airplane. Typically, the manufacturers of large transport category airplanes have confined the use of specific wheel and brake supplier’s assemblies to specific airplanes through approved equipment lists. While multiple wheel and brake suppliers (e.g., multiple original TSO holders) are often selected to provide wheel and brake assemblies on a specific airplane model, intermixing of wheel and brake assemblies has been discouraged to avoid potential problems such as unequal energy sharing; unfavorable dynamic cross coupling between brakes, landing gear, and the airplane; degradation of vibration and/or thermal controls; unique brake control system tuning requirements for each wheel and brake assembly, etc.

15.4.8.5 The FAA has, however, approved the use of replacement steel rotors. The following protocol for steel rotor equivalency findings has been updated to include brake wear and wear pattern assessments to assure that the worn brake capability of the original manufacturer's wheel and brake assembly is not degraded by a replacement steel rotor(s). The following criteria and evaluations represent protocol for replacement steel rotors to be considered as a minor change:

1. A very close correlation between the original part and the proposed replacement part;
2. Considerable and satisfactory prior manufacturing and in-service experience with a similar replacement part;
3. A reasonable plan of test for completion of the dynamometer portion of the test program;
4. Successful completion of the dynamometer testing; and
5. As a minimum, successful completion of a series of functional landings on the airplane.

15.4.8.6 The necessity of conducting maximum energy RTO testing and other brake system tests on the airplane will depend upon the outcome of the above evaluations and worn brake RTO airplane test experiences (if applicable).

15.4.8.7 If intermixing of replacement steel rotors with the original manufacturer's steel rotors is proposed, the applicant should propose an airplane test evaluation plan to the FAA that provides data to guide a worn brake rejected-takeoff equivalency assessment. If the applicant cannot provide evidence on similar overall wear and wear patterns from the new to worn condition for the proposed mixing configuration(s), intermixing will not be permitted in order to assure that the worn brake rejected-takeoff rating and approved wear limit of the original TSO holders wheel and brake assembly is not jeopardized.

15.4.8.8 The dynamometer test plan, and, if applicable, the overall wear and wear pattern test plan, should include:

1. TSO Minimum Standard Performance Demonstration. The wheel and brake assembly containing the applicant's proposed steel rotor configuration should successfully demonstrate compliance with the braking and structural tests of the applicable TSO, and
2. Compliance with the airplane manufacturer's specified requirements, or the alternate procedures specified in paragraph 15.4.8.9.

15.4.8.9 **Alternate Procedures (Steel Rotors Only).**

15.4.8.9.1 Energy and Torque Capacity Tests.

A series of tests (not only one) may be necessary to demonstrate, in back-to-back tests, that brake energy absorption and torque and pressure vs. time profiles are equivalent. All friction components and structures should be in the new condition to obtain credit for this test. If rebuilt or in-service components other than these fail during testing, it should be realized that the results of the test(s) may be questionable. Suspect tests will be carefully reviewed by the FAA, and may require retesting. Prior to test, the applicant should carefully document wheel hardness and wheel drive, torque tube spline, piston/bushing assembly conditions to assure comparable test articles are being used. The same tire size and ply rating, manufacturer, tire condition, radial load, and rolling radius should be used in each test. Test machines and test conditions should be consistent from test to test, including test brake, wheel and tire break-in stop histories, brake pressure onset rates (pound-force per square inch gauge per second) (psig/sec), maximum pressures, initial brakes-on-speeds, flywheel inertias, etc., to assure consistent test control. Artificial cooling is not permitted during or subsequent to the test until wheel and piston housing temperatures have peaked.

15.4.8.9.2 The initial kinetic energy (KE) level for this series of tests will be at the discretion of the applicant. For each succeeding run, the KE will be increased by approximately 5 percent over the previous run, until the ultimate KE level is determined (i.e., points at which pistons are about to exit bores or flywheel deceleration falls below 3 ft/sec^2 (one-half of the TSO RTO minimum average deceleration requirement)). The deceleration reported by the applicant should be based upon distance (and not time) in accordance with the following formula:

$$Distance\ Averaged\ Deceleration =$$

$$\frac{(Initial\ Brakes\text{–}\ on\ Speed)^2 - (Final\ Brakes\text{–}\ on\ Speed)^2}{2 * Braked\ Flywheel\ Distance}$$

1. A minimum of two runs at this ultimate energy level should be conducted on the original manufacturer's wheel and brake assembly for baselines. These test runs should show similar results. Maximum braking force pressure should be applied during the tests. Fuse plug

releases in any tests should demonstrate safe release of approved nitrogen-air mixtures.

2. A minimum of two test runs at the ultimate energy level should then be conducted on the applicant's proposed wheel and brake assembly (i.e., a back-to-back demonstration of the two manufacturers' brakes). Tests should show similar brake energy absorption, torque, and thermal performance capabilities, and torque and pressure versus time profiles, while demonstrating sealing and structural integrity comparable to the original manufacturer's wheel and brake assembly.

15.4.8.9.3 Worn Brake RTO Capability.

Worn brake RTO capability for the proposed wheel and brake assembly with steel rotor replacement configuration(s), and at the wear pin limit(s) proposed by the applicant, should be established during dynamometer test(s). The test brake energy absorption criteria, torque performance, and pass/fail requirements should be requested of the airplane manufacturer to provide supporting evidence that the worn brake RTO capability is equivalent to that achieved with the original TSO holder's wheel and brake assembly(ies). If unavailable, the applicant should propose a worn brake RTO test plan similar to that in paragraph 15.4.4 for new brakes. The applicant should also propose to the FAA the method which will be followed by the applicant to verify that the worn brake RTO capability of in-service worn brakes with replacement rotors is equivalent to the capability established in initial dynamometer test(s) in accordance with paragraph 15.4.4.2.1 of this AC.

15.4.8.9.4 Intermixing of steel rotor assemblies produced by two manufacturers will not be allowed until it can be demonstrated that wear patterns of the intermixed assembly(ies), through a determined number of in-service tours, does not jeopardize the worn brake RTO capabilities of the original or the replacement wheel and brake assemblies. Since dynamometer testing is generally impractical, the applicant should forward to the FAA an in-service plan to survey wear and wear patterns from a sampling of worn in-service brakes containing steel rollers from the original manufacturer only, from the applicant only, and from an intermix brake(s). Since the original manufacturer's brake often contains second, and possibly third tour reground steel rotors, at least two tours of in-service evaluation with replacement steel rotors may be required to assess equivalence. This data will provide guidance for approved worn brake RTO wear limits for brakes containing replacement rotors.

15.4.8.9.5 Torque/Pressure Ratio Profiles.

A torque/pressure ratio test plan and tests are required to demonstrate equivalent gain performances over a range of test speeds and test pressures. The test article conditions, break-in conditions and procedures, test speed range, and test pressure matrix, used to evaluate both the original and applicant wheel and brake assemblies, should be the same with tests conducted in the same order. The results of these tests will provide guidance for braking system control compatibility assessments.

15.4.8.9.6 As a minimum, the five functional landings described in paragraph 15.4.8.1 above are also a required part of this approval procedure.

15.4.8.9.7 Continued Airworthiness.

Past history with friction material couples has indicated the necessity of ongoing monitoring (by dynamometer test) of RTO capability to assure that the AFM limitations are not exceeded over the life of airplane programs. For larger transport category commercial airplanes, it has been shown that these monitoring plans have complemented the detection and correction of unacceptable deviations. The applicant should provide the FAA with a quality plan to demonstrate that the RTO capability of the friction couple is maintained with replacement steel rotors over time.

15.4.9 Auto-Braking.

The following are required for auto-braking installations based on function, non-hazard, and non-interference on airplanes for which performance without auto-braking has been determined:

15.4.9.1 The system design should be evaluated for integrity and non-hazard, including the probability and consequence of insidious failure of critical components. No single failure may compromise non-automatic braking of the airplane.

15.4.9.2 Positive indication of whether the system is operative or inoperative should be provided.

15.4.9.3 For each auto-brake setting for which approval is desired, the ground roll distance from touchdown to stop should be determined for the landing weights and altitudes within the envelope for which approval is desired. In determining ground roll distance, the performance should be established without reverse thrust, and any adverse effect upon performance associated with the use of reverse thrust should be established and accounted for. Repeatability of initial application should be shown by comparing the onset of braking for each of the range of settings. Landing ground roll distance data determined as prescribed herein should be presented in the performance information section of the AFM.

15.4.9.4 If the auto-braking system is to be approved for wet runways, auto-brake compatibility on a wet runway should be demonstrated. These tests may be limited to the highest auto-brake setting, where anti-skid activity is expected to occur throughout the stop, and a single lower setting, where anti-skid activity is expected to occur for only a portion of the stop. AFM stopping distances for other settings can be computed based on predicted wet-runway friction coefficients and do not require demonstrations on wet runways of all auto-brake settings. Landing ground roll distance data determined on a wet runway should also be presented in the AFM for all operating modes of the system. This information is considered necessary so that the pilot can readily compare the automatic brake stopping distance and the actual runway length available, to assess the effect of the use of the automatic braking system on the runway margin provided by the factored field length.

15.4.9.5 Automatic braking systems that are to be approved for use during rejected takeoff conditions should provide only a single brake setting that provides maximum braking. In the event that automatic brakes result in a longer rejected takeoff distance than manual brakes, the AFM should present the longer rejected takeoff distance.

15.4.9.6 Procedures describing how the automatic braking system was used during the FAA evaluation and in determining the landing ground roll distance of paragraph 15.4.9.3 should be presented in the AFM.

15.4.10 Wheel Fuse Plug Integrity.

15.4.10.1 Wheel fuse plug integrity should be substantiated during braking tests where the energy level simulates the maximum landing energy. It should be demonstrated that the wheel fuse plugs will remain intact, and that unwanted releases do not occur. One acceptable method to determine this is as follows:

1. Set engine idle power or thrust at the maximum value specified (if applicable).
2. Taxi at least three miles (normal braking, at least three intermediate stops, and all engines operating).
3. Conduct accelerate-stop test at maximum landing energy, maintaining the deceleration rate consistent with the values used to determine performance distance.
4. Taxi at least three miles (normal braking, at least three intermediate stops, and all engines operating).
5. Park in an area to minimize wind effects until it is assured that fuse plug temperatures have peaked and that no plugs have released.

15.4.10.2 In lieu of simulating the maximum kinetic energy landing during an accelerate-stop test, an actual landing and quick turn-around may be performed; however, caution should be exercised in order to prevent jeopardizing the safety of the flightcrew and airplane if the wheel plugs release right after liftoff, requiring a landing to be made with some flat tires. The following elements should be included in the tests:

1. Set engine idle power or thrust at maximum value specified (if applicable).
2. Conduct a landing stop at maximum landing energy, maintaining the deceleration rate consistent with the values used to determine stopping performance distance.
3. Taxi to the ramp (three miles minimum with normal braking, at least three intermediate stops, and all engines operating).
4. Stop at the ramp. Proceed immediately to taxi for takeoff.
5. Taxi for takeoff (three miles minimum with normal braking, at least three intermediate stops, and all engines operating).
6. Park in an area to minimize wind effects until it is assured that fuse plug temperatures have peaked and that no plugs have released.

15.4.10.3 Fuse plug protection of wheels and tires should be demonstrated to show that the fuse plugs will release when excessive energies are absorbed. Normally, this will occur during RTO performance tests.

15.5 **Skis—§ 25.737. [Reserved]**

CHAPTER 16. DESIGN AND CONSTRUCTION: FLOATS AND HULLS [RESERVED]

CHAPTER 17. DESIGN AND CONSTRUCTION: PERSONNEL AND CARGO ACCOMMODATIONS

17.1 **Pilot Compartment View—§ 25.773.**

17.1.1 Explanation.

[Reserved.]

17.1.2 Procedures.

For detailed guidance on complying with pilot compartment view requirements, see AC 25.773-1.

17.2 **[Reserved.]**

CHAPTER 18. DESIGN AND CONSTRUCTION: EMERGENCY PROVISIONS

18.1 Ditching—§ 25.801.

18.1.1 Explanation.

If certification with ditching provisions is requested, § 25.801 requires investigation of the probable behavior of the airplane in a water landing. As stated in the regulation, this investigation can be accomplished by model testing or by comparison with airplanes of similar configuration for which the ditching characteristics are known. Applicants should also demonstrate that their ditching parameters used to show compliance with § 25.801 can be attained without the use of exceptional piloting skill, alertness, or strength.

18.1.2 Procedures.

None.

18.2 Emergency Egress Assist Means and Escape Routes—§ 25.810.

18.2.1 Explanation.

18.2.1.1 Installation of slip-resistant escape route. (See §25.810(c), formerly § 25.803(e).) See AC 25-17A, § 25.803(e), for guidance regarding slip resistant material.

18.2.1.2 The effect of the slip-resistant surfaces on airplane performance, flight characteristics, and buffet should be evaluated. If there is a significant effect, this effect should be accounted for.

18.2.2 Procedures.

None.

CHAPTER 19. DESIGN AND CONSTRUCTION: VENTILATION AND HEATING.

19.1 Ventilation—§ 25.831.

19.1.1 Explanation.

19.1.1.1 This requirement deals with minimum ventilation requirements for each occupant of the airplane, control of the ventilating air, accumulation and evacuation of smoke and harmful or hazardous concentrations of gases or vapors, and failure conditions of the ventilation system. Specific quantities of fresh air along with carbon monoxide and carbon dioxide concentration limits are specified in the rule. AC 25-20 provides guidance for methods of showing compliance with the ventilation requirements. Reference should also be made to paragraphs 29.1 and 31.2 of this AC dealing with § 25.1121, *Exhaust systems*, and § 25.1197, *Fire extinguishing agents*, respectively.

19.1.1.2 The objective of the inflight smoke evacuation test is to confirm that the flightcrew emergency procedures and the ventilation system are capable of handling heavy smoke, and to show that when using the emergency procedures, the smoke will dissipate at a reasonable rate. This is a quantitative and qualitative evaluation.

19.1.2 Procedures.

19.1.2.1 Flight testing should be conducted to ensure the amount of ventilation air provided meets the requirements specified and the flightcrew is able to accomplish their duties without undue fatigue and discomfort. Ventilation system controls in the flight deck should be demonstrated to perform their intended function.

19.1.2.2 The passenger and crew compartment should be monitored for the presence of carbon monoxide. Various flight and equipment configurations should be tested. A carbon monoxide test kit is normally used for this evaluation.

19.1.2.3 Inflight smoke evacuation testing should be conducted in accordance with AC 25-9A.

19.2 Cabin Ozone Concentration—§ 25.832. [Reserved]

19.3 Combustion Heating Systems—§ 25.833. [Reserved]

CHAPTER 20. DESIGN AND CONSTRUCTION: PRESSURIZATION

20.1 Pressurized Cabins—§ 25.841.

20.1.1 Explanation.

20.1.1.1 Section 25.841(a) specifies cabin pressure altitude limits, as a function of the external pressure altitude, for cabins and compartments intended to be occupied. AC 25-20 provides additional guidance for pressurized cabins. These cabin pressure altitude limits, to be demonstrated by flight testing, are:

20.1.1.1.1 Not more than 8,000 feet, at the maximum operating altitude of the airplane, for normal operation of the pressurization system.

20.1.1.1.2 For airplanes to be operated above 25,000 feet, the airplane must be able to maintain a cabin pressure altitude of not more than 15,000 feet in the event of any reasonably probable failure or malfunction in the pressurization system.

20.1.1.2 The 8,000-foot limit on cabin pressure altitude applies during normal operations at all altitudes, up to the maximum operating altitude of the airplane. For airplanes operating at airports with altitudes higher than 8,000 feet (see paragraph 20.1.1.3), an equivalent level of safety finding must be made in accordance with § 21.21(b)(1) to allow the higher than 8,000-foot cabin pressure altitude needed for these operations.

20.1.1.3 Though not addressed by § 25.841, airplanes may incorporate a "high altitude mode" to permit takeoff and landing at airports above 8,000 feet. For takeoff and landing altitudes above 8,000 feet, the cabin pressure limits to be demonstrated by flight testing are:

20.1.1.3.1 Prior to beginning a descent into a high altitude airport, not more than 8,000 feet.

20.1.1.3.2 During a descent into or climb out of a high altitude airport, not more than 15,000 feet.

20.1.1.3.3 After a takeoff from a high altitude airport and after the cabin pressure altitude decreases to 8,000 feet, not more than 8,000 feet.

20.1.1.4 Section 25.841(b)(6) requires an aural or visual warning to the flightcrew when the cabin pressure altitude exceeds 10,000 feet. The intent of this requirement is to warn the crew when a safe or preset cabin pressure altitude limit is exceeded. However, complying with this regulation when operating at airports with altitudes higher than 10,000 feet (see paragraph 20.1.1.3) would result in nuisance cabin pressure warnings. For systems that set the cabin pressure altitude warning limit above 10,000 feet for operations at high altitude airports, an equivalent level of safety finding must be made in accordance with § 21.21(b)(1).

20.1.2 Procedures.

It is recommended that the test airplane have the maximum allowable leakage rate permitted by the type design specifications. If an airplane does not meet this criterion, it will be necessary to substantiate compliance by additional testing or analysis for the maximum leakage rate allowed by the type design.

20.1.2.1 **Normal Operating Conditions—8,000-Foot Cabin Pressure Altitude.**

20.1.2.1.1 With the pressurization system operating in its normal mode, verify that the cabin pressure altitude does not exceed 8,000 feet during climb, cruise, or descent at any altitude up to and including the maximum operating altitude for which the airplane is to be certificated.

20.1.2.1.2 A stable condition should be held long enough to record any cyclic fluctuations in cabin pressure due to relief valve operation.

20.1.2.2 **Failure Conditions—15,000-Foot Cabin Pressure Altitude.**

20.1.2.2.1 The critical probable system failure condition should be identified. The cabin pressure altitude warning system should be set to the high altitude side of its tolerance band or additional testing or analysis may be necessary for compliance. If more than one system failure mode is determined to meet the "probable failure condition" criterion, the flight test should be conducted for each failure mode identified.

20.1.2.2.2 The airplane should be stabilized in the cruise configuration at the maximum operating altitude it is to be certificated to, with the pressurization system operating in its normal mode.

20.1.2.2.3 After initiating the critical failure to allow the cabin pressure altitude to increase, the flight test crew should immediately don their oxygen masks, but take no further corrective action until 17 seconds after the 10,000-foot cabin pressure altitude warning activates. Emergency descent procedures should then be initiated and the descent continued to an altitude below 15,000 feet.

20.1.2.2.4 The cabin pressure altitude should not exceed 15,000 feet at any time during the test.

20.1.2.3 **High Altitude Takeoff Conditions (Greater than 8,000 Feet).**

20.1.2.3.1 The pressurization system should be placed in its high altitude mode. It may be necessary to configure the oxygen system to prevent deployment of the oxygen masks at 10,000 feet, if the system is so designed. AFM procedures may need to be developed. The same applies to high altitude landings above 10,000 feet.

20.1.2.3.2 The cabin pressure altitude should not exceed the maximum allowable takeoff and landing altitude (within an acceptable tolerance) during an actual climb-out from a high altitude airport to the maximum operating altitude the airplane is to be certificated for, or during an inflight simulation of such a climb-out. The simulation should commence the climb, from a starting altitude of 8,000 feet or more, with the airplane unpressurized.

20.1.2.3.3 The cabin pressure altitude should eventually decrease to 8,000 feet and then not exceed 8,000 feet for the duration of the test.

20.1.2.4 **High Altitude Landing Conditions (Greater than 8,000 Feet).**

20.1.2.4.1 The airplane should be stabilized in the cruise configuration prior to beginning a descent.

20.1.2.4.2 The pressurization system should be placed in its high altitude mode.

20.1.2.4.3 The cabin pressure altitude should not exceed the maximum allowable takeoff and landing altitude (within an acceptable tolerance) during the descent to an actual, or simulated, landing at a high altitude airport.

20.2 Tests for Pressurized Cabins—§ 25.843.

20.2.1 Explanation.

20.2.1.1 Section 25.843(b)(3) requires flight testing to evaluate the performance of the pressurization system and all related sub-systems at maximum altitude and under the dynamic conditions of climbing and descending flight. This testing substantiates the ability of the pressurization system to function correctly in stable and dynamic external pressure conditions.

20.2.1.2 Section 25.843(b)(4) requires an investigation of the functionality of all doors and emergency exits after the flight test required by § 25.843(b)(3). The concern is the potential for jamming caused by the variable relative positions of doors and fuselage structure during the pressurization/depressurization cycle.

20.2.2 Procedures.

The following tests may be initiated from an airport at any altitude within the airplane's proposed takeoff limitations. The pressurization system should be operated in its normal mode. MMEL dispatch may be taken into consideration and additional testing required to verify MMEL configuration.

20.2.2.1 **Steady Climb/Descent.**

The steady climb/descent pressurization system tests should be performed under conditions (i.e., weight, altitude, temperature, and configuration) that will result in rates of climb/descent corresponding to the maximum attainable within the operating limitations of the airplane.

20.2.2.1.1 After takeoff, maintain a stable, continuous climb to the maximum operating altitude for which the airplane will be certificated.

20.2.2.1.2 Maintain that altitude until the cabin pressure altitude has stabilized.

20.2.2.1.3 Initiate a steady, maximum rate of descent within the operating limitations of the airplane down to the airport.

20.2.2.2 **Stepped Climb/Descent.**

The stepped climb/descent pressurization system tests should be performed under conditions (i.e., weight, altitude, temperature, and configuration) that will result in rates of climb/descent corresponding to the maximum attainable within the operating limitations of the airplane.

20.2.2.2.1 After takeoff, initiate a stepped climb to the maximum operating altitude the airplane will be certificated to. Step increments should be 5,000 to 7,500 feet.

20.2.2.2.2 Maintain each level-off altitude long enough for the cabin pressure altitude to stabilize.

20.2.2.2.3 Initiate a stepped descent from the maximum altitude allowing the cabin pressure altitude to stabilize at each level-off altitude. Step increments should be 7,500 to 10,000 feet.

20.2.2.3 **Positive Pressure Relief.**

If two valves are provided, one should be deactivated for this test.

20.2.2.3.1 After takeoff, climb to the operating altitude that provides maximum cabin differential pressure.

20.2.2.3.2 Manually close the outflow valve, allowing the cabin differential pressure to increase.

20.2.2.3.3 Verify the cabin pressure differential pressure warning functions properly.

20.2.2.3.4 Verify that the relief valve functions and the maximum cabin differential pressure is not exceeded.

20.2.2.4 **Negative Pressure Relief/Emergency Descent.**

If two valves are provided, deactivate one for this test.

20.2.2.4.1 At cruise altitude, perform an emergency descent with the airplane in the critical condition for negative pressure on the fuselage.

20.2.2.4.2 Verify that the maximum negative differential pressure for the fuselage is not exceeded.

20.2.2.4.3 Manual Cabin Pressure Control. If manual means for pressure control are provided, these means should be evaluated under normal and emergency operations of the airplane and flight envelope.

20.2.2.5 **Testing of Doors and Exits.**

20.2.2.5.1 Prior to flight, all doors and exits should be checked for proper operation.

20.2.2.5.2 After returning from a flight where the airplane is subjected to the maximum certificated altitude and cabin differential pressure, and immediately upon landing, all passenger doors and emergency exits should be opened. There should be no change in the operating characteristics of any door or emergency exit relative to its pre-flight operation.

CHAPTER 21. DESIGN AND CONSTRUCTION: FIRE PROTECTION [RESERVED]

CHAPTER 22. DESIGN AND CONSTRUCTION: MISCELLANEOUS [RESERVED]

CHAPTER 23. POWERPLANT: GENERAL

23.1 Installation—§ 25.901. [Reserved]

23.2 Engines—§ 25.903.

23.2.1 Engine Isolation—§ 25.903(b).

23.2.1.1 **Explanation: Approval of Engine Isolation Criteria.**

The powerplants, and all systems controlling or influencing the performance of the powerplants, must be arranged and isolated from each other to allow operation, in at least one configuration, so that a failure of any engine or any said system will not:

- Prevent the continued safe operation of the remaining engines; or
- Require immediate action by any crewmember for continued safe operation.

23.2.1.2 **Procedures.**

23.2.1.2.1 Automated control functions incorporated to reduce crew workload, which impact the engine operation and control, may require flight tests to demonstrate the effects of various simulated failures, including engine surging and single engine failures. Failures in systems such as the auto-throttles, digital flight guidance computers, engine synchronizers, and electronic engine controls may need to be simulated to ensure that surging or a failure in one engine system will not hazardously affect control and operation of the remaining engine systems. Such failure simulations may include disruption of electrical power to selected control components, as well as simulated engine failures (throttle chops).

23.2.1.2.2 The applicant should submit a comprehensive test plan detailing the test conditions and failure modes to be simulated. Careful consideration should be given to conducting these tests at safe altitudes and airspeeds, since results of the failure simulations may not be entirely predictable. Where possible, without compromising tests results, on-aircraft (i.e., installed engines) tests of this type should be accomplished on the ground.

23.2.1.2.3 For propeller airplanes, when an automatic control system for simultaneous RPM control of all propellers is installed, it should be shown by analysis, flight demonstration, or a combination of analysis and flight demonstration that no single failure or malfunction in this system or in an engine controlling this system will:

1. Cause the allowable engine overspeed for this condition to be exceeded at any time.

2. Cause a loss of power or that will cause the airplane to descend below the takeoff path, established in accordance with § 25.111, if such a system is certificated for use during takeoff and climb. This should be shown for all weights and altitudes for which certification is desired. A period of five seconds should be allowed from the time the malfunction occurs to the initial motion of the cockpit control for corrective action taken by the crew.

23.2.2 Control of Engine Rotation—§ 25.903(c).

23.2.2.1 **Explanation.**

Section 25.903(c) requires that a means be provided to stop the rotation of any individual engine in flight. An exclusion is provided for turbine engines whereby a means to stop rotation need only be provided in cases where continued rotation could jeopardize the safety of the airplane. If means are not provided to completely stop the rotation of turbine engines, it should be shown that continued rotation, either windmilling or controlled, of a shutdown turbine engine will not cause:

23.2.2.1.1 Powerplant (including engine and accessories) structural damage that will adversely affect other engines or the airplane structure;

23.2.2.1.2 Flammable fluids to be pumped into a fire or into an ignition source; or

23.2.2.1.3 A vibration mode that will adversely affect the aerodynamic or structural integrity of the airplane.

23.2.2.2 **Procedures.**

None.

23.2.3 Turbine Engine Installations—§ 25.903(d).

23.2.3.1 **Explanation.**

Section 25.903(d) presents specific concerns related to turbine engine installations. The requirements presented in § 25.903(d)(2) are intended to ensure that the installed powerplant control devices, systems, and instrumentation will reasonably protect against exceeding engine operating limitations that adversely affect turbine rotor integrity.

23.2.3.2 **Intermixing of Engines.**

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

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

23.2.3.2.2 When more than one lower power or thrust engine is installed, the AFM performance should be based on the power or thrust of the lower/lowest rated engine.

23.2.3.2.3 The minimum control speeds (V_{MCG}, V_{MCA}, and V_{MCL}) should be based on the highest power or thrust engine(s).

23.2.3.2.4 The operating procedures should be provided for all engines installed (i.e., airstart altitude/airspeed envelopes, crew responses to engine warning systems, etc.). Differences in operating methods should be limited to the equivalent of having a maximum of two different engines on the airplane.

23.2.3.2.5 A maximum of two takeoff power or thrust settings, in terms of engine pressure ratio (EPR) or rotational speed of the low pressure compressor (N_1) are permitted for airplanes with intermixed engines; this includes differences related to air conditioning pack and compressor bleed configurations.

23.2.3.2.6 A placard, identifying the location of the non-standard engine type, should be installed. All engine limits and instrument markings should be appropriate to the engine installed at each location. EPR, N_1, N_2, exhaust gas temperature (EGT), etc. limits for each engine, or the ratings at which they will be operated, must be properly presented to the pilot in accordance with §§ 25.1541 and 25.1543 and 14 CFR part 121.

23.2.4 <u>Engine Restart Capability—§ 25.903(e).</u>

23.2.4.1 **Explanation.**

23.2.4.1.1 <u>Engine Restart Capability Requirements.</u>
Section 25.903(e), *Restart capability*, requires:

"(1) Means to restart any engine in flight must be provided.

(2) An altitude and airspeed envelope must be established for in-flight engine restarting, and each engine must have a restart capability within that envelope.

(3) For turbine engine powered airplanes, if the minimum windmilling speed of the engines, following the inflight shutdown of all engines, is insufficient to provide the necessary electrical power for engine ignition, a power source independent of the engine-driven electrical power generating system must be provided to permit in-flight engine ignition for restarting."

23.2.4.1.2 Methods for Restart.

There are several available methods used for in-flight engine restart. The primary method used to restart a turbine engine in flight is windmill or unassisted restart. The airplane forward speed provides airflow through the engine creating the rotational energy, or “windmilling,” needed to permit an engine restart. An assisted restart is an alternate restart method that may use a pneumatic, electrical, hydraulic, or some other source to power a starter that will assist in rotating the engine enough to restart it. The air for a pneumatic starter typically comes from another operable engine or an in-flight operable auxiliary power unit (APU). An engine accessory generator, hydraulic generator, APU, batteries, or a combination of these sources can provide electrical power for an electrical starter. A hydraulic starter requires an onboard hydraulic source. Start cartridges may also be used.

23.2.4.1.3 Background.

In general, airplane manufacturers use windmill restart to provide in-flight engine restart capability. Turbojet and early turbofan engines with low bypass ratios, approximately 1:1, had windmill restart capability throughout most of the approved airplane altitude-airspeed operating envelope. Since then, the evolution of technology to improve fuel efficiency has increased the bypass ratio of turbofan engines higher, as much as 10:1 on some engines. The high bypass ratio engines generally require higher airspeeds to provide enough airflow through the engine core to create sufficient windmilling rotational energy for an unassisted engine restart. Additional features incorporated in the later technology engines, such as compressors with higher operating pressures, new technology burners, and optimized operating schedules affording smaller stall margins, have also increased the airspeed required for windmilling restart. As a result, the altitude-airspeed windmill restart envelope has decreased significantly. These engines typically have assisted restart envelopes to provide larger in-flight engine restart envelopes. Turboprop engines, particularly those with free-turbines, have little to no windmill restart capability and mainly rely on assisted restart methods.

23.2.4.1.4 Engine Restart Envelope.

An engine restart envelope should clearly distinguish between the areas of different restart capabilities in terms of time to restart, windmilling only restart, and starter assisted restart. If an APU provides any essential functions, including in-flight restart over any portion of the operating envelope, the applicant should perform a flight test to substantiate a separate in-flight start envelope for the APU. The applicant should furnish engine and APU (if applicable) restart envelopes, and related procedures, in the AFM.

23.2.4.1.5 All-Engines-Out Restart Capability.

The applicant should demonstrate all-engines-out restart capability for critical conditions using a method agreed to by the FAA.

23.2.4.2 **Procedures.**

23.2.4.2.1 The applicant should conduct tests to determine if the flightcrew can restart an engine in flight within the envelope provided using the AFM procedures. The applicant should also conduct restarts at the conditions of the critical corners of the envelope and at or near the high altitude extremes of the envelope to verify the boundary conditions of the envelope. The applicant should establish any other critical test points if specific design features may reduce in-flight engine restart capability. The applicant should use a sample size of at least two different engines for each critical test condition. The applicant should conduct a sufficient number of test points to ensure the reliability and repeatability of an in-flight engine restart within the envelope. When establishing the critical test points, the applicant should seek advice from the engine manufacturer on potential needs to account for the effect of normal engine deterioration that occurs in service on restarting characteristics.

23.2.4.2.2 The applicant should evaluate the engine operating characteristics during each restart. In particular, the applicant should note any tendencies for the engine to surge, dwell for abnormally long periods below idle, or produce other unusual vibration or audible noises. The engine should not require a period of "warm-up" time before the engine is able to accelerate to a power necessary to maintain safe flight.

23.2.4.2.3 An in-flight engine restart sequence (from start initiation to stabilized idle) should occur within a maximum of 90 seconds, including a maximum of 30 seconds for ignition time. A longer time from ignition (light-off) to stabilized idle may be acceptable provided that the flightcrew has a clear indication of the engine start progressing. The applicant may use a dedicated flight deck indication or human factors assessment to provide the clear indication of progression. The human factors assessment should show that normally available flight deck instruments provide adequate and clear indications of engine start progression throughout the start. A clear indication of progression of the engine start is necessary to prevent the flightcrew from terminating a successful start attempt. This is important for engines that have characteristics where the engine temperature is climbing with no increase in engine speed and the start appears to the flightcrew to be "hung." An applicant may need to include appropriate notes in the AFM to describe an acceptable engine start progression to the flightcrew.

23.2.4.2.4 The applicant should evaluate the engine restarting performance impacts due to the effects of altitude and cold temperatures following engine shutdown. The applicant should determine critical conditions considering medium-to-high altitude cruise conditions and engine manufacturer recommendations. The applicant should use the following delay periods between engine shutdown or flameout to restart:

- Stabilized windmill conditions, and
- Until the powerplant installation exhaust gas temperature is stabilized at a total air temperature plus 18 °F (10 °C) or lower.

23.2.4.2.5 The applicant should seek advice from the engine manufacturer on the potential need to evaluate the engine restarting performance impact due to any other operating conditions anticipated to occur in service (e.g., rain, hail, or icing). The applicant is not required to perform engine restart testing in inclement weather. Instead, the applicant may adjust restart procedures to accommodate any anticipated impact from operating conditions. An applicant may need to include additional information in the restart procedure to inform the flightcrew of these effects, such as longer start times.

23.2.4.2.6 If an onboard APU is required to provide essential functions, including assisted in-flight engine restart, the applicant should determine the minimum APU start reliability. The applicant should also perform flight tests to evaluate APU operation within critical portions of the flight envelope. The applicant should conduct APU start reliability testing in flight following cold-soak cruise conditions; a maximum of two relight attempts are allowed.

23.2.4.2.7 If batteries are required to provide power for an assisted in-flight engine restart, the applicant should determine the minimum capacity and reliability. The applicant should also perform flight tests to evaluate battery operation within critical portions of the flight envelope. The applicant should include cold-soak cruise conditions when determining critical points.

23.2.4.2.8 The applicant should evaluate in-flight engine restart capability following loss of normal electrical power. (See § 25.1351(d).) The applicant should demonstrate suction feed capability for airplanes that only supply fuel pressure to engines using normal electrical power (electrical power sources excluding the battery). This condition can result in vapor formation in the fuel system that may inhibit restart. In one airplane design, the heat soak from the engine following flameout caused vapor lock in the engine fuel feed system, resulting in the inability to restart either engine. The applicant should conduct the evaluation at the maximum operating altitude with the critical fuel (type and temperature) from the standpoint of flameout and restart characteristics. An all-engines-out condition occurring at a lower altitude (e.g., just above the maximum altitude where fuel suction feed capability exists) may possibly result in a lower recovery altitude than if the all-engines-out condition occurred at a higher altitude. If possible, then the applicant should also demonstrate performance under that condition.

23.2.4.2.9 Flight test procedures to address all-engines-out conditions must be agreed to by the FAA.

23.2.4.2.10 Procedures to evaluate an installed engine's susceptibility to an engine rotor lock or rotor drag condition are found in FAA policy statement PS-ANM-25-02, *Guidance for Screening for Engine Rotor Lock in Transport Category Airplanes during Aircraft Certification*.

23.3 **Automatic Takeoff Thrust Control System—§ 25.904.**

23.3.1 Explanation.

23.3.1.1 Beginning in the 1970s, some manufacturers of turbojet powered airplanes elected to equip their airplanes with engine thrust control systems that automatically increased the thrust on the operating engine(s) when any engine failed. A similar system, referred to as an automatic takeoff thrust control system (ATTCS), was subsequently installed on turbopropeller airplanes.

23.3.1.2 Takeoff performance credit was granted for ATTCS based upon prescribed system functional and reliability requirements, and performance related restrictions (e.g., initial takeoff power or thrust not less than 90 percent of that set by the ATTCS).

23.3.1.3 These systems represented "novel or unusual design features" not adequately addressed by the requirements of part 25 at the time. Consequently, the airworthiness requirements for the early ATTCS certifications were prescribed in special conditions in accordance with § 21.16. The regulatory and technical content of those special conditions was added to § 25.904 and appendix I to part 25, at amendment 25-62.

23.3.2 Procedures.

Certification of an airplane with an ATTCS requires flight test demonstration of certain performance and functional aspects of the system, as outlined below:

23.3.2.1 In order to comply with the part 25 airplane performance requirements, as required by section I25.3(c) of appendix I to part 25, takeoff speeds, as limited by V_{MCG} and V_{MCA}, must reflect the effect of ATTCS operation following failure of the critical engine. It is permissible to publish two sets of takeoff performance data: one for ATTCS unarmed and one for ATTCS armed. In such cases, the AFM limitations, operating procedures, and performance information should clearly differentiate between the two sets of performance data.

23.3.2.2 Engine operating characteristics should be investigated during operation of the ATTCS, and with the operating engines at the steady-state maximum power or thrust level achieved following operation of the ATTCS. (See the guidance material provided in paragraph 23.11 of this AC.)

23.3.2.3 Manual override of the ATTCS should be verified in flight test. This capability has been provided by the ability of the pilot to push the throttle levers to a higher power or thrust setting, for airplanes that use less than "full-throttle" for takeoff, and by activating an override switch for "firewall-type" fuel control systems. The override switch must be located on or forward of the power or thrust levers, and it must be easily accessible to the pilot's hand that normally controls the power lever or thrust position in accordance with section I25.5(b)(2) of appendix I. It should also be demonstrated that the thrust/power level can be manually decreased at any time following ATTCS operation.

23.3.2.4 A critical time period must be determined during which the probability of concurrent engine and ATTCS failure must be shown to be extremely improbable (not greater than 10^{-9} per flight hour). This critical time period is defined in appendix I to part 25 as being from one second before the airplane attains V_1, to a time where the actual takeoff flight path (i.e., no gradient reductions), following a simultaneous engine and ATTCS failure, would intersect the normal (i.e., engine failure at V_{EF} and no ATTCS) one-engine-inoperative actual takeoff flight path at no less than 400 feet above the takeoff surface. The probability of failure of the ATTCS, itself, must be shown to be improbable (not greater than 10^{-5} per flight hour).

23.3.2.5 Performance credit for an operating ATTCS is not to be taken when operations are conducted using reduced takeoff power or thrust methods. If the ATTCS is armed during reduced power or thrust takeoffs, the relevant takeoff speeds should meet the required controllability criteria of part 25 at the power or thrust level provided by operation of the ATTCS. The applicant should demonstrate that the airplane has no adverse handling characteristics and the engine(s) do not exhibit adverse operating characteristics or exceed operating limits when the ATTCS operates.

23.3.2.5.1 In accordance with § 25.1585, the AFM must contain information, instructions, and procedures, as required, regarding the peculiarities of normal and abnormal operations when scheduling reduced power or thrust operations with an armed ATTCS.

23.3.2.5.2 Takeoff with an armed ATTCS is not restricted when airplane performance is based on an approved "derate" power or thrust rating that has corresponding airplane and engine limitations approved for use under all WAT conditions.

23.4 Propellers—§ 25.905. [Reserved]

23.5 Propeller Vibration and Fatigue—§ 25.907. [Reserved]

23.6 Propeller Clearance—§ 25.925. [Reserved]

23.7 Propeller Deicing—§ 25.929.

23.7.1 Explanation.

None.

23.7.2 Procedures.

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 rate for a time period (≈15 minutes) found operationally suitable. The operation should be checked at all engine speeds and powers. The tank should be refilled to determine the amount of fluid used after the airplane has landed.

23.8 Reversing Systems—§ 25.933.

23.8.1 Turbojet Reversing Systems—§ 25.933(a).

23.8.1.1 **Explanation.**

23.8.1.1.1 For reversers intended to be operable on the ground only, it must be shown that the airplane can be safely landed and stopped with a critical engine reverser deployed. In addition, if an undamaged reverser inadvertently becomes deployed in flight, it must be shown that it can be safely restored to a forward power or thrust position.

23.8.1.1.2 For turbojet reversing systems intended for ground and/or inflight use, it must be shown that unwanted deployment of a critical reverser under normal operating conditions will not prevent continued safe flight and landing. Flight tests may be required to obtain aerodynamic data with the critical reverser deployed, to confirm that its deployment in the normal operating envelope will not be catastrophic to the airplane.

23.8.1.2 **Procedures.**

23.8.1.2.1 Turbine engine thrust reversers may be approved provided the following basic criteria are met:

1. Exceptional piloting skill is not required in taxiing, or in 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.
4. The directional control is adequate using normal piloting skill. This is of particular importance for airplanes with aft-mounted engines, which may experience a loss of rudder effectiveness with reverse thrust. This may result in reductions in maximum reverse thrust levels (i.e., lower EPR or N_1 settings) and/or increases in reverse thrust minimum operational speeds. The stabilizing effect of the nose gear should also be investigated, particularly for the one-engine-inoperative use of reverse thrust on wet runway surfaces.
5. A determination is made that no dangerous condition is encountered in the event of the sudden failure of one engine in any likely reverse thrust operating condition throughout the airplane's approved operating envelope.
6. The operating procedures and airplane configuration are such as to provide reasonable safeguards against engine foreign object ingestion and serious structural damage to parts of the airplane due to the reverse airflow. This is normally accomplished by specifying in the limitations section of the AFM a minimum airspeed at which the thrust reversers must be retracted.
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. For seaplanes, it is determined that the pilot's vision is not dangerously obscured by spray due to reverse airflow under normal water operating conditions.
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:
   a. Sufficient power or thrust is maintained to keep the engine running at an adequate speed to prevent engine stalling during and after the reversing operation.
   b. The engine does not overspeed or stall during and after the reversing operation.
   c. The engine cooling characteristics should be satisfactory in any likely operating condition.
10. For airplanes equipped with thrust reversers intended for inflight use, the effect of non-deployment of a reverser (i.e., asymmetric deployment) on airplane controllability should be investigated.

23.8.1.2.2 For the failed reverser demonstration tests, the following criteria are provided:

1. The landing with a reverser deployed should be conducted with a flap setting and an airspeed such that a landing can be accomplished safely and consistently. The conditions and operating procedures to use when the landing is made with the deployed reverser must be defined and incorporated in the AFM per § 25.1585(a)(2) or (a)(3), whichever is applicable.
2. The restow test should be conducted at a reasonable and safe altitude and at an airspeed where the airplane can be safely controlled (approximately 200 knots). A procedure should be developed so that the reverser can be restowed (if undamaged) safely, without causing unacceptable airplane controllability problems. The restowing procedure, airspeed, and airplane flight controls configuration should be provided in the AFM.

23.8.1.2.3 Aircraft Backing Using Reverse Thrust.

Limited operational approvals have been granted for the use of thrust reverser systems to back away from terminal gates in lieu of a tug pushback. These approvals are granted by the cognizant FAA Flight Standards office for each operator, the approval consisting of an amendment to the operator's operations specifications identifying the airplane type, the airport, and the specific gates at that airport at which reverse thrust backing may be used. Though reverse thrust backing is not specifically an airworthiness approval item, there are certain areas of concern that overlap airworthiness and operations. (These items are addressed in paragraph 42.12 of this AC.)

23.8.2 Propeller Reversing Systems—§ 25.933(b).

23.8.2.1 **Explanation.**

None.

23.8.2.2 **Procedures.**

Reverse thrust propeller installations may be approved, provided the following is acceptable:

23.8.2.2.1 A reliable means for preventing the in-flight selection of a power setting below flight idle is provided.

23.8.2.2.2 Exceptional piloting skill is not required in taxiing or in any condition in which reverse thrust is to be used.

23.8.2.2.3 Necessary operating procedures, operating limitations, and placards are established.

23.8.2.2.4 The airplane control characteristics are satisfactory with regard to control forces encountered.

23.8.2.2.5 The directional control is adequate using normal piloting skill.

23.8.2.2.6 A determination is made that no dangerous condition is encountered in the event of sudden failure of one engine in any likely operating condition.

23.8.2.2.7 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 direct effects of the reverse airflow or any resultant buffeting.

23.8.2.2.8 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.

23.8.2.2.9 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.

23.8.2.2.10 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:

1. Sufficient power is maintained to keep the engine running at an adequate speed to prevent engine stalling during and after the propeller reversing operation.
2. The propeller does not exceed the approved speed limit of 14 CFR part 35 or the airplane-manufacturer-declared propeller speed limit during and after the propeller reversing operation.
3. This idle setting does not exceed 25 percent of the maximum continuous rating.

23.8.2.2.11 The engine cooling characteristics should be satisfactory in any likely operating condition.

23.9 Turbojet Engine Thrust Reverser System Tests—§ 25.934. [Reserved]

23.10 Turbopropeller-Drag Limiting Systems—§ 25.937.

23.10.1 Explanation: Approval of Automatic Propeller Feathering Systems.

All parts of the feathering device that are integral with the propeller, or attached to it in a manner that may affect propeller airworthiness, should be considered from the standpoint of the applicable provisions of part 35. The determination of the continuing eligibility of the propeller under the existing type certificate, when the device is installed or attached, will be made on the following basis:

23.10.1.1 The automatic propeller feathering system should not adversely affect normal propeller operation and should function properly under all temperature, altitude, airspeed, vibration, acceleration, and other conditions to be expected in normal ground and flight operation.

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

- Momentary loss of power or thrust, or
- Approaches with reduced throttle settings.

23.10.1.3 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 or thrust. 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. (See also §§ 25.101, 25.111, 25.121, and 25.1501.)

23.10.1.4 The automatic propeller feathering system installation should be such that not more than one engine will be feathered automatically, even if more than one engine fails simultaneously.

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

23.10.1.6 The automatic propeller feathering system installation should incorporate a switch, or equivalent means, by which to make the system inoperative.

23.10.2 Procedures: Propeller Feathering System Operational Tests.

23.10.2.1 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 safety speed, V_2.

23.10.2.2 The propeller feathering system should be tested to demonstrate non-rotation or as a minimum, non-hazardous rotation at up to 1.2 times the maximum level flight speed, with one engine inoperative or the speed employed in emergency descents, whichever is higher, with:

- The critical engine inoperative,
- Wing flaps retracted,

- Landing gear retracted, and
- Cowl flaps (if applicable) closed.

23.10.2.3 A sufficient speed range should be covered to assure that the propeller feathering angle, established on the basis of the high speed requirement, will not permit hazardous reverse rotation at the lower speeds. In addition, the propeller should not inadvertently unfeather during these tests.

23.10.2.4 In order to demonstrate that the feathering system operates satisfactorily, the propeller should be feathered and unfeathered at the maximum operating altitude established in accordance with § 25.1527. The following data should be recorded:

- Time to feather the propeller at the one-engine-inoperative cruising speed,
- Time to unfeather the propeller to the minimum declared governing speed at maximum operating altitude (note that some driftdown may occur) and one-engine-inoperative cruising speed,
- Altitude of propeller feathering tests, and
- Ambient air temperature of propeller feathering tests.

23.10.2.5 In order to demonstrate that the feathering system operates satisfactorily, the propeller should be feathered at the condition within the airplane operating envelope that is critical for the propeller.

23.11 **Turbine Engine Operating Characteristics—§ 25.939.**

23.11.1 Explanation.

The turbine engines of a transport category airplane must continue to operate safely during normal and emergency operation within the range of operating limitations of the airplane. Generally, compliance with § 25.939(a) can be determined to some extent while ascertaining compliance with other part 25 requirements, such as performance, controllability, maneuverability, and stall speed characteristics. Turbine engines should be stable in their operation and run free of adverse characteristics throughout the normal flight envelope. Certain adverse characteristics are allowed in specific flight regimes if they do not present a hazardous condition.

23.11.2 Reference.

See AC 25.939-1 for comprehensive guidance in the evaluation of turbine engine operating characteristics to show compliance with the requirements of § 25.939(a), only. The referenced AC does not provide guidance for compliance with § 25.939(c), which addresses inlet compatibility.

23.11.3 Inlet Compatibility—§ 25.939(c).

23.11.3.1 **Explanation.**

Section 25.939(c) requires substantiation that the engine inlet systems on turbine engines not cause harmful vibration to the engine as a result of airflow distortion. This should be verified in both static and transient power or thrust conditions.

23.11.3.2 **Procedures.**

Compliance with § 25.939(c) may require special instrumentation of the inlet itself, or the engine's most critical component (i.e., fan blades). Inlet rakes permit the applicant to verify that the installed airflow distortion patterns are within the limits established by the engine manufacturer. In addition, accelerometer and/or strain gauge data could be acquired in flight tests to verify that vibration and stress level limits are not exceeded during operation in the normal flight envelope.

23.12 Inlet, Engine, and Exhaust Compatibility—§ 25.941. [Reserved]

23.13 Negative Acceleration—§ 25.943.

23.13.1 Explanation.

Section 25.943 requires that no hazardous malfunction of an engine, APU, or any component or system associated with their operation, should result from airplane operation at negative accelerations. A hazardous malfunction in this case is considered to be one that causes loss or sustained malfunction of the engine or APU, or improper operation of the engine accessories or systems. This requirement can be satisfied by flight test demonstrations that take into consideration the critical airplane, engine, and APU configurations. The range of negative accelerations to be tested is prescribed by the flight envelope for the airplane, as defined in § 25.333. The duration of the negative acceleration excursions is intended to represent anticipated non-normal operational events such as atmospheric upsets, collision avoidance maneuvers, etc.

23.13.2 Procedures.

23.13.2.1 In conducting negative acceleration tests, consideration should be given to engine accessory configurations, and critical levels of fuel and oil.

23.13.2.2 Accelerations should be measured as close as practicable to the airplane's CG position.

23.13.2.3 With the engines operating at maximum continuous power or thrust, and the APU operating with normal load (if flight operable), the airplane should be flown at a critical negative acceleration within the flight envelope. The duration of each test condition should be a minimum of

7 seconds between 0 and -1.0 g, with a total accumulation of 20 seconds of negative acceleration operation.

23.13.2.4 Test data should be analyzed with regard to maintaining adequate fuel flow to the engines and APU, and maintaining lubrication of critical components.

23.13.2.5 Test planning should consider that sufficient altitude be available to conduct a suction feed relight in the unlikely event of an all-engine flameout, in which case the tank pump feed lines will become uncovered and air will enter each feed line.

23.14 **Thrust or Power Augmentation System—§ 25.945. [Reserved]**

CHAPTER 24. POWERPLANT: FUEL SYSTEM

24.1 Unusable Fuel Supply—§ 25.959.

24.1.1 Explanation.

24.1.1.1 The purpose of this test is to determine, for each fuel tank, the quantity of fuel that is not available to the engines, as specified in § 25.959. The unusable fuel quantity is the quantity of fuel that can be drained from the fuel tank sump with the airplane in its normal level ground attitude after a fuel tank unusable fuel test has been performed, plus the quantity remaining in the fuel tank (undrainable fuel).

24.1.1.2 A fuel tank that is not designed to feed the engines under all flight conditions need be tested only for the flight regime for which it is designed to do so (e.g., cruise conditions). Tanks that are not subject to aeroelastic effects of flight, such as wing bending or tank flexing, may have their unusable fuel quantity determined during a ground test. Suitable instructions on the conditions under which the tank may be used should be provided in the AFM. Other part 25 requirements, such as fuel flow (§ 25.955(a)(2)) and fuel quantity gauge calibration (§ 25.1553), are also related to the unusable fuel quantity. These other requirements must also be considered when the unusable fuel quantity is being determined for each fuel tank.

24.1.2 Procedures.

24.1.2.1 The fuel system and tank geometry should be analyzed to determine the critical conditions for the specific tanks being considered (i.e., main and auxiliary or cruise tanks). The analysis should determine the amount of unusable fuel as a function of airplane pitch and roll attitudes, including those encountered when executing sideslips and dynamic maneuvers such as go-around pitch-up and acceleration. Particular attention should be directed toward the fuel tank or cell geometry and orientation with respect to the longitudinal axis of the airplane and location of the fuel tank outlets (i.e., fuel pump inlets or pickups). Care should be taken in planning how the critical attitude conditions are tested, so that the test procedure does not result in a non-conservative unusable fuel quantity.

24.1.2.2 The term “most adverse fuel feed condition” is not intended to include radical or extreme conditions not likely to be encountered in operation. Judgment should be used in determining what maneuvers are appropriate to the type of airplane being tested. The test conditions should be selected using good judgment with regard to the kind of conditions the airplane under test will be subjected to in operation.

24.1.2.3 Airplane attitude limitations may be used as a means of reducing the unusable fuel quantity, provided it is demonstrated that likely operational flight maneuvers can be accomplished with those attitude limits. Nose down pitch attitude should not be less than that for normal descent, approach, and landing maneuvers. Nose up pitch attitude consistent with a normal go-around condition, or a minimum of 10° nose up, whichever is less, should be considered. Roll attitude limitations should not be less than that required to enter a normal traffic pattern, intercept the final approach course, and land with a 10-knot crosswind.

24.1.2.4 After the most adverse fuel feed condition and the critical flight attitude have been determined for the specific fuel tanks being considered, the appropriate flight tests should be conducted. The flight testing should investigate the effects of the following:

24.1.2.4.1 Steady state sideslips anticipated during operation with the airplane in both the approach and landing configurations.

24.1.2.4.2 For those airplanes capable of high roll and pitch rates, abrupt maneuvers should be considered.

24.1.2.4.3 A go-around condition at maximum acceleration and maximum rotation rate to the maximum pitch attitude should be considered.

24.1.2.4.4 Effects of turbulence on unusable fuel quantity should be considered.

24.1.2.4.5 If the airplane includes a low fuel quantity warning system, it should be demonstrated that the airplane can complete a go-around, approach, and return to landing, without fuel feed interruption, using the <u>normal go-around pitch attitude</u>; this should include go-arounds accomplished with the aid of automated flight guidance systems.

24.1.2.5 If airplane attitude limitations are employed to reduce the unusable fuel quantity, those attitude limitations must be published in the AFM (per § 25.1581(a)(2)) as limits for flight maneuvers after the low fuel warning light/message illuminates. This will provide assurance that the fuel remaining that is above the unusable quantity can be used without risk of fuel feed interruption to the engines. Flight tests should be conducted to confirm that the proposed pitch attitude limit:

- Is practical in terms of airplane flight characteristics for accomplishing a go-around; and
- Will not result in lift and drag characteristics that will increase the time and/or fuel quantity necessary to complete the go-around to a point where the fuel remaining is less than the unusable fuel quantity.

24.1.2.6 If fuel pump failure en route would result in a significant reduction in usable fuel, the unusable fuel supply test should include a determination of this quantity. The effects of pump failure on the unusable fuel quantity should be presented in the AFM so that the flightcrew can take the reduction in usable fuel into account for flight planning purposes.

24.1.2.7 Auxiliary fuel tanks and fuel transfer tanks designed or restricted for use during cruise flight only (i.e., not suitable for takeoff and landing) should be tested for unusable fuel quantity by appropriate investigation of the cruise environment. This should include reasonable turbulence levels, asymmetrical power or thrust, adverse fuel feed/transfer configuration, etc. However, the unusable fuel quantity should not be less than fuel tank sump quantity.

24.2 Fuel System Hot Weather Operation—§ 25.961.

24.2.1 Explanation.

24.2.1.1 A flight test is normally necessary to complete the hot weather operation tests required by § 25.961(a). If a ground test is performed, § 25.961(b) requires that the ground test closely simulate flight conditions. If a flight test is performed, the test should be conducted with hot fuel in the tanks normally used for takeoff and landing, and with the maximum number of engines drawing fuel from each tank, in accordance with the operating procedures provided in the AFM, to obtain the maximum anticipated fuel flow through the lines. In the case of symmetrical fuel tank systems, the tests may be confined to one of each such system. Critical fuel that is unweathered or has not been exposed to long storage periods should be used during the tests. This ensures that the fuel has the maximum Reid vapor pressure (RVP) for which approval is requested. Fuel samples should be taken from the fuel tank prior to the test; for typical JET B (JP-4) type fuels, a minimum RVP of 3.0 has been required. The fuel temperature, just prior to takeoff, should be as close as practical to the maximum value for which operational approval is sought, but not less than 110 °F as required by § 25.961(a)(5). If the fuel needs to be heated to this temperature, caution should be taken to prevent overheating during the process.

24.2.1.2 The desirable outside ambient air temperature at the airport from which the tests are being conducted should be at least 85 °F (29 °C). If tests are performed in weather cold enough to interfere with test results, § 25.961(b) requires insulating fuel tank surfaces, fuel lines, and other fuel system components from cold air to simulate hot-day conditions. It should not be necessary to provide additional heat to the fuel after the original fuel sample is heated to temperature during the hot weather tests. However, if the fuel is used as the cooling medium for any heat exchangers, the maximum heat available to the fuel should be considered.

24.2.1.3 If auxiliary pumps are being considered for use as emergency pumps, they should be inoperative. This test may be used to establish the maximum pressure altitude for operation with these pumps off. A fuel pressure failure is considered to occur when the fuel pressure decreases below the minimum prescribed by the engine manufacturer, or the engine does not operate satisfactorily.

24.2.2 Test Procedures and Required Data.

24.2.2.1 The fuel temperature, just prior to takeoff, should be as close as practical to the maximum value for which operational approval is sought. If heating of the fuel is required, a takeoff and climb should be made as soon as possible after the fuel in the tank has been heated to avoid cooling of the fuel.

24.2.2.2 Power or thrust settings should be maintained at the maximum approved levels for takeoff and climb in accordance with § 25.961(a)(2). Section 25.961(a)(3) requires the weight of the airplane to be the weight with full fuel tanks, minimum crew, and the ballast necessary to maintain the CG within allowable limits. The airspeed during the climb should not exceed that speed used in demonstrating the requirements specified in § 25.961(a)(4). The combination of power or thrust, airplane weight and climb airspeed establishes the climb rates that must be considered when determining the critical conditions for testing. The airplane fuel load and rate of climb are the critical parameters for this test. Although the weight of the airplane must be based on full fuel tanks, experience has shown that full fuel tanks may not always be the most critical fuel load. Generally, full tanks result in the maximum head pressure over the tank pumps. A lesser tank quantity results in a lesser head pressure that may be more critical to the formation of fuel vapor in the pumps and fuel system lines. A greater rate of climb results in more air per unit time being released in the feed lines during the climb. An analysis may be needed to determine the critical combination of fuel quantity state and airplane climb rate that is operationally likely to occur. The test should be conducted at this critical combination of fuel quantity state and airplane climb rate with the airplane loaded to the weight and flown within the range of climb airspeeds at the power or thrust required by the regulation.

Note: The fuel systems of some airplanes are designed to feed fuel to the engines from auxiliary and main fuel tanks. This results in variations in fuel feed configurations as part of the approved fuel management. Variations in fuel feed configurations, including changes in fuel feed configuration such as transition from feeding fuel to the engine(s) from one tank to feeding from another, should be considered in assessing fuel feed performance in demonstrating compliance to §§ 25.951 or 25.955 and considered in establishing the critical conditions for the hot fuel evaluation.

24.2.2.3 If the engines are normally operated with the auxiliary/emergency pumps "off," they should remain "off" until fuel pressure failure occurs. Restoration of fuel pressure should be noted and the climb continued to the maximum operating altitude selected by the applicant for certification. If a lower altitude is substantiated, appropriate operating limitations should be established and furnished in the AFM.

24.2.2.4 The tests should be conducted with the fuel system operating and configured normally, in accordance with the normal procedures outlined in the AFM. The following data should be recorded at reasonable time intervals:

1. Fuel temperature in the tank.
2. Engine fuel pressure, measured at the engine/airplane interface, at the start of the test and during climb (note any pressure failure, fluctuation, or variation).
3. Main and auxiliary/emergency fuel pump operation, as applicable.
4. Pressure altitude.
5. Ambient air temperature.
6. Airspeed.
7. Engine power or thrust setting and operating parameters (i.e., engine pressure ratio, gas generator speed, fan speed, exhaust gas temperature, fuel flow, etc.).
8. Comments on engine operation.
9. Fuel quantities in fuel tanks.
10. Fuel grade or designation determined prior to test.
11. Airplane pitch and roll attitudes.

24.2.2.5 If significant fuel pressure fluctuations occur during testing of the critical flight conditions, but pressure failure does not occur, additional testing should be considered to determine that pressure failure may not occur during any expected operating mode. Also, the fuel system should be evaluated for vapor formation when switching from different fuel feed configurations, or at low fuel flow and idling approach and landing.

24.3 Fuel Tank Vents and Carburetor Vapor Vents—§ 25.975.

24.3.1 Explanation: Approval of Fuel Tank Vents (§ 25.975(a)).

24.3.1.1 The tank venting arrangement must prevent siphoning of fuel during normal operation. Also the venting capacity and vent pressure levels must maintain acceptable differences of pressure between the interior and exterior of the tank during:

- Normal flight operation,
- Maximum rate of ascent and descent, and
- Refueling and defueling.

24.3.1.2 No vent or drainage provision may end at any point where the discharge of fuel from the vent outlet would constitute a fire hazard, or where the discharge of fumes could enter personnel compartments.

24.3.1.3 Each carburetor vent system must have means to avoid stoppage by ice.

24.3.2 Procedures.

24.3.2.1 Tests should be conducted to ensure that no hazardous quantities of fuel will be siphoned overboard during any likely maneuvers encountered during normal operations. Maneuvers that may require evaluation include, but are not necessarily limited to, the following:

24.3.2.1.1 Taxi turns and turning takeoff maneuvers with fuel tanks filled to the maximum volume (below the required 2 percent expansion space) allowed by the type design, including consideration of tolerances in the volumetric shutoff level. Typically, left and right-hand turns are conducted in a "figure eight" maneuver, followed by a maximum pitch and ascent rate takeoff.

24.3.2.1.2 Maximum climb power or thrust ascent at high climb angles.

24.3.2.1.3 Simulated turbulent air oscillations at or near the natural yawing and pitching frequency of the airplane.

24.3.2.1.4 Rapid descent with high initial pitch-down rate.

24.3.2.1.5 In-flight power-up turns.

24.3.2.1.6 Sideslip maneuvers on approach.

24.3.2.2 The changes in tank secondary barrier cavity pressure during all airplane maneuvers, including emergency descent, should be accounted for in the design of the fuel tank. Bladder type tanks may be critical under emergency descent conditions, depending on the cavity vent line sizing. According to § 25.975(a)(3), the vent/drain configuration must provide the required positive and negative pressure relief between the outer shell and the bladder or inner wall, to prevent collapse or over-expansion of the inner tank. Depending on the location of the overboard vent/drain exit and the airflow characteristics around the exit or exit mast, a flight test may be required to evaluate the ascent and/or emergency descent characteristics of the cavity vent system with the airplane in both the "clean" and "wheels and flaps down" configuration.

24.3.2.3 Verification that liquid discharge from the vent mast will flow clear of the airplane, not attaching itself to any airplane surface or re-entering any compartment of the airplane, may need to be accomplished by impingement tests conducted inflight. Small discharges of fuel from the fuel tank vent outlet have been acceptable, provided the fuel discharges clear of the airplane and does not result in siphoning of fuel from the tank. This can be accomplished using dyed fluid and/or coating the surfaces required to be free of impingement with powder compounds that will be washed away if contacted by liquid. If dyed water or other liquid is used, it may be necessary to add chemicals to prevent freezing during the test. Sufficient test maneuvers should be accomplished to ensure that impingement will not occur during any inadvertent discharge from the venting system.

24.3.2.4 Carburetor vent systems may require flight testing to ensure against stoppage by freezing. Such tests can be conducted in conjunction with the tests required by § 25.1093 and/or § 25.1101 (see the "Procedures" for those sections in this AC).

CHAPTER 25. POWERPLANT: FUEL SYSTEM COMPONENTS

25.1 Fuel Jettisoning System—§ 25.1001.

25.1.1 Explanation.

25.1.1.1 Section 25.1001(a) prescribes the conditions governing the need for installation of fuel jettisoning systems; if an airplane can meet the climb requirements of §§ 25.119 and 25.121(d), at the weight existing after a 15-minute flight consisting of a maximum weight takeoff and immediate return landing, a fuel jettisoning system is not required. Credit is given for the actual or computed weight of fuel consumed in the 15-minute flight using the airplane configurations, power or thrust settings, and speeds appropriate to each flight segment.

25.1.1.2 If a fuel jettisoning system is required, § 25.1001(b) prescribes the conditions that will determine the minimum flow rate of the system. Section 25.1001(b) requires the fuel jettisoning system to be capable of reducing the weight of the airplane, within 15 minutes of operation, from that specified in § 25.1001(a) to a weight at which the airplane will meet the climb requirements of §§ 25.119 and 25.121(d). Since the weight defined in § 25.1001(a) allows credit for a 15-minute fuel burn, a literal interpretation of this rule would result in a 15-minute jettisoning period beginning after a 15-minute takeoff, go-around, and approach flight. In application, the 15-minute jettisoning period will occur during a 30-minute flight in which weight reduction credit will be given for the fuel consumed and jettisoned. The airplane must be able to meet the specified climb requirements at the weight existing at the end of this 30-minute flight.

25.1.1.3 Airplanes should also be investigated for other elements that may limit their ability to safely accomplish an immediate return landing without a fuel jettisoning system. Advances in wing design and propulsion technology have resulted in transport category airplane designs that can take off at weights considerably above their maximum landing weights. Many of these airplanes are capable of meeting the climb requirements of §§ 25.119 and 25.121(d), following a 15-minute flight, without a fuel jettisoning system. Some of these airplanes, however, may not be capable of landing without exceeding other certification limits such as maximum brake energy, landing distance, and tire speed. This is particularly true when non-normal procedures, implemented as a result of failures that have been shown to be foreseeable events, call for reduced flap settings and increases of as much as 30 knots, for a given weight, over speeds associated with the normal landing flap setting. Margins to flap placard limit speeds and flap load-relief activation speeds should be established and maintained for non-normal configurations that may be used in immediate return landings.

25.1.1.4 An additional consideration that is representative of actual operating conditions is the ability to perform a go-around from field elevation with the flaps in the approach position and the landing gear down. Through compliance with § 25.1001(b), assurance will be obtained that the airplane can accomplish an all-engines-operating balked landing go-around, with normal landing flaps, followed by a one-engine-inoperative climb-out with approach flaps and landing gear up. However, non-normal procedures generally call for one-engine-inoperative landings to be made with the flaps in the position used to show compliance with the approach climb requirements of § 25.121(d). It should therefore be determined under what combinations of weight, altitude, and temperature the airplane can establish a positive rate-of-climb with one-engine-inoperative and the other operating at go-around power or thrust, with the flaps in the appropriate go-around position and the landing gear down.

25.1.2 Procedures.

The basic purpose of these tests is to verify that the minimum jettisoning rate will allow the airplane to safely execute an immediate return landing, and 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.

25.1.2.1 **Jettisoning Rate.**

25.1.2.1.1 In determining the minimum jettisoning rate, the tanks, tank combinations, or fuel feed configurations that are critical should be selected for demonstrating the flow rate.

25.1.2.1.2 It should be determined if airplane attitude or configuration has an effect on the jettisoning rate.

25.1.2.1.3 It should be demonstrated that the means to prevent jettisoning of the fuel in the tanks used for takeoff and landing, below the level to meet the requirements of § 25.1001(e) and (f), are effective.

25.1.2.1.4 It should be demonstrated that operation of the jettisoning system does not have a detrimental effect on operation of the engines (and the APU if installed and approved for inflight operation).

25.1.2.2 **Fire Hazard.**

25.1.2.2.1 The 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.

25.1.2.2.2 The fuel jettisoning flow pattern should be demonstrated for the flight conditions specified in § 25.1001(d)(1), (2), and (3). Steady-state sideslips anticipated during operation should be conducted during flight conditions.

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

25.1.2.2.4 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, a combustible mixture detector, or by visual inspection. In pressurized airplanes, the check for the presence of liquid or vaporous fuel should be accomplished with the airplane unpressurized.

25.1.2.2.5 There should be no evidence of leakage after the fuel jettisoning valve is closed.

25.1.2.2.6 Testing should be conducted with the wing flaps in all available positions and during transition from each position to the next. If there is any evidence that wing control surface (flaps, slats, etc.) positions may adversely affect the flow pattern and allow fuel to impinge on the airplane, the airplane should be placarded and a limitation noted in the AFM.

25.1.2.3 **Control.**

25.1.2.3.1 Changes in the airplane control qualities during the fuel jettisoning tests should be investigated, including asymmetrical jettisoning.

25.1.2.3.2 Discontinuance of fuel jettisoning should be demonstrated in flight.

25.1.2.4 **Residual Fuel.**

The quantity of usable fuel that cannot be jettisoned should be determined to meet the requirements of § 25.1001(e) or (f), as applicable. One acceptable means to show compliance with the requirement for sufficient fuel remaining to permit continued flight has been to drain the remaining fuel from the test tank(s) after landing. Applicants may propose other means of compliance.

25.2 **[Reserved.]**

CHAPTER 26. POWERPLANT: OIL SYSTEM [RESERVED]

CHAPTER 27. POWERPLANT: COOLING

27.1 Cooling Test Procedures—§ 25.1045.

27.1.1 Explanation.

The following guidance applies to cooling test procedures for turbine engine powered airplanes.

27.1.1.1 **Purpose.**

In accordance with § 25.1041, cooling tests must be 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 engine type certificate data sheet (TCDS), qualification specification sheet for the component, and/or in the approved engine installation handbook.

27.1.1.2 **Scope.**

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

27.1.2 Flight Test Procedures.

27.1.2.1 **Moisture.**

The tests should be conducted in air free of visible moisture.

27.1.2.2 **Weight and CG.**

Forward CG at maximum gross weight is usually the most critical condition as this results in the lowest airspeed and/or vertical speed. However, a lighter initial gross weight or a critical step climb profile may be necessary to get to maximum altitude. In any case, the most critical climb profile must be established by the applicant and agreed to by the FAA prior to commencing testing.

27.1.2.3 **Test Conditions.**

The critical flight profile(s) should be tested. It may be necessary to fly multiple flights with different flight profiles to assure all components under test are exposed to their most critical anticipated sequence of test conditions. Flight profiles with periods of relatively high heat rejection and relatively low cooling, such as can occur during step climbs and at the top of descent, may be more critical for some components, for example, those in or affected by the engine oil system. The period after engine shutdown on the ground may also be critical for some components. The applicant should identify and obtain the FAA’s approval of the flight test profile(s) prior to beginning certification testing. The following sequence of test conditions is usually adequate to cover the critical case for most components:

1. Initiate the flight test once critical temperatures have stabilized after engine start;
2. Use the test engine to perform a 1-mile single engine taxi.
3. Hold at idle power or thrust in a 10 knot or greater crosswind for 20 minutes or until temperatures stabilize (use ground test definition of stabilization).
4. Operate at least the test engine at the rated takeoff power or thrust for the maximum approved period (usually either 5 or 10 minutes) during a maximum gross weight/forward CG takeoff.
5. Perform simulated one-engine-inoperative and all-engines-operating climbs, operating the test engine at maximum continuous power or thrust until the engine temperatures stabilize or the airplane reaches maximum operating altitude (or until the airplane is essentially unable to climb further as indicated by a very low climb rate, e.g., 200 feet/minute).
6. Cruise with the test engine at maximum continuous power or thrust (but a speed no higher than V_{MO}/M_{MO}) at maximum operating altitude until temperatures stabilize.
7. Conduct a normal descent at V_{MO}/M_{MO} to a typical holding altitude and hold until temperatures stabilize.
8. Conduct a normal approach to landing, but from not less than 200 feet above the ground:
   a. Perform a simulated engine out go-around;
   b. Climb to pattern altitude; and then
   c. Perform a normal approach and landing.
9. Taxi back to the ramp and shut down the engines.
10. Allow the test engine’s heat-soak to peak.

27.1.2.4 **Oil Quantity.**

The critical condition should be tested.

27.1.2.5 **Thermostat.**

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

27.1.2.6 **Instrumentation.**

The applicant must identify all critical components (electronic components, actuators, etc.), including structural elements that have temperature limits. The limits are typically based on component qualification or certification testing. Each limit may be expressed in terms of a surface temperature or environmental temperature, and may have associated time limits. Instrumentation should be installed to provide data needed to show that each component corrected temperature remains below the identified limit. Accurate and calibrated temperature-measuring devices should be used, along with acceptable thermocouples or temperature pickup devices. The temperature pickup should be located at critical engine positions.

27.1.2.7 **Generator.**

The alternator/generator should be electrically loaded to the rated capacity for the engine/accessory cooling tests.

27.1.2.8 **Maximum Ambient Atmospheric Temperature.**

Section 25.1043(b) establishes 100 °F (38 °C) at sea level as the lowest maximum ambient temperature for cooling tests, except for winterization installations. (See paragraph 27.1.2.12 for guidance on certifying winterization equipment.) Applicants may establish a higher temperature limit if desired. In accordance with § 25.1041, applicants must show that cooling provisions can maintain the temperatures of powerplant components, engine fluids, and auxiliary power unit components and fluids within the established temperature limit. The assumed temperature lapse rate is -3.6 °F (-2 °C) per thousand feet of altitude above sea level until a temperature of -69.7 °F (-56.5 °C) is reached, above which altitude the temperature is considered constant at -69.7 °F (-56.5 °C). The compliance demonstration flight test should be conducted with an ambient temperature as close to the desired maximum ambient atmospheric temperature as practical. If testing is accomplished at lower ambient temperatures, then the test data must be corrected to that which would have resulted from testing on a day with the maximum ambient atmospheric temperature. (See paragraph 27.1.5.2.) The maximum ambient temperature selected and demonstrated satisfactorily, taking account of correction factors, shall not be less than the minimum hot day conditions prescribed by § 25.1043(b) and shall be an airplane operating limitation per the requirements of § 25.1521(d). The applicant should correct the engine temperatures to as high a value as possible in order to minimize the impact of this limitation.

27.1.2.9 **Temperature Stabilization.**

For the cooling flight tests, a temperature is usually considered stabilized when its observed rate of change is less than 2 °F per minute. However, regardless of the rate of temperature rise, if a component or fluid temperature is still rising and is near the limit for that component or fluid, sufficient test data must be gathered to show that the limit will not be exceeded in that steady state operating condition. A combination of test data and rational analysis may be used to determine the maximum temperature expected for a component or fluid rather than continuing a test condition for a long period of time after the rate of temperature rise has fallen below 2 °F per minute.

27.1.2.10 **Temperature inversion.**

During an inversion, where a layer of colder air is at ground level, component temperatures at the beginning of the cooling test climb will be lower relative to the ambient air temperature encountered during the climb. For components that require significant time to adjust to ambient temperature changes, the artificially low starting temperature may result in erroneous results. If cooling tests are conducted when an inversion exists, the applicant should present a more rational correction method than either the "degree for degree" method described in paragraph 27.1.5.2 or the method defined in § 25.1043. The FAA has accepted a correction method that used the difference between the test day ambient and the hot day atmospheric temperature taken at the beginning of the flight being used as the correction factor for all flight data. Although conservative, this method accounts for the effects of an inversion.

27.1.2.11 **Airport Altitude.**

The cooling tests should be conducted from the lowest practical airport altitude, usually below 3,000 feet mean sea level (MSL), to provide test data reasonably close to sea level.

27.1.2.12 **Winterization Equipment Procedures.**

The following procedures should be applied when certificating winterization equipment:

27.1.2.12.1 <u>Maximum Ambient Sea Level Atmospheric Temperature Less Than 100 °F (38 °C).</u>

Cooling test results for winterization installations may be corrected to any temperature desired by the applicant rather than the conventional 100 °F (38 °C) hot day. For example, an applicant may choose to demonstrate cooling to comply with requirements for a 50 °F (10 °C) or 60 °F (15.5 °C) 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 (2 °C) per thousand feet above sea level.

27.1.2.12.2 Tests.

Cooling tests and temperature correction methods should be the same as for conventional cooling tests.

27.1.2.12.3 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.

27.1.2.12.4 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.

27.1.2.12.5 Installation Instructions.

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

27.1.3 Ground Test Procedures.

27.1.3.1 **General.**

The flight testing guidance in paragraphs 27.1.2.1, 27.1.2.4, 27.1.2.5, 27.1.2.6, and 27.1.2.11 are equally applicable to ground testing.

27.1.3.2 **Test Conditions.**

Ground testing should be conducted with the engine operated at idle power or thrust until all critical temperatures have stabilized, followed by operation of the engine at rated takeoff power or thrust for 5 minutes, and then idle power or thrust until all critical temperatures have stabilized.

27.1.3.3 **Temperature Stabilization.**

During the ground operation portion of the compliance demonstration, the definition of stabilized temperatures defined for the flight test (rate of change less than 2 °F per minute (1 °C)) should not be used for determining the maximum component temperatures, unless it can be shown that ground operation of the engine is limited to the conditions tested. The reason for using a different definition of stabilized temperatures for ground operation is that during sustained ground operations at a particular condition, such as at idle power or thrust for using the engines as a pneumatic source, may result in temperatures that gradually exceed the defined temperature limits. To address this concern, some manufacturers have used engine operating limitations for ground operations that limit engine operation for discrete time periods. For example, engine operation at takeoff power or thrust may be limited to 2 minutes at ambient temperatures above 110 °F (43 °C), or engine operation at idle power or thrust is limited to 2 hours at ambient temperatures above 110 °F.

27.1.3.4 **Temperature Correction.**

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.

27.1.4 Data Acquisition.

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

- Outside air temperature (OAT).
- Altitude.
- Airspeed (knots).
- Gas generator RPM.
- Engine torque.
- Time.
- Fan RPM.
- Engine oil temperature.
- Pertinent engine temperature.
- Pertinent nacelle and component temperatures.

27.1.5 Data Reduction.

27.1.5.1 **Purpose.**

Seldom is testing actually accomplished at the maximum required ambient temperature of at least 100 °F at sea level lapsed 3.6 °F (2 °C) per 1,000 feet pressure altitude. Component and fluid temperatures must therefore be corrected to derive the item temperature that would have been reached if the test day had matched exactly the maximum ambient temperature day. The applicant may select a higher maximum ambient temperature for cooling certification than the 100 °F (38 °C) sea level hot day prescribed. Provisions are also made for selecting a maximum ambient temperature less than the 100 °F sea level hot day for winterization installations not intended to function at the hot day conditions.

27.1.5.2 **Correction Factors for Ambient Conditions.**

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]. A correction factor other than "degree-for-degree" should be based on engineering test data. The corrected temperature is then compared with the maximum permissible temperature to determine compliance with the cooling requirements. No corrected temperatures may exceed established limits.

Sample Calculation:

$$True\ Temperature = 300\ °\mathrm{F}\ (149\ ℃)$$

$$True\ OAT = 15\ °\mathrm{F}\ (-9\ ℃)$$

$$Hp = 5{,}000\ feet$$

$$Corrected\ temperature = 300 + 1.0[100 - 0.0036(5{,}000) - 15] = 367\ °\mathrm{F}\ (186\ ℃)$$

27.1.5.3 **Correction Factor for Minimum Engine.**

An important correction factor that is not discussed in the regulations, but is frequently necessary to show the cooling adequacy required by § 25.1041, is the minimum engine (i.e., the thermal limit) correction factor. This factor is sometimes required if, at test day conditions, the engine measured temperature does not correspond to the engine temperature that would have occurred on a minimum specification engine in hot day conditions. The correction factor would not apply to those components not affected by changes in exhaust gas temperature (EGT) at a constant power or thrust. Typical items expected to be affected by changes in the EGT at constant power or thrust would be engine oil temperature, thermocouple harnesses, or other fluid, component, or ambient temperatures in the vicinity of the engine hot-section or exhaust gases. Other items remote from the hot section, like the starter-generator or fuel control, would not be expected to be influenced by EGT variations; however, the items affected and the magnitude of the factor to be applied should be established by testing. There are several acceptable methods for establishing the appropriate correction factor during development testing. The general idea is to establish a stabilized flight condition, typically during ground runs, and vary the measured EGT at approximately fixed power or thrust and OAT conditions. This may be accomplished by using engine anti-ice bleed air, customer bleed air, or by ingesting warmer than ambient air (either an external source or the engine bleed air) into the engine inlet. Care should be used when ingesting warmer than ambient air to assure that the warm air is diffused in order to avoid possible engine surge. If it is not possible to attain an adequate variation in EGT by these methods, an acceptable, but conservative correction may be obtained by allowing both power or thrust and EGT to vary at stabilized engine operating conditions and OAT. The component temperature is plotted as a function of EGT, and the correction from test EGT for any flight condition, to the EGT that would have existed with minimum specification engines on a hot day, is then applied to derive the corrected component temperature. Both of these methods assume the inlet air and cooling air sources are essentially independent. Where they are not independent, such as those designs that take cooling air from the fan exit stream (e.g., via a fan box in bifurcation) rather than via a free stream scoop, care needs to be taken in selecting a technique to assure the results are neither overly conservative as may result from use of the hot air technique nor overly optimistic as may result from use of the higher power or thrust technique.

27.2 **[Reserved.]**

CHAPTER 28. POWERPLANT: INDUCTION SYSTEM

28.1 Air Induction—§ 25.1091.

28.1.1 Explanation—§ 25.1091(d)(2).

The turbine engines of transport category airplanes are susceptible to surge, stall, and flameout when excessive amounts of water are ingested. The certification requirements for turbine engines include the demonstration of a capability to operate in simulated rainfall with no adverse operating effects. The quantities of water spray that may be directed toward the engine inlets, resulting from the airplane passing through standing water on taxi and runways, may exceed that used in the simulated rainfall ingestion testing. This becomes particularly important during takeoff, where the engines are operated at high power or thrust settings and the airplane will experience a wide range of speeds. During takeoff and landing ground rolls, the airplane's tires generate bow waves, side spray, and "rooster tails" (spray that is thrown off the tires as they rotate), which can collect into concentrated streams of water that, if ingested into the engines, APU, or air conditioning systems, could affect operation sufficiently to cause an unsafe condition. Similarly, water ingestion into the airspeed system during ground operations may cause errant cockpit indications of airspeed. It is often practical to investigate these effects concurrently with the engine water ingestion evaluation.

28.1.2 References.

- AC 20-124.
- AC 91-79A.

28.1.3 Procedures.

28.1.3.1 Method of Compliance.

The applicant may show compliance with the requirements of § 25.1091(d)(2) by test or by reasonable analysis. The analytical approach may be acceptable in cases where an airplane and/or its engines were modified, but the overall geometry and configuration remained unchanged.

28.1.3.2 Water Depth.

Takeoffs should not be attempted when the depth of standing water, slush, or wet snow is greater than one-half inch over an appreciable part of the runway. (See AC 91-79A). Therefore, one-half inch of standing water is the accepted criteria for conducting tests to demonstrate compliance with the water ingestion requirements of § 25.1091(d)(2). Testing may be conducted in specially constructed water test beds, where the selected water depth is maintained over not less than 90 percent of the test bed area. If the airplane successfully completes testing with a one-half inch water depth, no operating limitations will be imposed for wet runway operations.

28.1.3.3 **Airplane Configuration.**

Testing should be conducted to demonstrate all critical phases of taxi, takeoff, and landing operations. High lift devices and landing gear doors should be in the position appropriate to each phase of operation tested. All portions of the airplane that may affect water spray patterns should be in the production configuration desired for approval (e.g., chine tires, fenders). The most critical powerplant operating configuration (bleed air, electrical load, ignition system, etc.) that is consistent with the applicant's recommended procedures for operation on wet runways should be used.

28.1.3.4 **Test Facility.**

The test facility needs to have adequate space for simulated takeoff and landing runs. Intermediate dams may be used in the water test bed to maintain the selected water depth over not less than 90 percent of the test bed area. The test bed length should not be less than that required to produce a spray pattern of one second duration at critical test speeds. The test bed width need only accommodate one landing gear, if acceptable data are presented to the FAA that show the combined nose and main gear spray is not more hazardous than the spray produced by either gear separately.

28.1.3.5 **Test Procedures.**

The tests should be conducted with the appropriate power or thrust setting. To establish the critical speed ranges, test runs should be made through the water test bed in speed increments of not more than 20 knots. If the rotated airplane attitude is suspected to be critical, at least one run at V_R should be conducted with the airplane rotated to the normal rotation pitch attitude. If thrust reversers or reversing propellers are provided, testing should also be conducted with those systems operating.

28.1.3.6 **Test Data.**

The applicant is expected to provide personnel and equipment to collect the following data:

28.1.3.6.1 Test Site Data.

The outside air temperature, wind velocity, and water depth should be recorded before each test run.

28.1.3.6.2 Airplane Performance Data.

The airplane velocity should be recorded when it enters and exits the water test bed. Engine rotor speeds and interstage turbine temperature (ITT) or EGT, as applicable) should be recorded and any engine abnormal engine sounds noted.

28.1.3.6.3 Water Spray Pattern.

Appropriate areas of the airplane should be coated with agents that will permit identification of water spray impingement. Suitable high speed photography or video equipment should be used to record the origin, trajectory, and configuration of the water spray.

28.1.3.6.4 Pilot Comments.

Pilot comments should be noted to determine if the takeoff would have been affected by abnormal audible engine sounds, airplane instrument anomalies, etc.

28.1.3.7 **Test Results.**

No hazardous quantities of water are considered to have been ingested when review of the collected test data shows that:

28.1.3.7.1 No engine flameout, performance degradation, distress, or airspeed fluctuations occurred that would create a safety hazard; and

28.1.3.7.2 No abnormal engine sounds occurred, such as pops or bangs, or cockpit instrument indications of incipient engine surge or stall, or they were not of sufficient magnitude to cause a pilot in service to abort the planned operation.

28.2 Induction System Icing Protection—§ 25.1093.

28.2.1 References.

- AC 20-73A.
- AC 20-147A.

28.2.2 Reciprocating Engines—§ 25.1093(a).

28.2.2.1 **Explanation.**

28.2.2.1.1 Conditions for Tests.

The carburetor air temperature measurement has been found to provide satisfactory average readings through the use of a minimum of three thermocouples so arranged as to give an average air temperature. This indicator should be calibrated prior to the test. Operationally, it has been determined that the tests should be conducted at an altitude where the free air temperature is 30 °F (-1 °C), or at two altitudes of different temperatures, one of which is near 30 °F (-1 °C).

28.2.2.1.2 Configuration.

The test should be conducted in the configuration that follows:

- Weight—optional.
- CG Position—optional.
- Wing Flap Position—optional.
- Landing Gear Position—optional.
- Engines—60 percent maximum continuous power.
- Cowl Flaps—appropriate for flight condition.
- Mixture Setting—normal cruising position.

28.2.2.2 **Procedures.**

Test procedures and required data.

28.2.2.2.1 After all temperatures have stabilized (i.e., when the rate of temperature change is less than 2 °F (1 °C) per minute), and with the airplane in level flight and full cold carburetor at 60 percent maximum continuous power, the following data should be recorded:

- Pressure altitude.
- Ambient air temperature.
- Indicated airspeed.
- Carburetor air temperature.
- Engines' RPM and manifold pressure.
- Torque pressure.
- Mixture setting.
- Cowl flap setting.

28.2.2.2.2 Preheat should then be applied slowly (power may be restored to 60 percent maximum continuous at the applicant's option) and the above data recorded again after the temperatures have stabilized. The carburetor heat rise is determined by comparing the results of the data obtained with and without preheat.

28.2.3 Turbine Powered Airplanes—§ 25.1093(b).

28.2.3.1 **Explanation.**

28.2.3.1.1 Section 25.1093(b) requires that each turbine engine operate throughout its flight power or thrust range without adverse effect on engine operation or serious loss of power or thrust in the icing conditions specified, including those related to falling and blowing snow. This requirement must be met for all operating conditions of the airplane and is not limited to operations where icing can be predicted or when icing penetrations are specifically intended. It is clear that the engines require protection against the possible hazardous effects of ice ingestion for all operating conditions, while the remaining airframe need be protected only if certification for flight in icing conditions is desired. This can also be verified by a review of § 25.1093(b) and 25.1419 and 14 CFR 33.68.

28.2.3.1.2 One purpose of flight in natural and/or tanker-provided icing conditions is to demonstrate that chunks of ice discharged from unprotected surfaces do not cause damage to the engine or other critical parts of the airplane, and to demonstrate that ice discharged from protected surfaces after an undetected icing encounter, during which the ice protection system was inoperative, does not cause engine damage or malfunction, or damage to other critical parts of the airplane. In order to accomplish these objectives, the airplane should be exposed to an icing condition of a magnitude and duration sufficient to accumulate enough ice to produce an acceptable demonstration. If, after installation on the airplane, it is possible for the engines to ingest ice shed from the airframe, which will cause an adverse effect or serious loss of power or thrust on the engine, compliance with § 25.1093(b) has not been achieved, and the required level of airworthiness for the engine installation has not been obtained.

28.2.3.1.3 It has been established from experience that turbine engines can be affected seriously and adversely by inadvertent in-flight ice encounters in which only a minor performance loss could be attributable to the amount of ice accumulated on the airframe. Based upon this experience, it was deemed necessary to require a higher level of ice protection for the engines than was found necessary for the airframe. The requirements of §§ 25.1093(b), 25.1419, and 33.68 reflect this concept. Satisfactory operation of protected surfaces at the design point condition, as described in AC 20-73A, should be demonstrated by icing tunnel tests or by analysis supported by tests. The ability to de-ice and anti-ice protected surfaces should be demonstrated during the natural and/or tanker-provided icing tests.

28.2.3.1.4 The secondary effects of falling and blowing snow should also be considered in the evaluation of susceptibility to, and protection from, ice accumulations. The critical ambient temperatures should be defined; this evaluation should take into consideration not only temperatures in the immediate vicinity of the freezing point, where “wet, sticky snow” is likely, but also colder temperatures where snow may adhere to partially heated interior inlet surfaces, melt, and refreeze in a colder location. Any hardware or ancillary systems (e.g., screens, particle separators, oil coolers) installed in turbine engine inlets may facilitate the accumulation of snow and potential for generation of ice. The effects of falling and blowing snow should be evaluated for both ground and flight conditions. The number of actual airplane tests within the critical snow and temperature environment should be maximized. In accordance with § 21.35(a)(3), the test article must be in production configuration with respect to surface finish, texture, and material type, to assure accurate representation of the in-service configuration. Recognizing that the desired atmospheric conditions may be difficult to find, some conditions may be substantiated by analysis, provided that analysis is supported by some form of test data (e.g., temperature survey data).

28.2.3.1.5 It would be inconsistent to consider that § 25.1093(b) pertains only to the engine or engine inlet lip. The wording is broad and objective. It should be noted that the icing requirements pertaining specifically to the engine are included in § 33.68. Section 25.1093(b) was included to assure that the engine, as installed in the airplane, did not suffer adverse effects when the airplane was subjected to the icing envelope requirements covered by appendix C to part 25. It is not logical to exclude any part of the airplane that might shed ice so as to produce an adverse effect on the engine.

28.2.3.1.6 The preceding paragraphs are intended to describe the minimum program to achieve certification for flight in icing conditions.

28.2.3.2 **Procedures.**

None.

CHAPTER 29. POWERPLANT: EXHAUST SYSTEM

29.1 General—§ 25.1121.

29.1.1 Explanation: Section 25.1121(a)—Carbon Monoxide Contamination.

Carbon monoxide detection tests are conducted in accordance with this requirement to determine that the disposal of exhaust gases from each exhaust system does not cause carbon monoxide contamination of any personnel compartment.

29.1.2 References.

Also see information related to the evacuation of other personnel compartment atmosphere contaminants contained in paragraphs 19.1 and 31.2 of this AC addressing the requirements of §§ 25.831 and 25.1197, respectively.

29.2 [Reserved.]

CHAPTER 30. POWERPLANT: CONTROLS AND ACCESSORIES [RESERVED]

CHAPTER 31. POWERPLANT: FIRE PROTECTION

31.1 Drainage and Ventilation of Fire Zones—§ 25.1187.

31.1.1 Explanation.

Section 25.1187 requires that each part of each designated fire zone be drained completely of flammable fluids to minimize hazards resulting from malfunctioning or failing components that contain flammable fluids. The drainage means must be:

31.1.1.1 Effective under conditions expected to prevail when drainage is needed;

31.1.1.2 Arranged so that no discharged fluid will cause an additional fire hazard; and

31.1.1.3 Arranged so that no discharged fluid will enter any other fire zone.

31.1.2 Procedures.

None.

31.2 Fire Extinguishing Systems—§ 25.1197.

31.2.1 Explanation: Carbon Dioxide in Flightcrew Compartments.

Carbon dioxide has been found to adversely affect flightcrew personnel in the performance of their duties. Therefore, in airplanes equipped with built-in carbon dioxide fuselage compartment fire extinguisher systems, the carbon dioxide concentration occurring at the flightcrew stations as a result of discharging the fire extinguishers should be determined in accordance with the procedures of this section (also see paragraph 19.1 of this AC), except that such determination is not considered necessary if:

31.2.1.1 Five pounds or less of carbon dioxide will be discharged into any one such fuselage compartment in accordance with established fire control procedures; or

31.2.1.2 Protective breathing equipment is provided for each flight crewmember on flight deck duty.

31.2.2 Procedures: Flight Test Investigation.

31.2.2.1 The carbon dioxide concentrations at breathing level at the flightcrew stations should be determined in flight tests during which fuselage compartment fire extinguishers are discharged in accordance with established fire control procedures. Since carbon dioxide is heavier than air, a nose-down attitude is likely to produce the critical concentrations in the crew compartment. Perform the tests described in paragraphs 31.2.2.1.1 and 31.2.2.1.2 below.

31.2.2.1.1 A rapid descent at the "maximum operating limit speed" of the airplane with the flaps and landing gear up.

31.2.2.1.2 A rapid descent with the flaps and landing gear down, at the maximum permissible speed for this configuration. If it appears that any other condition is likely to be critical on a particular airplane, it should also be investigated.

31.2.2.2 In the flight tests specified above, it will be permissible to institute emergency ventilating procedures immediately prior to or following the discharge of carbon dioxide, provided such procedures can be accomplished easily and quickly by the flightcrew, and do not appreciably reduce the effectiveness of the fire protection system.

31.2.2.3 If the measured carbon dioxide concentrations exceed three percent by volume (corrected to sea level, standard day conditions), protective breathing equipment should be provided for each flight crewmember on flight deck duty.

31.2.2.4 Appropriate emergency operating procedures should be entered in the AFM.

CHAPTER 32. EQUIPMENT: GENERAL

32.1 Equipment: Function and Installation—§ 25.1301.

32.1.1 Explanation.

32.1.1.1 Certification of the installation of modern avionics/electrical systems on airplanes can be summarized, generally, by stating that the systems/equipment must:

32.1.1.1.1 Perform its intended function (§ 25.1301);

32.1.1.1.2 Be adequately protected for failure conditions (§ 25.1309);

32.1.1.1.3 Be arranged to provide proper pilot visibility and utilization (as appropriate) (§ 25.1321);

32.1.1.1.4 Be protected by circuit breakers to preclude failure propagation and/or minimize distress to the airplane's electrical system (§ 25.1357); and

32.1.1.1.5 Be installed in a manner such that operation of the system will not adversely affect the simultaneous operation of any other system (§ 25.1431).

32.1.1.2 Accordingly, the recommended flight test procedures for equipment covered in subpart F of part 25 (excluding powerplant instruments, airspeed calibration, safety equipment, and lights) are grouped together under this section and are organized as follows:

- Paragraph 32.1.2, communication systems.
- Paragraph 32.1.3, navigation systems.
- Paragraph 32.1.4, instruments and displays.
- Paragraph 32.1.5, sensors and warning systems.
- Paragraph 32.1.6, recording systems.
- Paragraph 32.1.7, engine interfacing systems (autothrottle, power/thrust rating, ATTCS, etc.).
- Paragraph 32.1.8, stability augmentation systems.
- Paragraph 32.1.9, all weather operation (reduced visibility) systems.

32.1.1.3 Section 25.1301 refers to each item of installed equipment. Type certification involving equipment approvals is governed by Title 49 United States Code, section 44704. That section requires the Administrator to make, or require the applicant for a type certificate to make, such tests "necessary in the interest of safety." Tests may be necessary in order to allow the Administrator to find that the aircraft is properly designed and manufactured, performs properly, and meets the regulations and minimum standards prescribed under section 44701(a) of Title 49. “Optional equipment,” however, is not a term that is meaningful under the Act in connection with the type certification of any given airplane. Where equipment or a system is a part or appurtenance of the airplane and is designed to aid and will obviously be used by the crew, the statutorily required tests and findings are the same, regardless of whether or not it is characterized as optional. Moreover, the regulatory requirement of § 21.21(b)(2) specifies that the Administrator must find that no feature or characteristic of the airplane makes it unsafe for the category in which certification is requested. Therefore, the extent to which that equipment needs to be tested or evaluated, in order that the Administrator may make the necessary finding with respect to the whole airplane, is a technical determination within the engineering and operational expertise of the Administrator. (For further information, see AC 20-168.)

32.1.1.4 Criteria and requirements for flight should consider the applicant’s engineering analysis and laboratory (simulator) test program. The combination of analysis, laboratory, and flight evaluation will form the whole of the certification requirement and, as such, should be in harmony and provide full evaluation. The flight evaluations supplement the analysis and simulation as required in both the representative operating conditions of the airplane and for analysis of the airplane modes of operation and configuration conditions.

32.1.1.5 The requirement for demonstrating safe operation should normally include induced failures during flight. The requirement for failure demonstrations is also an outgrowth of the analysis and laboratory test results submitted by the applicant and is a result of the particular design being evaluated (e.g., consideration should be made for multiple channel systems specifically designed to be self-adaptive to failure conditions). Performance and malfunctions testing should include those flight conditions and airplane configurations that have been identified to be the most critical by analysis and/or test. Such items as weight, CG, speed, altitude, flaps, slats, gear, speed brakes, and airplane system degradation should be considered.

32.1.1.6 The amount of flight testing should be determined through the cooperative efforts of the assigned project personnel. It is recommended that the procedures that follow be used as a guide in preparing for the flight testing of an initial certification program. Follow-on items relevant to system derivative certification may result in considerably reduced flight testing. However, sufficient testing should be accomplished to assure satisfactory performance. When ground or flight test data, available from similar previously approved installations, are sufficient to properly evaluate a system’s performance, additional testing may not be required. In the absence of such data, additional testing or analysis should be presented to substantiate the areas potentially affected.

32.1.1.7 Particular attention should be given to those installations where an external piece of gear, such as an antenna, could affect the flight characteristics. All installations of this nature should be evaluated by the flight test pilot.

32.1.1.8 Installations that can or may change the established limitations, flight characteristics, performance, operating procedures, or any required systems require approval by an FAA ACO flight test branch. New installations of equipment in the cockpit, or modifications that affect existing equipment in the cockpit, should be evaluated through the cooperative efforts of the FAA, the project engineer, and the assigned flight test pilot, and assessed for the need of an FAA flight test demonstration.

32.1.1.9 Throughout the systems/equipment evaluation, the operation of annunciators should be assessed to determine that proper conspicuity and display are provided to the appropriate flight crewmember. Any mode of operation selected by a manual action, or automatically, should be positively identified. Any submode should be evaluated to determine the need for annunciation.

32.1.2 <u>Procedures—Communication Systems.</u>

32.1.2.1 **Very High Frequency (VHF) Systems.**

32.1.2.1.1 <u>Airplanes to be Operated Above 18,000 Feet.</u>

Intelligible communications should be provided between the airplane and facilities throughout circle-turns within 160 NM of an FAA approved ground facility and above minimum radio line-of-sight with no intervening terrain. Bank angles up to 10° on all headings should be used. Drop outs that are relieved by a reduction in bank angle at the same relative heading to the station are satisfactory. It is suggested that the “Long Range Reception Test” of paragraph 32.1.2.1.4 below be conducted first. If this test is successful, the circle-turns (within 160 NM) of this paragraph need not be conducted. Skidding turns may be used to minimize turn radius.)

32.1.2.1.2 <u>Airplanes to be Operated Below 18,000 Feet.</u>

For airplanes limited to operation below 18,000 feet, intelligible communications should be provided as given in paragraph 32.1.2.1.1 above, except that the distance from the ground facility need not exceed 80 NM.

32.1.2.1.3 Antenna Coverage Measurement.

If the antenna is located on the airplane centerline, tests may be conducted using only one direction of turn. When antenna radiation pattern data are available, flight testing in a 360° turn may not be necessary, if satisfactory communication is achieved during checks in the vicinity of the predicted bearings and bank angles of worst performance.

32.1.2.1.4 Long Range Reception.

At a distance of at least 160 NM (or 80 NM for airplanes to be operated below 18,000 feet) from the ground facility antenna on a heading and above radio line-of-sight, perform a right and/or left 360° turn at a bank angle of at least 10°. Communicate with the ground facility every 10° of turn to test the intelligibility of the signals received at the ground station and in the airplane. The minimum line-of-sight altitude for 160 NM is approximately 17,000 feet. and for 80 NM is approximately 4,000 feet. Radio line-of-sight distances versus flight level (or altitude) are given in table 32-1 below.

Table 32-1. Radio Line-of-Sight Distance versus Flight Level or Altitude

Flight Level or Altitude in Feet	Radio Line-of-Sight in Nautical Miles	Flight Level or Altitude in Feet	Radio Line-of-Sight in Nautical Miles
FL500	275.0	FL260	198.3
FL490	272.3	FL250	194.5
FL480	269.5	FL240	190.6
FL470	266.7	FL230	186.5
FL460	263.8	FL220	182.4
FL450	260.9	FL210	178.2
FL440	258.0	FL200	173.9
FL430	255.1	FL190	169.5
FL420	252.1	FL180	165.0
FL410	249.1	17,000	160.4
FL400	246.0	16,000	155.6
FL390	242.9	15,000	150.6
FL380	239.8	14,000	145.5
FL370	236.6	13,000	140.2
FL360	233.4	12,000	134.7
FL350	230.1	11,000	129.0
FL340	226.8	10,000	123.0
FL330	223.4	9,000	116.7
FL320	220.0	8,000	110.0
FL310	216.6	7,000	102.9
FL300	213.0	6,000	95.3
FL290	209.5	5,000	87.0
FL280	205.8	4,000	77.8
FL270	202.1	3,000	67.4

32.1.2.1.5 High Angle Reception.

Repeat the above test at a distance of 50 to 70 NM from the ground station and at an altitude of 35,000 feet, or the maximum operating altitude of the airplane (20 to 30 NM for airplanes to be operated below 18,000 feet).

32.1.2.1.6 Approach Configuration.

With the landing gear extended and the flaps in the approach configuration, demonstrate intelligible communications between the airplane and the ground facility.

32.1.2.1.7 Electromagnetic Compatibility (EMC).

With all systems operating in flight, if practicable, verify, by observation, that no adverse effects are present in the required flight systems.

32.1.2.2 **High Frequency (HF) Systems.**

32.1.2.2.1 Acceptable communication should be demonstrated by contacting one or more ground stations on several of the frequencies allowed by HF propagation conditions. Distances may vary from 100 to several thousand NM, and at least one over-the-horizon communication link should be established via ionospheric propagation. When a new HF antenna installation is being evaluated, the test should be conducted at an altitude of not less than 90 percent of the maximum altitude to check for possible corona arcing at the antenna.

32.1.2.2.2 The effect of precipitation static should be considered. This type of static is normally found in areas of high cirrus clouds, dry snow, dust storms, etc.

32.1.2.2.3 EMC should be evaluated with all systems operating in flight, if practicable, to verify, by observation, that no adverse effects are present in the required flight systems.

32.1.2.3 **Audio Systems.**

32.1.2.3.1 Acceptable communications should be demonstrated for all audio equipment, including microphones, speakers, headsets, interphone amplifiers, and public address systems. If provisions for passenger entertainment are included, adequate override of the music/audio by the cockpit crew attendants, or by prerecorded announcements, should be demonstrated. All modes of operation should be tested, including operation during emergency conditions (e.g., emergency descent with oxygen masks) with all airplane engines running, all airplane pulse equipment transmitting, and all electrical equipment operating. Flight tests, except as described in paragraph 32.1.2.3.2 below, are generally not necessary unless airstream noise is considered a factor or unless excessive feedback with cockpit speakers is encountered during ground tests, which makes cockpit sound levels questionable.

32.1.2.3.2 If a flight evaluation of the PA system is deemed to be necessary (or the prudent thing to do), PA announcements should be made from each handset station, including the cockpit, with the airplane operated at mid to high altitude at speeds approaching V_{MO}/M_{MO}.

32.1.2.3.3 EMC should be evaluated with all systems operating during flight, verify, by observation, that no adverse effects are present in the required flight systems.

32.1.2.4 **Aircraft Communications Addressing and Reporting System (ACARS).**

32.1.2.4.1 ACARS is an addressable VHF digital data link system that permits communication between the airplane and a ground-based facility. The display medium is a printer and/or electronic multifunction display.

32.1.2.4.2 Acceptable performance should be demonstrated by verifying that pre-flight loaded data is retained in memory during power interrupts generated during transfers from ground to APU power, from APU to engine generators, and during cross-tie switching in all possible combinations.

32.1.2.4.3 Verify that simultaneous transmission of ACARS data and VHF voice communication is satisfactory and is free of interference between the two independent VHF systems, considering frequency and VHF antenna isolation. Exercise all possible switching combinations.

32.1.2.4.4 If the selective calling system (SELCAL) can be initiated by the ground station via the ACARS data link, demonstrate performance of that function by observing that the cockpit aural and visual indications are proper.

32.1.2.4.5 If the flight management system (FMS) database or operational program can be accessed in flight by ACARS, exercise all interface functions to demonstrate performance of the intended function.

32.1.2.4.6 ACARS should not cause interference with the operation of any of the airplane's radio/navigation systems. Particular attention should also be devoted to non-interference with flight guidance takeoff and approach functions, particularly autoland, since these are likely flight regimes for ACARS transmissions.

32.1.2.5 **SELCAL.**

Verify performance of intended function of the SELCAL by receipt of VHF and HF (if appropriate) calls from ground stations.

32.1.2.6 **Satellite Communications (SATCOM).**

[Reserved]

32.1.2.7 **Portable Battery-Powered Megaphones.**

32.1.2.7.1 Conduct hearing range and intelligibility tests on the airplane to demonstrate that the amplified speech is heard and clearly understood throughout the interior cabin region served by the megaphones, with the engines off and with all significant conditions associated with an accident (including the presence of passengers and the normally-attendant confusion din) appropriately simulated.

32.1.2.7.2 Verify that the megaphone reliably performs its intended function and is designed:

- For ease of handling, and use, with one hand;
- With sufficient acoustical feedback suppression; and
- With a volume control.

32.1.3 Procedures: Navigation Systems.

32.1.3.1 **Very High Frequency Omnidirectional Range (VOR) Systems.**

32.1.3.1.1 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, i.e., flaps, landing gear, etc.). Particular note should be made in recognition that certain propeller RPM settings may cause modulation of the course deviation indication (prop-modulation). This information should be presented in the AFM.

32.1.3.1.2 The airborne VOR system should operate normally with warning flags out of view at all headings of the airplane (wings level) throughout the airspace within 160 NM of the VOR facility (for airplanes to be operated above 18,000 feet), from the radio line-of-sight altitude to within 90 percent of the maximum altitude for which the airplane is certified or the maximum operating altitude.

32.1.3.1.3 The accuracy determination should be made such that the indicated reciprocal agrees within 2°. The test should be conducted over at least two known points on the ground such that data are obtained in each quadrant. Data should correlate with the ground calibration and in no case should the absolute error exceed ±6°. There should be no excessive fluctuation in the course deviation indications.

32.1.3.1.4 <u>En Route Reception.</u>

Fly from a VOR facility rated for high altitude along a radial at an altitude of 35,000 feet. (or to within 90 percent of the airplane maximum certificated altitude or the maximum operating altitude) to a range of 160 NM (80 NM for airplanes not to be operated above 18,000 feet). 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° ±5° (10° either side at the selected radial). 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.

32.1.3.1.5 <u>Long Range Reception.</u>

Perform a right and/or left 360° turn at a bank-angle of at least 10°, at an altitude above the radio line-of-sight, and at a distance of at least 160 NM (80 NM for airplanes to be operated below 18,000 feet) from the VOR facility. Signal dropout should not occur as evidenced by the malfunction indicator 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. Skidding turns may be used to minimize turn radius.

32.1.3.1.6 <u>High Angle Reception.</u>

Repeat the turns described in paragraph 32.1.3.1.5 above, but at a distance of 50 to 70 NM (20 to 30 NM for airplanes not to be operated above 18,000 feet) from the VOR facility and at an altitude of at least 35,000 feet. (or to within 90 percent of the maximum certificated altitude of the airplane or the maximum operating altitude).

32.1.3.1.7 <u>En Route Station Passage.</u>

Verify that the TO-FROM indicator correctly changes as the airplane passes through the cone of confusion above a VOR facility.

32.1.3.1.8 <u>VOR Approach.</u>

Conduct VOR approach(es) with gear and flaps down. The facility should be 12-15 NM behind the airplane with the approach conducted after a 30° radial change over the station. Use sufficient maneuvering in the approach to assure the signal reception is maintained during beam tracking.

32.1.3.1.9 <u>EMC.</u>

EMC should be evaluated with all systems operating in flight, to verify by observation that no adverse effects are present in the required flight systems.

32.1.3.1.10 Identifier.

The audio identifier should be checked, as should the decoded identifier, if equipped with a digital bus.

32.1.3.1.11 Station tuning.

Evaluate various methods of station tuning, including automatic and manually through a FMS. Also, a check for proper indications for loss of signal or receiver failure should be done.

32.1.3.2 **Localizer Systems.**

32.1.3.2.1 These flight tests may be reduced if adequate antenna radiation pattern studies have been made, and those studies show the patterns to be without significant holes. A significant hole is one that is greater than 10 decibels (dB) from the average within 30° horizontally and 15° vertically of the nose of the airplane.

32.1.3.2.2 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 at least 25 NM from the station. 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 an altitude of approximately 2,000 feet.

32.1.3.2.3 Satisfactory results should also be obtained at bank angles up to 30°, when the airplane heading is within 60° of the inbound localizer course. Results should be satisfactory 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.

32.1.3.2.4 The deviation indicator should properly direct the airplane back to course when the airplane is right or left of course.

32.1.3.2.5 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 electrical equipment operating and pulse equipment transmitting.

32.1.3.2.6 Localizer Intercept.

In the approach configuration and at a distance of at least 25 NM 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.

32.1.3.2.7 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 less above the threshold.

32.1.3.2.8 EMC.

With all systems operating in flight, verify by observation that no adverse effects are present in the required flight systems.

32.1.3.3 **Glideslope Systems.**

32.1.3.3.1 These flight tests may be reduced if adequate antenna radiation pattern studies have been made, and those studies show the patterns to be without significant holes. A significant hole is one that is greater than 10 dB from the average within 30° horizontally and 15° vertically of the nose of the airplane.

32.1.3.3.2 The signal input to the receiver should be of sufficient strength to keep the warning flags out of view at all distances up to 10 NM from the final approach fix. This performance should be demonstrated at all airplane headings between 30° right and left of the localizer course. The deviation indicator should properly direct the airplane back to the glideslope path when the airplane is above or below the path.

32.1.3.3.3 Interference with the navigation operation 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 glideslope operation.

32.1.3.3.4 Glideslope Interception.

Fly the localizer course inbound, at the altitude at which the glideslope beam intercepts the final approach fix, and at least 10 NM from the fix. The glideslope deviation indicator should be centered (±25 percent of full scale) at the final approach fix. There should be no flags from the time the needle leaves the full scale fly-up position until it reaches the full scale fly-down position.

32.1.3.3.5 Glideslope Tracking.

While tracking the glideslope, maneuver the airplane through normal pitch and roll attitudes. The glideslope deviation indicator should show proper operation with no flags. Acceptable approaches to 100 feet or less above the threshold should be conducted.

32.1.3.3.6 EMC.

EMC should be evaluated with all systems operating in flight, to verify by observation that no adverse effects are present in the required flight systems.

32.1.3.4 **Marker Beacon System.**

32.1.3.4.1 In low sensitivity, the marker beacon annunciator light should be illuminated for a distance of 2,000 to 3,000 feet when flying at an altitude of 1,000 feet on the localizer centerline in all flap and gear configurations.

Note: An acceptable test to determine distances of 2,000 to 3,000 feet is to fly at a ground speed listed in table 32-2 and time the marker beacon light duration.

Table 32-2. Marker Beacon System

Altitude = 1,000 feet (AGL)			
Ground Speed (knots)		Light Time (seconds)	
	Distance →	2,000 feet	3,000 feet
90		13	20
110		11	16
130		9	14
150		8	12

32.1.3.4.2 For ground speeds other than the values in table 32-2 above, the following formulas may be used:

$$Upper\ Limit = \frac{1775}{Ground\ speed\ in\ Knots}\ (sec)$$

$$Lower\ Limit = \frac{1183}{Ground\ speed\ in\ Knots}\ (sec)$$

32.1.3.4.3 If a high/low sensitivity feature is installed and selected, the marker beacon annunciator light and audio will remain on longer than when in low sensitivity.

32.1.3.4.4 The audio signal should be of adequate strength and sufficiently free from interference to provide positive identification.

32.1.3.4.5 As an alternative procedure, cross the outer marker at normal ILS approach altitudes and determine adequate marker aural and visual indication.

32.1.3.4.6 Illumination should be adequate in bright sunlight and at night.

32.1.3.4.7 EMC should be evaluated with all systems operating in flight to verify by observation that no adverse effects are present in the required flight systems.

32.1.3.5 **Automatic Direction Finder (ADF) System.**

32.1.3.5.1 Receiving Function.

Determine that, when flying toward or away from a station with all required electrical and radio equipment in operation, the average bearing pointer indications are such that they present a usable bearing at the below-listed distances, during daylight hours (between one hour after local sunrise and one hour before local sunset) and when atmospheric disturbances are at a minimum. The amplitude of pointer oscillation is relatively unimportant, provided a valid direction to the station can be determined. At the distances shown below, the tone audio identification of the station to which the receiver is tuned should be intelligible.

32.1.3.5.2 General Information.

See table 32-3 below.

Table 32-3. Classification of LF/MF Radio Beacons in U.S. National Service

Class	Power (Watts)
Comlo	Under 25
MH	Under 50
H	50-1999
HH	2000 or more
Facility	Range (Nautical miles)
Compass locators	15
Transmitters < 50 Watts	25
Transmitters 100-200 Watts	50
Transmitters 200-400 Watts	60
Transmitters over 400 Watts	75
Note: In areas where the known service range is less than the above distances, the actual shorter range may be used. It is advisable to ascertain the operating status of the facility to be used, prior to flight testing.	

32.1.3.5.3 Pointer Reversal.

While flying the airplane directly over a properly operating ground-based station, note the airplane's altitude and measure the complete pointer reversal time by using a stopwatch. Using the airplane's true ground speed and the airplane's altitude, determine that the pointer reversal occurred within a circular area centered over the station, having a radius equal to the altitude being flown. Partial reversals that lead or lag the main reversal are permissible.

32.1.3.5.4 Bearing Accuracy.

Using a properly operating directional gyro, and a ground checkpoint whose location is known with respect to the ground-based station to which the ADF is tuned, fly the airplane over the ground checkpoint at a minimum of six airplane headings (relative to the station to which the ADF is tuned), including headings of 0°, 180°, and headings 15° each side thereof. Determine that the compensated or otherwise corrected ADF bearing indication is not in error by more than ±5° at any of the six headings. Repeat the foregoing procedure but fly at a minimum of six headings relative to the ground based station, including 45°, 90°, 135°, 225°, 270°, and 315°. In this case, the compensated or otherwise corrected bearing indication should not be in error by more than ±10° at any of these six headings.

Note: The distance between the ground checkpoint and the ground-based station used should be at least one-half of the service range of that station.

32.1.3.5.5 Indicator Response.

With the ADF indicating station dead ahead, switch to a station having a relative bearing of 175°. The indicator should indicate within ±3° of the bearing in not more than 10 seconds.

32.1.3.5.6 Antenna Mutual Interaction.

If the ADF installation being tested is dual, check for coupling between the antennas by using the following procedures.

1. 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.
2. Repeat 1 with the #1 ADF receiver tuned to a station near the high end of the ADF band.

32.1.3.5.7 EMC.

EMC should be evaluated with all systems operating in flight, to verify by observation that no adverse effects are present in the required flight systems.

32.1.3.5.8 Precipitation Static.

The effect of precipitation static should be considered. This type of static is normally found in areas of high cirrus clouds, dry snow, dust storms, etc.

32.1.3.6 **Distance Measuring Equipment (DME).**

32.1.3.6.1 Airplanes to be Operated Above 18,000 Feet.

The DME system should continue to track without dropouts when the airplane is maneuvered throughout the airspace within 160 NM of the VORTAC station and at altitudes above radio line-of-sight up to the maximum altitude for which the airplane is certificated. This tracking standard should be met with the airplane:

- In cruise configuration,
- At bank angles up to 10° (skidding turns may be used to minimize turn radius),

- Climbing and descending at normal maximum climb and descent attitudes,
- Orbiting a DME facility, and
- Providing clearly intelligible (visual/aural) identification of the DME facility.

32.1.3.6.2 Airplanes to be Operated at Altitudes Below 18,000 Feet.

The DME system should perform as specified in paragraph 32.1.3.6.1 above, except that the maximum distance from the DME facility need not exceed 100 NM.

32.1.3.6.3 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 NM from a DME facility and at an altitude of 2,000 feet above the DME facility, fly the airplane on a heading so it will pass over the facility. At a distance of 5 to 10 NM beyond the DME facility, operate the airplane at its normal maximum climb attitude, up to an altitude of 35,000 feet or to within 90 percent of the maximum certificated altitude, maintaining the airplane on a station radial (within 5°). The DME should continue to track with no unlocks to a range of 160 NM (100 NM for airplanes not to be operated at altitudes above 18,000 feet).

32.1.3.6.4 Long Range Reception.

Perform two 360° turns, one to the right and one to the left, at a bank angle of 8 to 10° at not less than 160 NM (100 NM for airplanes not to be operated above 18,000 feet) from the DME facility. A single turn will be sufficient if the antenna installation is symmetrical. There should be no more than one unlock, not to exceed one search cycle (maximum 35 seconds) in any five miles of radial flight. Tests may be conducted up to a maximum certificated altitude.

32.1.3.6.5 High Angle Reception.

Repeat the flight pattern and observations of paragraph 32.1.3.6.4 above at a distance of 50-70 NM (20 to 30 NM for airplanes not to be operated above 18,000 feet) from the DME facility and at an altitude of at least 35,000 feet (or to within 90 percent of the maximum altitude for which the airplane is certificated or the maximum operating altitude).

32.1.3.6.6 Penetration.

From an altitude of at least 35,000 feet (or the airplane maximum altitude, if lower), perform a letdown directly toward the ground station using normal maximum rate of descent procedures to a DME facility, so as to reach an altitude of 5,000 feet above the DME facility 5 to 10 NM before reaching the DME facility. The DME should continue to track during the maneuver with no unlocks.

32.1.3.6.7 Orbiting.

At an altitude of 2,000 feet above the terrain, at holding pattern speeds appropriate for the type of airplane and with the landing gear extended, fly at least 15° sectors of left and right 35 NM 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.

32.1.3.6.8 Approach.

Make a normal approach to a field with a DME. The DME should track without an unlock (station passage excepted).

32.1.3.6.9 EMC.

EMC should be evaluated with all systems operating in flight to verify by observation that no adverse effects are present in the required flight systems.

32.1.3.7 **Transponder Equipment.**

32.1.3.7.1 The air traffic control (ATC) transponder system should furnish a strong and stable return signal to the interrogating radar facility when the airplane is flown in straight and level flight throughout the airspace within 160 NM of the radar station, from radio line-of-sight to within 90 percent of the maximum altitude for which the airplane is certificated or to the maximum operating altitude. Airplanes to be operated at altitudes not exceeding 18,000 feet should meet the above requirements to only 80 NM.

32.1.3.7.2 The dropout time should not exceed 36 seconds when the airplane is flown in the following maneuvers within the airspace described above:

1. In turns at bank angles up to 10 degrees (skidding turns may be used to minimize turn radius).
2. Climbing and descending at typical climb and descent attitudes.

32.1.3.7.3 Climb and Distance Coverage.

1. Beginning at a distance of at least 10 NM from, and at an altitude of 2,000 feet above that of the radar facility, and using a transponder code assigned by the air route traffic control center (ARTCC), fly on a heading that will pass the airplane over the facility. Operate the airplane at its normal maximum climb attitude up to within 90 percent of the maximum altitude for which the airplane is certificated, or to a maximum operating altitude, 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 NM (or 80 NM for airplanes to be operated below 18,000 feet) from the radar facility.

2. Communicate with the ground radar personnel for evidence of transponder dropout. During the flight, check the "ident" mode of the ATC transponder to assure 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, that is, when there is no return for two or more sweeps. If ring-around, spoking, or clutter appears on the ground radar scope, the airplane should switch to "low" sensitivity to reduce the interference. Uncontrollable ringing that hinders use of the ground radar should be considered unsatisfactory.

32.1.3.7.4 Long Range Reception.

At 90 percent of maximum certificated altitude, perform two 360° turns, one to the right and one to the left, at bank angles of 8° and 10° with the flight pattern at least 160 NM (or 80 NM for airplanes to be operated below 18,000 feet) from the radar facility. During these turns, the radar display should be monitored and there should be no signal dropouts (two or more sweeps). (Airspeed adjustments may be made to reduce turn radius.)

32.1.3.7.5 High Angle Reception.

Repeat the flight pattern and observations of paragraph 32.1.3.7.4 above at a distance of 50 to 70 NM from the radar facility and at an altitude of at least 35,000 feet or within 90 percent of the maximum altitude for which the airplane is certificated or 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. If a problem surfaces, a placard so noting should be required.

32.1.3.7.6 High Altitude Cruise.

Fly the airplane within 90 percent of its maximum certificated altitude or its maximum operating altitude beginning at a point 160 NM (or 80 NM for airplanes to be operated below 18,000 feet) from the radar facility on a course that will pass over the radar facility. There should be no transponder dropouts (two or more sweeps) or "ring-around," except when station passage occurs or when known site features produce anomalies.

32.1.3.7.7 Holding and Orbiting Patterns.

1. At an altitude of 2,000 feet or minimum obstruction clearance altitude (whichever is greater) above the radar antenna, and at holding pattern speeds, flaps and gear extended, fly one each standard rate 360° turn, right and left, at a distance of approximately 10 NM from the air route surveillance radar (ARSR) or airport surveillance radar (ASR) facility. There should be no signal dropout (two or more sweeps).
2. At an altitude of 2,000 feet or minimum obstruction clearance altitude (whichever is greater) above the radar antenna and at holding pattern speeds appropriate for the type of airplane, fly a 45° segment of a 10 NM orbit centered on the radar facility with gear and flaps extended. There should be no signal dropout (two or more sweeps).

32.1.3.7.8 Surveillance Approach.

From an altitude of 35,000 feet or within 90 percent of the maximum certificated altitude of the airplane or the maximum operating altitude, whichever is less, perform a letdown and approach to a runway of an airport served by ASR having an air traffic control radar beacon system (ATCRBS) facility. Alternately, a simulated approach and letdown may be made along a path parallel to, but separated three to four miles from, a vertical plane through the location of an ARSR facility. The approach should be made at the maximum normal rate of descent and in the normal approach and landing configuration for the airplane, and should continue down to an altitude of 200 feet or less above the ground radar antenna elevation. Not more than one dropout should occur for any 10 sweeps during final approach; if ring-around occurs, the flightcrew should reduce the sensitivity and the ring-around should cease.

32.1.3.7.9 Altitude Reporting.

Conduct a functional test of the altitude encoder (transponder Mode C) by comparison with ATC-displayed altitudes. Verify correspondence at several altitudes between ATC readings and the captain's altimeter, when set at or corrected to 29.92 inches of mercury.

Note: Throughout all tests, verify self-test function and radar interrogation reply light.

32.1.3.7.10 EMC.

EMC should be evaluated with all systems operating in flight to verify by observation that no adverse effects are present in the required flight systems.

32.1.3.8 **Weather Radar System.**

32.1.3.8.1 Warm-Up Period (If Applicable).

All tests should be conducted after the manufacturer's specified warm-up period.

32.1.3.8.2 Display.

Check that the scope trace and sweep display move smoothly and are without gaps or objectionable variations in intensity. For color displays, verify appropriate colors and color contrast.

32.1.3.8.3 Range Capabilities.

While maintaining level flight at 90 percent of maximum approved altitude of the airplane, set the radar controls so that large radar-identifiable objects such as mountains, lakes, rivers, coastlines, storm fronts, turbulence, etc., are displayed on the radar scope. Objects should be displayed at the maximum range specified by the manufacturer. Maneuver the airplane and adjust the radar controls so that tests may be conducted for the range requirements. The radar should be capable of displaying line-of-sight known prominent targets.

32.1.3.8.4 Beam Tilting and Structural Clearance.

1. With the airplane maintained in level flight, adjust the radar controls so that large radar-identifiable targets appear on the radar scope when the antenna tilt control is adjusted for 0°. Maneuver the airplane so that an appropriate target appears at the dead ahead (0°) bearing position. Slowly change the tilt control through an appropriate range and observe that the radar scope presentation does not change erratically, which might indicate structural interference between the radome and antenna. This interference should not occur throughout the operational speed envelope of the airplane.
2. Bearing Accuracy. Fly under conditions that allow visual identification of a target, such as an island, a river, or a lake, at a range within the range of the radar. When flying toward the target, select a course from the reference point to the target and determine the error in the displayed bearing to the target on all range settings. Change the heading of the airplane in increments of 10° to ±30° maximum, and verify the error does not exceed ±5° maximum in the displayed bearing to the target.

32.1.3.8.5 Stability.

While observing a target return on the radar indicator, turn off the stabilizing function and put the airplane through pitch and roll movements. Observe the blurring of the display. Turn the stabilizing mechanism on and repeat the roll and pitch movements. Evaluate the effectiveness of the stabilizing function in maintaining a sharp display.

32.1.3.8.6 Contour Display (Iso Echo).

1. 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.
2. 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.

32.1.3.8.7 Antenna Stability 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. Put the airplane through down pitch, then roll movements. No ground return should be present.

Note: Roll right and left approximately 15°; pitch nose down approximately 10°.

32.1.3.8.8 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.

32.1.3.8.9 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 other equipment. Particular attention should be devoted to radar effect on electronic display systems and on localizer, glideslope, and ADF signals during approach to landing.

32.1.3.8.10 EMC.

EMC should be evaluated with all systems operating in flight to verify by observation that no adverse effects are present in the required flight systems.

32.1.3.9 **Inertial Navigation System (INS).**

32.1.3.9.1 AC 20-138D, Change 2, contains the basic criteria for the engineering evaluation of an inertial navigation system and offers acceptable means of compliance with the applicable regulations that contain mandatory requirements in an objective form.

32.1.3.9.2 The INS equipment supplier, through the applicant, will generally provide system reliability data sufficient so that additional testing for equipment reliability demonstration will not be required. Assuming adequate cooling is available for the installation, the data can be considered independent of which type of airplane was used for derivation.

32.1.3.9.3 Temperature.

Some systems have temperature monitors built into the sensor block. When the device temperature reaches a given level, the system automatically shuts down. This condition could represent a common mode failure wherein insufficient cooling is provided to the multiple sensors with the consequent result that they all trip the temperature monitor simultaneously. Some equipment may be constructed with the cooling mechanization integral to the individual unit. Regardless of how the equipment cooling is accomplished, if the proper operation of the unit is below acceptable levels due to failures of the cooling function, then the cooling function should be addressed by analysis and demonstration, where applicable.

32.1.3.9.4 INS On-Airplane Test Procedure.

1. With INS equipment off, verify all avionics equipment are operating normally.
2. Close INS primary, heater, and excitation circuit breakers and set the mode selector to start warm-up, as required by the manufacturer's normal procedures.
3. Alignment.
    a. Initiate INS alignment according to the manufacturer's procedures and input flight plan waypoints and record. (The airplane's present position needs to be loaded before the system can complete alignment. Do not move the airplane until the system is aligned and in the Navigate mode, (NAV) if so equipped.) Present position accuracy should be known to within 0.1 NM.
    b. Normal wind buffeting and movement of cargo and personnel will not affect alignment quality, but severe buffeting may lengthen the time required for alignment.
    c. Continue operation in the NAV mode until a minimum of one hour has passed.
4. Pre-Departure.
    a. Recheck that other avionics operate normally and that all systems and instruments using INS information operate correctly.

b. Set up INS for a track from present position to any stored waypoint and check proper cockpit display unit (CDU) and instrument displays.

c. When the conditions as described by the manufacturer are satisfied, set the mode selector to “Navigate.” Verify that the NAV mode is achieved and no warning condition is indicated. Record the time at which NAV mode is verified.

5. Departure Procedure.

a. Taxi. While taxiing the airplane, monitor INS performance with the CDU data selector set to display track angle and ground speed.

b. Takeoff. With the CDU set as required to observe ground speed, track angle, heading, and drift angle during takeoff and initial airborne conditions, verify normal and proper performance. Reasonable assessment may be accomplished using other instruments and avionics.

c. Initial track. Define a track from present position to first available waypoint and fly to intercept using instrument display or autopilot.

6. In Flight. During flight conditions, perform and/or check the following:

Note: Do not change system mode selector from “Navigate” during navigational tests. If a system is installed to provide attitude for the airplane system, the “ATT REF” mode should be checked after navigation mode tests are completed. When selector is changed to “ATT REF,” ascertain that all appropriate equipment annunciators indicate the disconnect.

a. Exercise all procedures, such as waypoint navigation, offset navigation, selected track navigation, etc., that are listed as system capabilities by the manufacturer and in the AFM.

b. If updating capabilities are provided, either as manual or automatic, use defined procedures to verify operation.

c. Operate the INS in both the manual and automatic modes for waypoint sequencing.

d. Verify satisfactory control of the airplane, proper flight director indication, and flight instrument presentation, as appropriate to the installation. When the INS is operating, all airplane displays that would be affected or changed in meaning should be clearly annunciated to the pilot (e.g., compass heading (true versus magnetic) autopilot coupled modes, etc.).

e. Operate the CDU in all display settings and verify functions and operation.

f. Operate other avionics and airplane electrical systems to determine if any mutual interference results that would cause either the INS or other systems' performance to be less than required.

g. If basic accuracy has been previously established, a triangular course should be flown with a base leg length of at least one hour. The required accuracy is defined in paragraph 32.1.3.9.1 above.

7. Post Flight.

a. Park the airplane at a position known to within 0.1 NM and determine the radial error rate using the total time in NAV mode and the measured radial error. Record end point position, time, and error rate calculations.

Note 1: On some models, radial error may be obtained as follows: Load the park position as waypoint N; then define track (LEG) O to N. The value of distance read on the CDU is the radial error.

Note 2: If the system has been updated, remove the update prior to error calculations.

b. Pull INS primary power circuit breaker and verify operation on battery for 5 minutes. Reset breaker and verify that the system functions normally and the waypoint data is correct.

c. Turn system to off.

32.1.3.9.5 Attitude (if Provided to the Basic Instruments).

1. The system should be installed to provide pitch and roll data to ±1° relative to the airplane's reference level.
2. During navigation tests, the vertical gyro data should be checked. Additionally, after NAV tests are completed, the airplane should be flown and placed in a 25° bank with the INS in NAV mode. While in the turn, switch to ATT REF mode, and level the airplane. The attitude data should indicate properly. If the system requires level flight at the time ATT REF is selected, the AFM should contain that information as a limitation.
3. Power Bus Transients. After the normally expected electrical bus transients due to engine failure, attitude should not be off or unstable for more than one second and should affect only displays on one side of the airplane. If power-up initialization or self-tests are started by the transient, any change in attitude should not be a distraction; recognizably valid pitch and roll data should be available within one second. For most airplanes, an engine failure after takeoff will simultaneously create a roll rate acceleration, new pitch attitude requirements, and an electrical transient. Attitude information is paramount; transfer to standby attitude or transfer of control of the airplane to the opposite pilot cannot be reliably accomplished under

these conditions in a timely enough fashion to prevent an unsafe condition. In testing this failure mode, switching the generator off at the control panel will usually result in the quickest switching time. Conversely, during an engine failure, as the engine speed decays, the generator output voltage and frequency each decay to a point where the bus control relays finally recognize the failure. This can be a significantly larger disturbance resulting in a different effect on the using equipment. The only known way to simulate this failure is with a fuel cut. Both means should be tested.

32.1.3.9.6 EMC.

The INS should not cause the performance of other systems aboard the airplane to be degraded below their normal function, and INS operation should not be adversely affected by other equipment.

32.1.3.10 **Vertical Navigation (VNAV) System.**

A complete and comprehensive flight test evaluation is contained in AC 20-138D, Change 2.

32.1.3.11 **Area Navigation (RNAV).**

Information pertinent to flight evaluation of RNAV is contained in AC 20-138D, Change 2. Operational approval guidance is contained in AC 90-100A, AC 90-101A, and AC 90-105A. The RNAV function is most often performed by the systems identified in paragraphs 32.1.3.9, 32.1.3.10, and 32.1.3.12 of this AC. Flight test requirements should be reviewed accordingly.

32.1.3.12 **Multi-Sensor Navigation System.**

A complete and comprehensive flight test evaluation is contained in AC 20-138D, Change 2.

32.1.3.13 **Performance Management System.**

A complete and comprehensive flight test evaluation is contained in AC 25-15.

32.1.3.14 **Flight Management System.**

A complete and comprehensive flight test evaluation is contained in AC 25-15.

32.1.3.15 **Global Navigation Satellite System (GNSS).**

A complete and comprehensive flight test evaluation is contained in AC 20-138D, Change 2.

32.1.4 <u>Procedures—Instruments and Displays.</u>

32.1.4.1 **Flight and Navigation Instruments.**

32.1.4.1.1 Flight demonstration of the following pilots' instruments should address evaluation with regard to display, function, and lighting:

- Attitude director indicator (ADI)—primary and standby
- Horizontal situation indicator (HSI)
- Radio magnetic indicator (RMI)
- Airspeed and Mach number indicator—primary and standby (if installed)
- Altimeter-primary and standby
- Instantaneous vertical speed indicator (IVSI)
- Standby compass
- Clock
- Total air temperature (TAT) indicator
- Radio altimeter (R/A)

32.1.4.1.2 The instruments should be evaluated for suitability of location and performance during flight operation. Agreement between displayed functions, primary to standby, and captain's to first officer's display (where applicable) should be examined during takeoff, cruise, and landing, and during flight maneuvers of bank angles of ±60° and pitch angles from +25 to -10°.

32.1.4.1.3 In addition to the above instruments, the controls on the instrument, and those associated with changing the function of that instrument, should be evaluated.

32.1.4.1.4 Day and night lighting of instruments should be demonstrated. Evaluate for adequate illumination of the instruments and associated control panels and placards.

32.1.4.2 **Electronic Display Systems.**

A complete and comprehensive description and flight evaluation is contained in AC 25-11B.

32.1.5 Procedures—Sensors and Warning Systems.

32.1.5.1 **Compass System.**

32.1.5.1.1 Conduct a ground compass swing and record deviations from correct magnetic headings at 15° intervals. Be particularly attentive for errors induced by intermittently operated electrical equipment that is not removable by compass compensation plates. (See chapter 16, section 5, of AC 43.13-1B, Change 1, or latest revision.)

32.1.5.1.2 Compare indicated heading information with known runway directions during takeoffs and landings.

32.1.5.1.3 Conduct an inflight compass check by stabilizing the airplane on the four cardinal headings and recording the respective compass headings of both primary compass systems (in the slaved mode) and the standby compass system. These readings should be compared with the flight recorder data as a check on compass repeater capability.

32.1.5.1.4 Observe indicators for evidence of electronic or magnetic interference. Specifically, observe the standby compass operation as a function of windshield heat cycling and while keying radio transmissions.

32.1.5.2 **Attitude System—"Strapdown" (AHRS & IRS).**

32.1.5.2.1 In addition to flight evaluation of the pitch and roll attitude characteristics of conventional vertical gyros, which is rather straight-forward, the microprocessor-based strapdown attitude (and heading) systems present some additional considerations for certification and flight testing, as discussed in this paragraph. Attitude and heading reference systems (AHRS) and inertial reference systems (IRS) are the types of systems envisioned.

32.1.5.2.2 Validation of acceptable equipment installations includes, but is not limited to, the validation of proper installation considering the combined effects of temperature, altitude, electromagnetic interference (EMI), vibration, and other various environmental influences. These installation requirements are applicable to critical, essential, and non-essential systems. However, there may be cases where non-essential installations do not warrant the expense of having all, or even part, of these tests and analyses conducted. The necessity for conducting these on non-essential installations should, therefore, be determined on a case-by-case basis by the FAA project engineer, based on the specific and individual circumstances involved. Particular attention should be paid to the following environmental considerations:

1. Vibration. Testing is generally accomplished on the sensor level to the criteria of RTCA DO-160G, *Environmental Conditions and Test*

Procedures for Airborne Equipment. The structural mounting provisions on the airplane should provide assurance that the DO-160G levels are not exceeded when the airplane encounters gusts, as defined in appendix G to part 25. The concern is that the dynamic range of the sensor may be exceeded during this vibration encounter.

2. Temperature. Some systems have temperature monitors built into the sensor block. When the device temperature reaches a given level, the system automatically shuts down. This condition could represent a common mode failure wherein insufficient cooling is provided to the multiple sensors, with the consequent result that they all trip the temperature monitor simultaneously. Some equipment may be constructed with the cooling mechanization integral to the individual unit. Regardless of how the equipment cooling is accomplished, if the proper operation of the unit is below acceptable levels due to failures of the cooling function, then the cooling function should be addressed by analysis and demonstration, where applicable.

3. Power Bus Transients. After the normally expected electrical bus transients due to engine failure, attitude should not be off or unstable for more than one second and should affect only displays on one side of the airplane. If power-up initialization or self-tests are started by the transient, any change in attitude should not be distracting; recognizably valid pitch and roll data should be available within one second. For most airplanes, an engine failure after takeoff will simultaneously create a roll rate acceleration, new pitch attitude requirements, and an electrical transient. Attitude information is paramount; transfer to standby attitude or transfer of control of the airplane to the opposite pilot cannot be reliably accomplished under these conditions in a timely enough fashion to prevent an unsafe condition. In testing this failure mode, switching the generator off at the control panel will usually result in the quickest switching time. Conversely, during an engine failure, as the engine speed decays, the generator output voltage and frequency each decay to a point where the bus control relays finally recognize the failure. This can be a significantly larger disturbance resulting in a different effect on the using equipment. One way to simulate this failure is with a fuel cut, at a safe altitude and airspeed. Both means should be tested.

32.1.5.2.3 Multi-Axis Failures.

FMEAs generally do not rule out the combined pitch/roll attitude failures. If this failure condition can propagate through the autopilot, a need may exist for demonstrating multi-axis autopilot hardovers, as described in paragraph 33.7 of this AC. If the autopilot system architecture is such that the failure cannot get through to the control surface (i.e., input sensor screening, fail-passive autopilot, reasonableness tests, etc.), the need for hardover demonstration may be eliminated. Be aware of the fact that most fail-passive cruise mode autopilots may not be truly fail-passive when reconfigured to reversionary modes.

32.1.5.2.4 Attitude Sensor Intermix.

If the applicant is seeking certification credit for sensor intermix (e.g., vertical and directional gyros (VG/DG)) on the captain's side, and AHRS on the first officer's side), compatibility of the two systems should be demonstrated (i.e., no excessive attitude monitor trips, no adverse influence on system availability (such as autoland) due to monitor trips, etc.). This also holds true for either mode of AHRS operation (NORMAL/BASIC or STANDBY), if this feature is available in the system.

32.1.5.2.5 For systems that have two operational modes (NORMAL and BASIC), annunciation of the fact that the system is operating in the reversionary (BASIC) mode is largely dependent on the user system's architecture. For example, if the airplane is equipped with a CAT III autoland system or CAT III head up display (HUD) system, the performance in these modes with Basic Attitude may be degraded to the point where airplane safety is compromised in CAT III weather conditions. There should then be clear and unmistakable annunciation of the fact that this attitude condition exists.

32.1.5.2.6 For triple AHRS installations, switching is provided to substitute the third AHRS for either the captain's or first officer's system. Annunciation of the fact that the switched condition is in existence may or may not be required, depending on cockpit layout, pilot workload considerations, etc. This is an assessment generally made by the FAA project pilot. The same holds true for annunciation of whether or not the third system is inoperative.

32.1.5.2.7 Some additional flight evaluation suggestions to follow:

1. While on the ground, determine that the attitude system provides usable attitude information through 360° of roll and pitch by rotating the platform through 360° of roll and pitch while observing the appropriate attitude indicator.
2. Verify the system performs as intended, providing satisfactory attitude and heading information to the pilot's and copilot's attitude and heading instruments throughout the normal airplane flight envelope, including unusual attitudes that may be expected in service.
3. Verify that the flight control system functions properly when interfaced with the attitude system. This functional evaluation may be accomplished during a typical flight profile encompassing en route, maneuvering, and coupled approach operations.

4. Determine that loss of the air data system or airspeed input is properly annunciated and that the systems continue to provide satisfactory attitude/heading information.
5. Verify that the comparator monitor provides proper annunciation of attitude/heading disparity.
6. Verify that loss of a single power source does not cause loss of both attitude systems simultaneously.
7. Verify that attitude/heading data from each is not lost for more than 1 second following loss of a primary power source (generator, alternator, inverter, etc.) simultaneous with loss of the associated powerplant.
8. Verify that the system can be realigned in flight after being shut down for more than 3 minutes (if applicable).
9. Verify that each attitude system continues to operate correctly following a simulated airplane electrical power loss of X seconds (equipment specific), by removing power from each respective electrical bus.
10. Verify proper operation of the back-up battery (if installed) and display of appropriate flags by pulling the attitude circuit breaker. Note that the system operates correctly on back-up battery power for approximately X minutes (equipment specific) and then shuts down. Determine that the appropriate flag appear on the effected displays.
11. Verify that all controls, displays, and annunciations are satisfactorily identified, accessible, operable, and adequate for direct sunlight and night conditions.

Note: It is possible that some of the above items can be accomplished in a laboratory or simulator environment.

32.1.5.2.8 Verify that there is no unacceptable mutual interference between the attitude system and other systems and equipment.

32.1.5.3 **Angle-of-attack (AOA) System.**

32.1.5.3.1 Pilot interface with this system will generally be a consequence of presenting a raw data readout in the cockpit and/or driving the Slow/Fast (S/F) display on the ADI, (if so equipped).

32.1.5.3.2 Evaluate the displays during normal approaches and landings to assure reasonable/proper information is being presented for the particular flap setting and V_{REF} speed over the gross weight and CG range of the airplane (S/F should be centered).

32.1.5.3.3 Conduct left and right sideslips that would be representative of normal operation on approach during crosswind landings or engine-out conditions.

32.1.5.3.4 Determine that the malfunction indicators (flags) are appropriately displayed and are satisfactory annunciators.

32.1.5.3.5 Qualitatively assess that the thresholds of displays are wide enough to permit the pilot to follow the indicators, as appropriate to the operation of the airplane.

32.1.5.3.6 Determine that instrument presentation is sufficiently damped to permit use in turbulent air and that hysteresis, if present, is acceptable.

32.1.5.3.7 Verify that the AOA system neither contributes to, nor is affected by, radio frequency or electromagnetic interference (RFI/EMI).

32.1.5.4 **Air Data System.**

32.1.5.4.1 The air data system performance, with the exception of airspeed calibration, will generally be demonstrated qualitatively by observation of the output displays.

32.1.5.4.2 Be particularly observant of barometric altimeter and vertical speed reversals as a function of rapid pitch attitude changes (e.g., takeoff rotation).

32.1.5.4.3 Verify that the Mach/airspeed indicators operate smoothly throughout the complete speed envelope of the airplane.

32.1.5.4.4 Observe correct operation of the overspeed warning indicator (barber pole) while approaching V_{MO}/M_{MO} speeds.

32.1.5.4.5 Observe the static and total air temperature (SAT/TAT) indicators for reasonableness of data presentation.

32.1.5.4.6 Verify that the air data system neither contributes to, nor is affected by RFI/EMI.

32.1.5.5 **Radio Altimeter System.**

32.1.5.5.1 The radio altimeter system should display to the flightcrew, clearly and positively, the altitude information that indicates the airplane main landing gear wheel height above terrain.

32.1.5.5.2 Verify that the altimeters display altitude without loss of signal indications or excessive fluctuations, under the following measurement conditions:

- Pitch angle ±5° about the mean approach attitude.
- Roll angle zero to ±20°.
- Forward velocity from minimum approach speed up to 200 knots, in appropriate configurations.

- At altitudes from 0 to 200 feet with sink rates of 0 to 15 feet per second, in landing, approach, and go-around configurations.

32.1.5.5.3 Under the measurement conditions described above, verify that the altimeters track the actual altitude of the airplane over level ground without significant lag or oscillation.

32.1.5.5.4 With the airplane at an altitude of 200 feet or less, verify that any abrupt change in terrain, representing no more than 10 percent of the airplane's altitude, does not cause the altimeter to unlock. The indicator response to such changes should be appropriate. If the system unlocks, it should re-acquire the signal promptly without pilot intervention.

32.1.5.5.5 Caution should be exercised on airplanes equipped with automatic landing systems if the radio altimeter system is prone to unlock while flying final approach over irregular terrain, since in all probability, the unlock will adversely affect the autoland availability requirement.

32.1.5.5.6 If a decision height (DH) function is provided, verify proper operation at minimum altitudes of 200 feet, 100 feet, and 50 feet.

32.1.5.5.7 Verify that the push-to-test self-test feature generates a simulated radio altitude of less than 500 feet, and that no other systems experience untended effects or interference. For aircraft with automatic landing systems, the self-test feature should be shown to be inhibited during the low altitude phases of the autoland.

32.1.5.5.8 Verify that the system provides a positive failure warning display any time there is a loss of power or a failure of the altimeter to function properly.

32.1.5.5.9 Verify that the radio altimeter system neither contributes to, nor is affected by RFI/EMI.

32.1.5.6 **Onboard Weight and Balance System.**

AC 20-161 provides guidance for certification of onboard weight and balance systems dated April 11, 2008.

32.1.5.7 **Central Aural Warning System (CAWS).**

32.1.5.7.1 Most CAWS functions include aural (and voice, in some installations) warnings of the typical airplane conditions specified in table 32-4 below:

Table 32-4. Types of Aural Warnings

Airplane Condition	Aural Warning
Engine Fire	Altitude Advisory
APU Fire	Speedbrake
Overspeed	Autopilot Disconnect
Takeoff	Flap/Slat Overspeed
Stall	Cabin Altitude
Landing Gear	Stabilizer-In-Motion
Evacuation	Autothrottle Disconnect

32.1.5.7.2 Pilot call and SELCAL tones may also be included, although they are advisories as opposed to warnings.

32.1.5.7.3 The logic for this system usually resides in another computer (e.g., the flight warning computer or master caution/master warning computer) in which case the two systems should be evaluated simultaneously. However, if the logic and/or computer governing activation of the warnings, priority logic, inhibits, etc., are contained in the CAWS itself, refer to the section covering the computers noted above for additional guidance on flight evaluation. Compliance may be shown by equivalent tests in a flight simulator or by bench tests.

32.1.5.7.4 Individual activation of each warning tone should be accomplished in flight under the most adverse noise conditions appropriate to the warning (e.g., V_{MO}/M_{MO} for overspeed, high speed descent for APU fire, acceleration following takeoff for flap/slat overspeed, etc.). Test switches and/or the self-test feature of the system would be an appropriate means to activate the warning.

32.1.5.7.5 The flight evaluation will be a pilot qualitative assessment of the clarity, tone, and volume of each warning.

32.1.5.8 **Overspeed Warning System.**

This system should be demonstrated in conjunction with the airspeed system calibration and should exhibit that it is consistently within the prescribed tolerances. The system tolerance is from V_{MO} to V_{MO} + 6 knots in the airspeed limited range, and from M_{MO} to M_{MO} + 0.01 M in the Mach limited range.

32.1.5.9 **Altitude Advisory (or Altitude Alerting) System.**

32.1.5.9.1 A ground test should be conducted to check the adequacy of the required pre-flight procedure provided in the AFM.

32.1.5.9.2 A flight demonstration should be conducted at low, mid, and high altitudes to verify performance of the intended function of:

- Alerting to, and
- Alerting to an uncommanded departure from an assigned (selected) altitude.

32.1.5.9.3 Low and high rates of vertical speed should be included in the evaluation with captures from above and below the pre-selected altitude.

32.1.5.9.4 Determine adequacy of the alert light location and its visibility under various lighting conditions, and adequacy of the aural warning.

32.1.5.9.5 A flight simulator may be used to perform appropriate tests.

32.1.5.10 **Terrain Awareness and Warning System.**

AC 25-23 contains guidance for flight test considerations for TAWS approvals.

32.1.5.11 **Master Caution System (MCS)/Master Warning System (MWS).**

32.1.5.11.1 This system provides inputs to master warning and master caution lights located on the glareshield in front of each pilot and to the CAWS. (See paragraph 32.1.5.8 of this AC.) It contains the sensors, switches and logic required to assess the requirement for the warning and caution annunciations.

32.1.5.11.2 The system may contain logic to assess priority of the various warnings in order to sequence simultaneous actuation. If so, ground, flight, or bench tests may have to be conducted to verify this logic.

32.1.5.11.3 Some cautions may be inhibited during various phases of flight, particularly during the final stages of a Category III automatic landing operation (below alert height). If so, ground or flight tests may have to be structured to verify the inhibit logic. Also, certain warnings may be inhibited during the high speed stages of a takeoff roll. If this feature is incorporated, it too should be carefully substantiated.

32.1.5.11.4 Simulate failure of selected sensor inputs to verify that the MCS/MWS computer detects the faults and illuminates the fail annunciator (if installed).

32.1.5.11.5 Verify that there is no unacceptable mutual interference between the MCS/MWS and other systems and equipment.

32.1.5.12 **Flight Warning Computer (FWC).**

32.1.5.12.1 The FWC is a key subset of the overall warning, caution, and alerting system on the more modern airplanes. It is a microprocessor-based system that works in conjunction with, or totally replaces, the CAWS and MCS/MWS.

32.1.5.12.2 The FWC incorporates sufficient computer capacity to perform many more functions than the MCS/MWS and, in addition to outputting to the visual warning displays and aural warning speakers, outputs hundreds of alerts/messages to other display media, most often an electronic display (multi-function CRT on the instrument panel or the CDU portion of the FMS).

32.1.5.12.3 The added computer capacity also enables incorporating rather complex inhibit algorithms which, in turn, dictates a requirement for structuring a very complex ground test to verify operation of the inhibits. Review of the system description document will probably be required before any ground, flight, or bench tests can be defined.

32.1.5.12.4 The flight evaluation should incorporate the tests described under CAWS and MCS/MWS.

32.1.5.12.5 Verify that the self-test feature functions properly.

32.1.5.12.6 Simulate failure of selected sensor inputs to verify that the FWC detects the faults and illuminates the FWC fail annunciator.

32.1.5.12.7 Demonstrate freedom from nuisance warnings by observing and logging nuisance events as they occur throughout the flight demonstration program. Assess the status at the end of the program by examining the log.

32.1.5.13 **Stall Warning Computer (SWC).**

32.1.5.13.1 The SWC should be evaluated in conjunction with the stall tests described in chapter 8 of this AC. Adequacy of the various warnings (stick shaker, warning light, aural (and voice) warning) should be assessed, in addition to the speed schedules.

32.1.5.13.2 Demonstrate freedom from nuisance warnings during the takeoff, landing, and maneuvering flight tests described in chapter 8 of this AC. Further testing may be required to show freedom from nuisance warnings by the test requirements in chapter 42 of this AC, if special airworthiness approvals are sought.

32.1.5.14 **Takeoff Warning (TOW) System.**

32.1.5.14.1 The TOW system is usually a subset of the CAWS or MCS/MWS or FWC and is generally inhibited at nose wheel liftoff during the takeoff maneuver. It is usually armed when the squat switch indicates that the airplane is on the ground and one or more power or thrust levers are advanced beyond a prescribed position or engine power or thrust setting. The system alarms if the flaps/slats/stabilizer/spoiler/brakes are not set correctly for takeoff.

32.1.5.14.2 Determine that each event is annunciated properly by conducting a static ground test.

32.1.5.14.3 Flight evaluation during takeoff roll should be a qualitative assessment of the clarity, tone, and volume of each warning. Some systems incorporate a TEST switch, which facilitates activation during takeoff. If this feature is not available, it may suffice to check the audio level of a warning during touch and go landings (e.g., the stabilizer warning while accelerating to V_R speed).

32.1.5.14.4 Simulate failure of selected sensor inputs to verify that the TOW system detects the faults and illuminates the fail annunciator (if installed).

32.1.5.14.5 Verify that the system's arming status is not affected by electrical power transients, which occur when switching from ground or APU power, during engine start, following bus priority checks, etc.

32.1.5.14.6 Verify that there is no unacceptable mutual interference between the TOW system and other airplane systems and equipment.

32.1.5.15 **Instrument Comparator System.**

32.1.5.15.1 If an instrument comparator system is installed and activated, ensure the system monitors validity of and compares (side 1 vs. side 2) pitch and roll attitude, heading, altitude, airspeed, radio altitude, localizer, and glideslope deviation information used for display in the cockpit instruments.

32.1.5.15.2 When these parameters exceed a preset threshold or trip level, or if an invalid condition is detected in any of the displayed information, an appropriate annunciator to that parameter will be illuminated.

32.1.5.15.3 A ground test on the airplane should be conducted to demonstrate performance of intended functions and validate the detector threshold levels. If annunciation is suppressed under certain conditions, these conditions should also be checked.

32.1.5.15.4 A flight evaluation should also be conducted to determine adequacy of the annunciator light locations and visibility under various lighting conditions and that the annunciators are properly identified.

32.1.5.15.5 During flight, verify that the system is free from nuisance warnings and is compatible with other electronic systems.

32.1.5.16 **Reactive Windshear Warning System.**

A complete and comprehensive demonstration program (simulator and flight test) is contained in AC 25-12.

32.1.5.17 **Traffic Alert and Collision Avoidance System.**

A complete and comprehensive demonstration program (laboratory/ground/flight test) is contained in AC 20-131A.

32.1.6 Procedures—Recording Systems.

32.1.6.1 **Cockpit Voice Recorder (CVR).**

32.1.6.1.1 Demonstrate operation of the CVR self-test function and bulk erase feature.

32.1.6.1.2 During ground operations prior to and after engine start; during takeoff, climbout, and cruise at V_{MO}/M_{MO}; and during landing approach. Except where specifically noted, obtain the following CVR recordings:

1. Flightcrew conversations using the area microphone.
2. Flightcrew conversations using the oxygen mask microphones and the boom-microphone/handset, and the hand-held microphones in flight and during ground operations.
3. Radio transmissions by each crew member during cruise.
4. Audio signals identifying navigation aids (through cockpit speakers and on radio channels) during landing approach.
5. PA announcement during cruise.
6. Selective (based on analysis) aural warning signals (see CAWS) during appropriate flight phases.

32.1.6.1.3 Use CVR circuit breaker to limit CVR recording to available capacity.

32.1.6.1.4 Verify that all controls, displays, and annunciators consistent with normal and abnormal crew procedures, are satisfactorily identified, accessible, operable, and visible.

32.1.6.1.5 EMC. Verify by observation that no adverse effects are present in the required flight systems.

32.1.6.1.6 Following the flight, test the CVR audio recording in an appropriate laboratory, and evaluate for clarity of the recorded messages. Preferably the evaluators should not have advance information concerning the flightcrew conversations.

32.1.6.1.7 Verify that the hot mike feature at each position allows for recording regardless of the position of the interphone transmit key switch (§ 25.1457(c)(5)).

32.1.6.2 **Digital Flight Data Recorder (DFDR).**

32.1.6.2.1 Demonstrate operation of the DFDR self-test feature and, prior to collection of test data, set the trip number and date on the code switches of the Trip and Data Encoder, if so equipped.

32.1.6.2.2 The certification data will be derived automatically during any appropriate flight that encompasses operation throughout the full flight envelope. Hand recorded data of heading (magnetic or true), barometric altitude, pitch attitude, indicated airspeed, and time (UTC) should be collected at several stabilized flight conditions for subsequent data correlation purposes.

32.1.6.2.3 Following the flight, the data should be retrieved for correlation and accuracy verification.

32.1.6.2.4 Demonstrate performance of intended function of the DFDR for all parameters specified in the operating rules. (See appendix B to part 121 for the relevant data ranges, accuracies, and recording intervals.) Accuracy will be verified at stabilized points by correlating against, and comparing with, an approved instrumentation system or manual notes.

32.1.6.2.5 EMC. Verify by observation that no adverse effects are present in the required flight systems.

32.1.7 Engine Interfacing Systems.

[Reserved]

32.1.8 Stability Augmentation Systems.

[Reserved]

32.1.9 All Weather Operation (Reduced Visibility) Systems.

[Reserved]

32.2 Flight and Navigation Instruments—§ 25.1303.

32.2.1 Explanation.

32.2.1.1 Section 25.1303(b)(1) requires an airspeed indicator to be visible at each pilot station. Additionally, if airspeed limitations vary with altitude, airspeed indicators must have a maximum allowable airspeed indicator showing the variation of V_{MO} with altitude. Presenting this variation in V_{MO} as a marker on the airspeed indicator whose position varies as a function of altitude is an acceptable means of compliance with this requirement.

32.2.1.2 Production tolerances for speed warning devices at V_{MO}/M_{MO} are required to be taken into account in accordance with § 25.1303(c).

32.2.1.3 Section 21.127(b)(2) requires each production flight test to include "An operational check of each part or system operated by the crew while in flight to establish that during flight, instrument readings are within normal range." Nowhere in these requirements is there any inference that the finite performance or quantitative limits, defined during type certification, need to be determined for each production airplane.

32.2.1.4 Section 25.1303(c) requires that turbine-powered airplanes be equipped with a speed warning device that will provide aural warning whenever the speed exceeds V_{MO} plus 6 knots or M_{MO} + 0.01 M. The regulations specify that the upper limit of the production tolerances permitted for the warning device must be at a speed not greater than the prescribed warning speed.

32.2.1.5 Accuracy requirements specified in §§ 25.1323 and 25.1325 that apply to the airspeed indicator and altimeter required by § 25.1303(b)(1) and (2), respectively, apply equally to all installed airspeed indicators and altimeters, including standby airspeed indicators and altimeters.

32.2.2 Procedures.

The applicant should substantiate, by appropriate ground and/or flight tests, with possible production instrument error corrections, that the system operates within the boundaries established by the regulation. Understanding that other procedures may be acceptable, this could be accomplished in accordance with the following:

32.2.2.1 If the maximum allowable airspeed varies as a function of altitude, and is indicated by means other than a maximum airspeed versus altitude presentation in the airspeed indicator, it should be substantiated that the chosen means of maximum allowable airspeed indication provides an accurate presentation of the relationship between V_{MO} and altitude. The indicated V_{MO} should not exceed the actual V_{MO} for any altitude by more than six knots. This is particularly important for airplanes that have a step function in V_{MO} at a specific altitude (e.g., 10,000 feet) due to bird strike considerations below that altitude.

32.2.2.2 During production flights, the speed warning device must provide warning at a speed equal to or less than V_{MO} + 6 knots or M_{MO} + 0.01 M, minus the sum of the values stipulated in 32.2.2.2.1 and 32.2.2.2.2 below:

32.2.2.2.1 The possible error of the airspeed indicator or Mach meter used as the reference.

32.2.2.2.2 Three knots or 0.005 M, if the airspeed indicator or Mach meter used as the reference has a static or pitot pressure source different from the pressure sources of the warning devices.

32.2.2.3 The speed warning device must be shown to comply with the requirements of § 25.1303(c), as explained in paragraph 32.2.2.3.1 and 32.2.2.3.2 below:

32.2.2.3.1 During ground test using calibrated reference instruments, the installed speed warning device must provide warning at a speed equal to or less than V_{MO} + 6 knots or M_{MO} + 0.01 M. The procedure for this test should be processed in accordance with § 21.127(b)(5) or § 21.143(a)(3).

32.2.2.3.2 For each type design, a test should be conducted to show satisfactory correlation between the operation of the warning device during flight and the data obtained during the ground tests.

32.3 **Powerplant Instruments—§ 25.1305. [Reserved]**

32.4 **Miscellaneous Equipment—§ 25.1307. [Reserved]**

32.5 **Equipment, Systems, and Installations—§ 25.1309.**

32.5.1 Explanation.

The following procedures outline and paraphrase the appropriate provisions of § 25.1309. Further definition and explanation, if required, may be found in part 25 and in AC 25.1309-1A.

32.5.2 Procedures.

32.5.2.1 Evaluate functioning of required installed equipment to verify that performance is as intended under any foreseeable operating and environmental conditions.

32.5.2.2 Evaluate failure conditions, as appropriate, to determine their impact on the capability of the airplane or the ability of the crew to operate it.

32.5.2.3 Review, as appropriate, any design analyses, proposals, studies, or tests that correlate probabilities of failure condition occurrence with the effects of those failure conditions, to determine that they are properly categorized for the appropriate criticality level.

32.5.2.4 Verify that adequate warnings are provided of unsafe conditions, and that these warnings enable the flightcrew to take appropriate corrective action with a minimum of error.

32.5.2.5 In accordance with § 25.1310, for probable operating combinations of required electrical installations, verify that the following power loads are provided for probable durations:

32.5.2.5.1 Loads connected to the system with the system functioning normally;

32.5.2.5.2 Essential loads after failure of any one prime mover, power, converter, or energy storage device;

32.5.2.5.3 Essential loads after failure of one engine on a two-engine airplane;

32.5.2.5.4 Essential loads after failure of two engines on airplanes with three or more engines; and

32.5.2.5.5 Essential loads for which an alternate source of power is required, after any failure or malfunction in any one power supply system, distribution system, or other utilization system.

32.5.2.6 For probable operating combinations of required electrical installations that must be provided with an alternate source of power in accordance with § 25.1331(a), verify that power is provided for probable durations after failure of any one power system.

CHAPTER 33. EQUIPMENT: INSTRUMENTS INSTALLATION

33.1 Arrangement and Visibility—§ 25.1321. [Reserved]

33.2 Warning, Caution, and Advisory Lights—§ 25.1322. [Reserved]

33.3 Airspeed Indicating System—§ 25.1323.

33.3.1 Explanation.

33.3.1.1 **Methods.**

33.3.1.1.1 Unless a calibrated reference system is provided, the airspeed system should be calibrated throughout as wide a range as necessary to cover the intended flight tests. The procedures of this section are for the purpose of showing compliance with § 25.1323(b) and are not intended to cover the speed range of the flight tests. If an alternate airspeed indicating system is provided, it should be calibrated. The airspeed indicating system should be calibrated in accordance with the following methods:

33.3.1.1.2 The tests should be conducted in stabilized flight at airspeeds throughout the speed range for the airplane configurations to be tested. The airplane's airspeed system should be calibrated against a reference airspeed system.

33.3.1.1.3 A reference airspeed system should consist of either of the following:

1. An airspeed impact pressure and static pressure measurement device (or devices) that are free from error due to airplane angular changes relative to the direction of the free stream or due to slipstream variation resulting from changes in airplane configuration or power/thrust. In addition, the device or devices should have a known calibration error when located in the free stream
2. Any other acceptable airspeed calibration method (e.g., the altimeter method of airspeed calibration).

33.3.1.1.4 If an alternate system is provided, it may be calibrated against either the reference system or the airplane's system.

33.3.1.1.5 An acceptable means of compliance when demonstrating a perceptible speed change between 1.23 V_{SR} to stall warning speed (§ 23.1223(d)) is for the rate of change of IAS with CAS to be not less than 0.75.

33.3.1.1.6 An acceptable means of compliance when demonstrating a perceptible speed change between V_{MO} to V_{MO} + 2/3 (V_{DF} - V_{MO}) (§ 23.1323(e)) is for the rate of change of IAS with CAS to be not less than 0.50.

33.3.1.1.7 Airspeed Lag.

With the advent of electronic instruments in the cockpit, the pneumatic signals from the pitot and static sources are processed and digitized in the Air Data Computer (ADC) and then filtered and transported to the cockpit display. As a result of the data processing and filtering, the associated time lag, and, consequently, airspeed lag at the cockpit display, can be an important consideration in the airspeed indicating system calibration during ground acceleration. As stated in § 25.1323(b), the calibration for an accelerated takeoff ground run must determine the system error, which is the relation between indicated and calibrated airspeeds. The system error is the sum of the pneumatic lag in the pressure lines, airspeed lag due to time lags in processing the data, and static source, position error.

33.3.1.1.8 Airspeed lag should be measured during ground acceleration tests or determined by analysis. Increments should be developed for a range of airplane gross weights considering airspeed lag at V_1 and the associated increase in accelerate-stop and takeoff distances due to lag. The error due to lag in the airspeed indicating system during ground acceleration should not be greater than 3.0 knots throughout the takeoff operating envelope of the airplane. Further, an increase in the takeoff distance or the accelerate-stop distance as a result of airspeed lag should not exceed 100 feet. The 3 knots limitation is intended to establish the maximum acceptable systematic error. Even though the lag may be within the 3 knots limit, an airspeed correction may be required to stay within the 100 feet of increased distance.

33.3.1.1.9 Corrections may be applied directly in the ADC or they may be introduced via the ground airspeed calibration provided in the AFM. If corrections are applied directly in the ADC, it is possible to display calibrated airspeed in the cockpit. Further, if acceleration data are input, the airspeed error can be computed and accounted for in real time, assuming the time lag is known. The alternative would be to use an airspeed lag increment derived from calibration tests that would represent a range of conditions within the takeoff envelope. After correction, an increase in distance due to lag should be less than 100 feet throughout the takeoff envelope, whether applied in the ADC or AFM. Consideration should be given to short field, lighter weight takeoffs (higher acceleration), as well as maximum weight and higher V_1 speeds, in deriving the increment.

33.3.1.2 **Configuration.**

Airspeed calibration tests should be conducted in the following configurations:

- Weight—between maximum takeoff and maximum landing.
- CG position—optional.
- Takeoff configuration(s)—ground roll.

- Wing flaps and landing gear—all combinations of positions used to show compliance with the takeoff, climb, and landing requirements of part 25.
- Power or thrust—as required.

33.3.2 Procedures.

33.3.2.1 Any one or any desired combination of the procedures in paragraphs 33.3.2.2 or 33.3.2.3 of this AC may be used for calibrating the airspeed indicating system. The airspeed should be measured or determined simultaneously from the airplane’s system and the reference system during stabilized runs for at least five speeds spaced throughout the speed range, the lowest not to exceed 1.23 V_{SR}. The highest speed should not exceed V_{MO}/M_{MO}. The speed spread between the test speeds should be limited to 10 knots from 1.23 V_{SR} to 1.5 V_{SR} or V_{FE}, and 20 knots from 1.5 V_{SR} to V_{MO}.

33.3.2.2 **Reference Airspeed System.**

Stabilized runs at the test speeds listed in this paragraph should be made. The airspeed from the airplane’s airspeed system and the reference airspeed system should be read simultaneously. The following data should be recorded:

- Time of day.
- Airplane’s indicated airspeed.
- Reference indicated airspeed.
- Pressure altitude.
- Ambient air temperature.
- Wing flap position.
- Landing gear position.

33.3.2.3 **Other Acceptable Airspeed Calibration Methods.**

Stabilized flight runs at the test speeds should be made, and the necessary data recorded, to establish the airplane’s airspeed system error and the configuration of the airplane. Calibration methods may also include airspeed boom, static trailing cone, and radar range.

33.3.2.4 The procedures presented in this paragraph pertain to the calibration of the airspeed indicating system during takeoff ground acceleration. In particular, airplanes with electronic instruments in the cockpit must account for the airspeed lag at the cockpit display associated with data processing and filtering as required by § 25.1323(g). The airspeed indicating system should not have a lag in excess of 3 knots at the V_1 speed during any takeoff condition. Further, if airspeed lag causes an increase of more than 100 feet in takeoff or accelerate-stop distances, a lag correction should be applied to the airspeed indicating system. Airspeed lag should be determined by one of the following methods:

33.3.2.4.1 Conduct ground acceleration tests for a range of airplane gross weights to calibrate IAS at the cockpit display against the reference CAS. Determine airspeed lag from the calibration data by comparing the cockpit displayed airspeed with the reference calibration speed for a given gross weight and V_1 speed.

33.3.2.4.2 Determine airspeed lag by analysis using a computer program suitable for AFM development. Compute takeoffs for a range of gross weights to determine the acceleration at V_1. Calculate airspeed lag at V_1 for a corresponding acceleration and a known time lag due to data processing and filtering. The analysis should also consider other sources of airspeed lag as appropriate, such as the pneumatic lag in the pressure lines for the pitot and static sources.

33.3.2.4.3 Having established the calibration data, one acceptable method of adjusting for airspeed lag is to apply corrections directly in the ADC data processing to result in a lag-corrected airspeed at the cockpit display. Another would be to include an airspeed lag correction in the takeoff ground speed calibration of IAS vs. CAS in the AFM. A single airspeed lag increment can be developed as the correction for the range of gross weights and corresponding accelerations at V_1. This increment, when applied to the calibration, should result in no more than a 100-ft increase in takeoff or accelerate-stop distances due to airspeed lag for any takeoff condition. A more accurate correction would result from presenting airspeed lag as a function of airplane acceleration based on the calibration data. If acceleration data are available in the ADC, a real time correction for lag during the takeoff can be applied in the data processing.

33.4 Static Pressure Systems—§ 25.1325(d) and (e).

33.4.1 Explanation.

33.4.1.1 If the altimeter installation is of the pressure type, its operation will be affected by any error that exists in the measurement of the static air pressure. Since the accuracy of the altimeter is of utmost importance, the static air vent system should be calibrated. If separate or alternate vent systems are employed for the altimeter and airspeed indicator, separate calibrations are required. Where the altimeter, rate of climb indicator, and airspeed indicators are vented to the same static systems, the altimeter calibration may be made in conjunction with the airspeed calibrations.

33.4.1.2 The theoretical relationship between airspeed error and altimeter error may be used to derive an altimeter calibration from the airspeed calibration, or vice versa, if both use the same static vent, provided any error in total pressure over the angle-of-attack range is taken into account.

33.4.2 Procedures.

None.

33.5 Pitot Heat Indication Systems—§ 25.1326. [Reserved]

33.6 Magnetic Direction Indicator—§ 25.1327. [Reserved]

33.7 Flight Guidance System—§ 25.1329.

33.7.1 Explanation.

33.7.1.1 On most modern airplane installations, the autopilot and flight director are integrated into a single computer, use common control laws, and are identified as a flight guidance system (FGS). The FGS is primarily intended to assist the flightcrew in the basic control and tactical guidance of the airplane. The system may also provide workload relief to the pilots and provide a means to fly a flight path more accurately to support specific operational requirements, such as reduced vertical separation minimum (RVSM) or required navigation performance (RNP). To perform these functions, the FGS typically includes an integrated autopilot, autothrust, and flight director. The FGS functions also include flight deck alerting, status, mode annunciations (instrument displays), and associated information displayed to the flightcrew for situation awareness. Also included are those functions necessary to provide guidance and control with an approach and landing system, such as an instrument landing system (ILS), microwave landing system (MLS), global navigation satellite system (GNSS), or a GNSS landing system (GLS). Although a HUD system, if installed, is generally a separate system, evaluation of its modes of operation would be identical to a flight director system. For these reasons, the systems flight test evaluation criteria provided here also apply to HUDs.

Note: For applicants considering type certification of a HUD system, we recommend that the flight technical error be characterized during certification testing. This data will be required if the applicant chooses to seek operational credit for advanced performance-based navigation applications.

33.7.1.2 For the purposes of this AC, the FGS includes all the equipment necessary to accomplish the FGS function, including the sensors, computers, power supplies, servo-motors/actuators, and associated wiring. It also includes any indications and controllers necessary for the pilot to manage and supervise the system.

33.7.1.3 A flight test program should be established that confirms the performance of the FGS for the modes of operation and the operational capabilities supported by its design. The operational implications of certain failures and failure conditions may require flight evaluation. Also, the pilot interface with FGS controls and displays in the cockpit will need to be assessed. Some aspects of the FGS design may be validated by laboratory test and/or simulator evaluation.

33.7.1.4 The scope of the flight demonstration program will depend on the operational capability being provided, including any new and novel features. Early coordination with the FAA is recommended to reduce certification risks associated with the flight demonstration program. The intent of the flight demonstration program is to confirm that the operation of the FGS is consistent with its use for the intended flight operations of the airplane type and configuration. The modes of the FGS should be demonstrated in representative airplane configurations and under a representative range of flight conditions.

33.7.1.5 Additional guidance material related to FGS operation, testing, and approval is contained in the following ACs:

- AC 25-15.
- AC 25.1329-1C.
- AC 120-28D.
- AC 120-29A.

33.7.2 <u>Procedures: General.</u>

33.7.2.1 The evaluation of an FGS should primarily concentrate on the intended function(s) and safe operation of the system. Flight test evaluations supplement analysis, laboratory testing, and simulator testing for showing compliance with the applicable part 25 requirements.

33.7.2.2 The requirement for demonstrating safe operation should include evaluation of FGS failure conditions that a system safety assessment identifies as needing to be validated by flight test.

33.7.2.3 The FGS should be installed and adjusted so that the system tolerances established during certification tests can be maintained in normal operation. This may be addressed by conducting flight tests at the extremes of the tolerances. Those tests conducted to determine that the FGS will adequately control the airplane should establish the lower limit, and those tests to determine that the FGS will not impose dangerous loads or deviations from the flight path should be conducted at the upper limit. Appropriate airplane loading to produce the critical results should be used.

33.7.2.4 The system should be demonstrated to perform its intended function in all configurations in which it may be used throughout all appropriate maneuvers and environmental conditions, including turbulence, unless an appropriate operating limitation is included in the AFM. All maneuvers should be accomplished smoothly, accurately, and without sustained nuisance oscillation.

33.7.2.5 In addition to performance of intended function of each mode examined, the FGS should cause no sustained nuisance oscillations, undue control activity, or sudden large attitude changes, especially when configuration or power/thrust changes are taking place.

33.7.2.6 When use of the FGS is permitted with any of its functions inoperative (e.g., autothrust, yaw damper, etc.), the system should be evaluated with these functions both operative and inoperative.

33.7.3 Procedures: FGS Protection Features.

33.7.3.1 Section 25.1329(h) requires that, when the flight guidance system is in use, a means must be provided to avoid excursions beyond an acceptable margin from the speed range of the normal flight envelope. The FGS itself may contain protection features to aid the flight crew in assuring that the boundaries of the flight envelope or operational limits are not exceeded. The means to alert the flightcrew to a boundary or for the system to intervene may vary, but certain operational scenarios can be used to assess the performance of the system in providing the protection function. The procedures in the following paragraphs can be used to evaluate the protection features as required by § 25.1329(h), regardless of whether they are included in the FGS itself, or invoked by other means.

33.7.3.2 **Low Speed Protection.**

Low speed protection is intended to prevent loss of speed leading to an unsafe condition. If the FGS remains in the existing mode, a suitable alert should be provided to annunciate the low speed condition. In this case, note the pilot response to the alert and the recovery actions taken to maintain the desired vertical path and to accelerate back to the desired speed. The following scenarios should be considered when evaluating the low speed protection means that must be present when the FGS is in use:

33.7.3.2.1 High Altitude Cruise Evaluation.

1. At high altitude at normal cruise speed, engage the FGS into an Altitude Hold mode and a heading or lateral navigation (LNAV) mode.

2. Engage the autothrust into a speed mode.
3. Manually reduce one engine to idle power or thrust.
4. As the airspeed decreases, observe the FGS behavior in maintaining altitude and heading/course.
5. When the low speed protection feature becomes active, note the airspeed and the associated aural and visual alerts including possible mode change annunciations for acceptable operation.

33.7.3.2.2 Altitude Capture Evaluation at Low Altitude.

1. At a reasonably low altitude (e.g., approximately 3000 feet above MSL where terrain permits) and at 250 knots, engage the FGS into Altitude Hold and a heading or LNAV mode.
2. Engage the autothrust into a speed mode.
3. Set the altitude pre-selector to 5000 feet above the current altitude.
4. Make a flight level change to the selected altitude feet with a 250 knots climb at maximum climb power or thrust.
5. When the FGS first enters the Altitude Capture mode, reduce thrust/power on one engine to idle.
6. As the airspeed decreases, observe the airplane trajectory and behavior.
7. When the low speed protection condition becomes active, note the airspeed and the associated aural and visual alerts including possible mode change annunciations for acceptable operation.

33.7.3.2.3 High Vertical Speed Evaluation.

1. Engage the FGS in the Vertical Speed mode with a very high rate of climb.
2. Set the thrust/power to a value that will cause the airplane to decelerate at approximately 1 knot per second.
3. As the airspeed decreases, observe the airplane trajectory and behavior.
4. When the low speed protection condition becomes active, note the airspeed and the associated aural and visual alerts including possible mode change annunciations for acceptable operation.

33.7.3.2.4 Approach Evaluation.

1. Conduct an instrument approach with vertical path reference.
2. Couple the FGS to the localizer and glideslope (or LNAV/VNAV, etc.).

3. Cross the final approach fix/outer marker at a reasonably high speed at idle thrust/power until low speed protection activates.
4. As the airspeed decreases, observe the airplane trajectory and behavior.
5. When the low speed protection becomes active, note the airspeed and the associated aural and visual alerts including possible mode change annunciation for acceptable operation.
6. Note the pilot response to the alert and the recovery actions taken to recover to the desired vertical path and the re-capture to that path and the acceleration back to the desired approach speed.

33.7.3.3 **High Speed Protection.**

High speed protection, which may either be included in the FGS or provided by other means, is intended to prevent a gain in airspeed leading to an unsafe condition. If the FGS remains in the existing mode with reversion to high speed protection, a suitable alert should be provided to annunciate the high speed condition. In this case, note the pilot response to the alert and the recovery actions taken to maintain the desired vertical path and to decelerate back to the desired speed. The following scenarios should be considered when evaluating the means used to provide protection from high speed excursions while the FGS is in use, as required by § 25.1329(h):

33.7.3.3.1 <u>High Altitude Level Flight Evaluation with Autothrust Function.</u>

1. Select autothrust off, if an automatic wake-up function is provided; otherwise, select autothrust on.
2. Engage the FGS in Altitude Hold.
3. Select a power or thrust level that will result in an acceleration that would cause, without intervention (either automatic or manual), a speed/Mach beyond V_{MO}/M_{MO}.
4. As the airspeed increases, observe the behavior of the high-speed protection condition and any autothrust reactivation and thrust/power reduction, as applicable.
5. Assess the performance of the FGS to control the airspeed to V_{MO}/M_{MO}, or other appropriate speed.

33.7.3.3.2 <u>High Altitude Level Flight Evaluation Without Autothrust Function.</u>

1. Set a power/thrust level that will result in acceleration that would cause, without intervention (either automatic or manual), a speed/Mach beyond V_{MO}/M_{MO}.
2. As the airspeed increases, observe the basic airplane overspeed warning activate.

3. Observe activation and effectiveness of the high speed protection means and note any FGS indications and behavior.
4. Maintain the existing power or thrust level and observe the airplane depart the selected altitude.
5. After sufficient time has elapsed to verify and record FGS behavior, reduce the thrust/power as necessary to cause the airplane to begin a descent.
6. Observe the FGS behavior during the descent and subsequent altitude capture at the original selected altitude.

33.7.3.3.3 High Altitude Descending Flight Evaluation with Autothrust Function.

1. Select autothrust off (with automatic wake-up function) with power or thrust set to maintain airspeed 10 percent below V_{MO}/M_{MO} with the FGS engaged in Altitude Hold.
2. Select Vertical Speed mode with a vertical speed that will result in an acceleration that would cause, without intervention (either automatic or manual), a speed/Mach beyond V_{MO}/M_{MO}.
3. As the airspeed increases observe the autothrust function reactivate and reduce power or thrust towards idle.
4. Observe the activation and effectiveness of the high speed protection means and note any FGS indications and behavior.

33.7.4 Procedures: FGS Takeoff Mode.

33.7.4.1 AC 25-15 contains some basic criteria and airspeed tolerance criteria that should be included in the flight evaluation of systems containing takeoff guidance. Additional testing considerations, which should be considered for inclusion in the flight test plan, are presented in paragraphs 33.7.4.2 through 33.7.4.19 below.

33.7.4.2 There are no test conditions specifically identified for evaluating the roll axis control function. The performance of this function should be evaluated during the normal course of flight testing. The test conditions for the pitch axis control function identified below is for a system providing computed command guidance (flight director, Head Up Guidance System (HGS), and automatic pilot after liftoff) to achieve and maintain a reference speed to be flown during second segment climb-out.

33.7.4.3 For a normal all-engines-operating (AEO) takeoff, the reference speed should be the normal AEO initial takeoff climb speed selected by the applicant (typically V_2+10 knots). In the event that an engine failure occurs during the takeoff maneuver, at an airspeed greater than V_{EF}, the reference speed should be:

- V_2, if an engine failure occurs prior to V_2.

- The existing speed, if engine failure occurs between V_2 and the AEO initial climb speed.
- The AEO initial takeoff climb speed for all other conditions, if appropriate.

33.7.4.4 Evaluate takeoff performance with different flap settings and different loading conditions (gross weight and CG) to cover the various flight conditions. Use normal rotation and cleanup procedures unless noted otherwise.

33.7.4.5 Evaluate abnormal/simulated failure conditions including:

- Late rotation.
- Early rotation.
- Simulated engine failure at V_{EF}.
- Simulated engine failure at V_2+20 knots.
- Simulated engine failure at V_2+5 knots.

33.7.4.6 Evaluate the ability of the FGS to command the correct speed for the conditions in the testing described in paragraphs 33.7.4.3, 33.7.4.4, and 33.7.4.5 above.

33.7.4.7 If a variable takeoff power or thrust derate or reduced thrust (power) feature is provided, perform takeoff demonstrations to cover the range of derated/reduced power or thrust levels for which approval is requested.

33.7.4.8 If an ATTCS is included on the airplane, evaluate its performance of intended function in conjunction with the above.

33.7.4.9 Conduct takeoffs with and without, as applicable, autothrust, yaw damper, autobrakes, control wheel steering, and any other automated equipment configurations, and combinations thereof, for which the applicant is seeking certification approval. Include all sensor and instrument switching combinations.

33.7.4.10 Evaluate Slow/Fast display behavior, if applicable, in conjunction with these takeoff tests.

33.7.4.11 Evaluate the FGS behavior with both series and parallel rudder (if available) configurations, particularly in conjunction with simulated engine failure tests.

33.7.4.12 Evaluate “fade-out” of parallel rudder (with simulated engine failure) during FGS takeoff mode transition to automatic altitude captures (if this feature is available).

33.7.4.13 Evaluate pitch axis takeoff behavior during simultaneous heading select turns during climb-out.

33.7.4.14 Evaluate mode transition from takeoff to other approved modes using flight director, HGS, and automatic pilot guidance (e.g., from pitch axis takeoff mode to Indicated Airspeed (IAS) Hold, Vertical Speed, Altitude Hold, or Vertical Navigation (VNAV) mode; from roll axis takeoff mode to Heading Select, radial tracking, or Lateral Navigation (LNAV) mode, etc.).

33.7.4.15 Evaluate all reversion modes appropriate to the design. Most speed command takeoff modes will be fail-passive (or fail-soft) and will probably contain reversion modes. Consult the system description, failure modes and effects analysis (FMEA), and the responsible systems engineer for definition of the appropriate evaluation. This may be accomplished in an appropriate simulator environment.

33.7.4.16 Evaluate adequacy of mode annunciations and controls and displays associated with takeoff mode operation.

33.7.4.17 In addition to evaluating speed performance to the criteria shown in Table 2 of AC 25-15 evaluate command bar flyability, dynamics of the airplane while following the commanded guidance, initial pitch target presented during and immediately following rotation, etc.

33.7.4.18 Evaluate takeoff pitch attitude limit, if applicable, for compatibility and command harmony.

33.7.4.19 Quantitative time history data should be recorded with an onboard data system to facilitate post-flight evaluation of performance and to provide type inspection report (TIR) records.

33.7.5 Procedures: FGS Climb, Cruise, Descent, and Holding Modes.

33.7.5.1 The acceptability of the FGS performance may be based on subjective judgment, taking into account the experience acquired from similar equipment and the general behavior of the airplane. The acceptable performance may vary according to airplane type and model.

33.7.5.2 Examination of the following modes are considered appropriate for inclusion in this section:

- Altitude Hold/Select.
- Area Navigation.
- Backcourse.
- Heading Hold/Select.

- IAS Hold/Select.
- Lateral Navigation.
- Level Change.
- Localizer (only).
- Mach Hold/Select.
- Non-Precision Approach.
- Pitch Attitude Hold.
- Roll Attitude Hold.
- Turbulence.
- Vertical Navigation.
- Vertical Speed Hold/Select.
- VOR.
- VOR Navigation.

33.7.5.3 Evaluation/approval of the modes in the paragraph above generally will not require derivation of quantitative flight data.

33.7.5.4 Special characteristics associated with some specific modes worthy of note are:

33.7.5.4.1 Operation of the system should not result in performance for which the pilot would be cited during a check ride (i.e., exceeding a speed target of 250 knots by more than 5 knots, if appropriate, during operations below 10,000 feet altitude, or overshooting a target altitude by more than 100 feet during capture of the pre-selected altitude).

33.7.5.4.2 Where the FGS has the ability to acquire and maintain a pre-selected altitude, it should be shown in particular that:

1. With the autopilot function of the FGS engaged without autothrust, if the pilot fails to advance the throttles following an altitude acquisition from a descent, ensure that the FGS speed protection function activates to avoid an unsafe speed excursion.
2. Resetting the datum pressure or the selected altitude at any time during altitude capture should not result in hazardous maneuvers.

33.7.5.4.3 The altitude hold mode should be evaluated:

1. During turning flight.
2. During accelerating and decelerating flight.

3. With engagement of the mode from climbing and descending flight conditions.

33.7.5.4.4 Thoroughly explore transition of VOR navigation from cruise/holding to the approach mode. Include appropriate procedures or limitations in the AFM if special procedures or limitations are deemed to be necessary.

33.7.6 Procedures: FGS Go-Around Mode.

33.7.6.1 AC 25-15 contains some basic criteria and airspeed tolerance criteria for go-around systems that should be included in the flight evaluation. Also, AC 120-28D contains additional go-around criteria pertinent to this flight evaluation if the airplane is to be approved for CAT III operation.

33.7.6.2 As with the takeoff mode, the go-around roll axis control law will probably be a heading hold or roll attitude hold/wings-level mode. The pitch axis control law may be an angle-of-attack control law system, but most modern systems will have control laws for speed control. The speed should be compatible with that used for a manually controlled go-around without guidance.

33.7.6.3 The system should not command a go-around speed less than 1.13 V_{SR1} for the go-around flap setting or the minimum control speed (e.g., V_{MCL}) established for that particular airplane. In making this evaluation, consideration should be given to the autopilot roll axis control law and its effect on minimum control speeds. If the autopilot employs a wings-level control law, the minimum control speeds may be considerably higher than the AFM values that are determined with some degree of bank into the operating engine(s).

33.7.6.4 Evaluate go-around performance with normal conditions for each landing flap setting through a full range of gross weight and CG conditions. Use normal cleanup procedures to the appropriate go-around flap setting.

33.7.6.5 Evaluate go-around performance with simulated engine failure conditions occurring:

- Just prior to go-around initiation,
- Just after go-around initiation, and
- During climb-out, both before and after initiation of altitude capture mode.

33.7.6.6 If engine-out approach/landing approval is sought by the applicant, then evaluate go-around performance initiated from an engine-out approach.

33.7.6.7 It should be demonstrated that the FGS will command the correct speed to accomplish a go-around for the conditions in the testing described in paragraphs 33.7.6.4, 33.7.6.5, and 33.7.6.6 above.

33.7.6.8 Flight path control following an engine failure during go-around should not require exceptional piloting skill or alertness.

33.7.6.9 Conduct go-arounds with and without, as applicable, automatic throttles, yaw damper, automatic ground spoilers, control wheel steering, and any other equipment configurations, and combinations thereof, for which the applicant is seeking certification credit. Include all sensor and instrument switching combinations.

33.7.6.10 Evaluate Slow/Fast display behavior, if applicable, in conjunction with these go-around tests.

33.7.6.11 Evaluate the autopilot behavior with both series and parallel rudder (if available) configurations, particularly in conjunction with simulated engine failure tests.

33.7.6.12 Evaluate "fade-out" of parallel rudder (with simulated engine failure) during autopilot go-around mode transition to automatic altitude captures (if this feature is available).

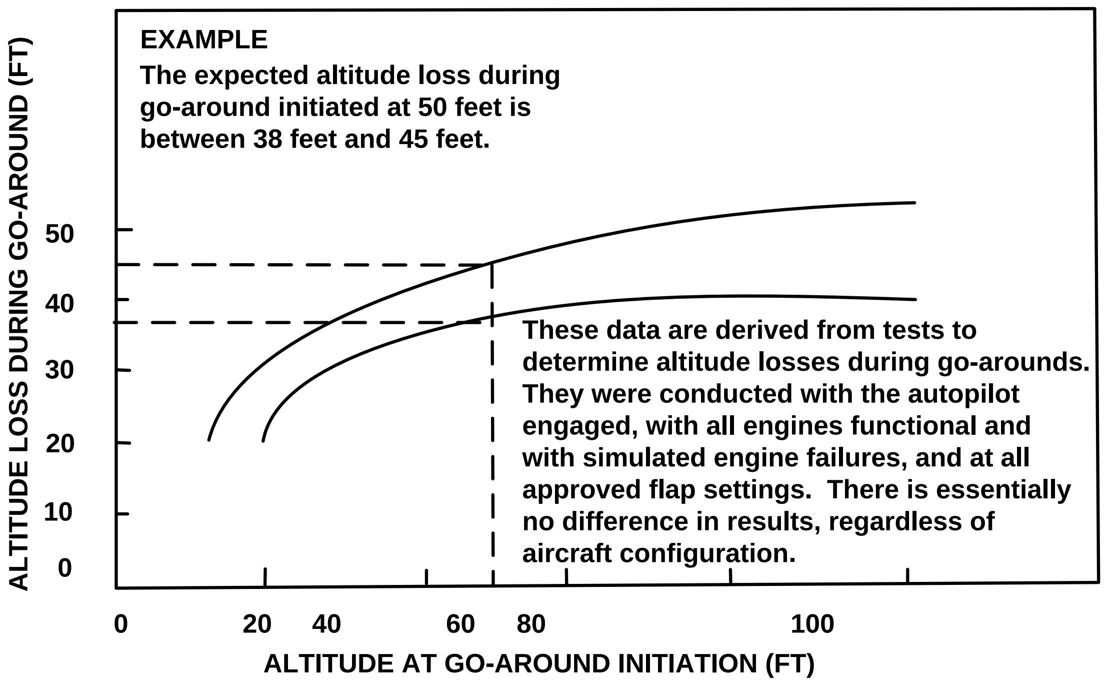
33.7.6.13 Verify that when automatic go-around is engaged, subsequent momentary ground contact will not cause its disengagement or a mode reversion out of go-around.

33.7.6.14 Structure the test program such that altitude loss during the go-around maneuver can be determined as a function of height above the ground at go-around initiation. Altitude loss during the maneuver is directly proportional to the rate of descent when the go-around is initiated.

33.7.6.15 Go-around altitude loss is defined as the difference in altitude between the selection of the go-around mode and the minimum height above the ground achieved during the maneuver.

33.7.6.16 Go-around altitude loss information should be included in the AFM, especially if the airplane is to be approved for low visibility (Category I, II, or III) approaches. An example of how such information has been presented in the AFM is shown in figure 33-1 below.

Figure 33-1. Altitude Loss versus Altitude at Go-Around Mode Initiation



33.7.6.17 Evaluate the go-around maneuver under conditions with automatic spoilers armed and go-around initiated at an altitude low enough to result in wheel contact with the runway surface. Verify that momentary deployment of the ground spoilers under these conditions is acceptable.

33.7.6.18 In addition to evaluating speed performance to the criteria shown in Table 2 of AC 25-15 evaluate command bar flyability, the dynamics of the airplane while following the commanded guidance, etc. The control action and flight path during the initial rotation should not be significantly different from those of a manually controlled go-around without command guidance.

33.7.6.19 The go-around from any point on the approach to touchdown should not require exceptional piloting skill, alertness, or strength, and should ensure that the airplane remains above the obstacle limitation surface specified in AC 120-29A.

33.7.6.20 Evaluate pitch axis go-around mode behavior with simultaneous heading select turns during climb-out.

33.7.6.21 Evaluate mode transitions from go-around to other approved modes using flight director, HGS, and automatic pilot guidance (i.e., from pitch axis go-around mode to IAS Hold, Vertical Speed, Altitude Hold, or VNAV; from roll axis go-around mode to Heading Select VOR, or LNAV, etc.).

33.7.6.22 Evaluate all reversion modes appropriate to the design. Most speed command go-around modes will be fail-passive (or fail-soft) and will probably contain reversion modes. Consult the system description, the FMEA, and the responsible system engineer for definition of the appropriate evaluation. It may be possible to perform this testing in a simulator.

33.7.6.23 Evaluate adequacy of mode annunciations and controls and displays associated with the go-around maneuver.

33.7.6.24 Evaluate the go-around pitch attitude limit (if applicable) for compatibility and command harmony.

33.7.6.25 **Fixed Pitch Go-Around.**

Missed approaches using the calibrated attitude markings on the Attitude Director Indicator (ADI) should be demonstrated to be an acceptable alternative technique for low visibility operations (CAT II & CAT III), in the event that automatic or flight director go-around modes are not available. A sufficient sample size should be collected to establish the transitional altitude loss. The target attitude for go-around (13° to 17° is usually the target) should be established by the applicant. Use normal cleanup procedures. Simulate various failure conditions that would force the pilot to revert to this configuration. (e.g., simultaneous loss of autoland and go-around computation).

33.7.6.26 Quantitative time-history data should be derived with an on-board data system to facilitate post-flight evaluation of performance and to provide TIR records.

33.7.7 Procedures: FGS Instrument Landing System (ILS) Approach Mode.

33.7.7.1 A complete and comprehensive description of flight test evaluation for automatic pilot and flight director system ILS approach mode approval, including HUDs, is contained in AC 120-29A. Further guidance is provided below:

33.7.7.2 For airworthiness approval to Category I (CAT I) minimums:

33.7.7.2.1 Conduct a series of approaches (usually 4 or more) on Type I rated ILS beams to a radio altitude of 160 feet. (Twenty percent below the CAT I decision height of 200 feet).

33.7.7.2.2 Conduct the approaches with and without automatic throttles, with and without yaw damper, alternate flap setting and so forth, for all configurations and combinations of equipment for which the applicant seeks approval.

33.7.7.2.3 At least three Type I beams should be included in the evaluation, one of which should exhibit very noisy localizer and glideslope characteristics.

33.7.7.2.4 Failure modes/conditions described in paragraph 33.7.8.6 of this AC, appropriate to ILS approach modes, should be conducted.

33.7.7.2.5 The definition of a successful approach is one that positions the airplane at the decision height (DH) such that the airplane can be safely landed without exceptional piloting skill or strength.

33.7.7.3 For airworthiness approval to Category II (CAT II) minimums for each candidate system (automatic pilot, flight director, and HGS):

33.7.7.3.1 Conduct a series of approaches on Type II rated ILS beams to a radio altitude of 100 feet.

33.7.7.3.2 For initial system approval, approximately 20 approaches (total for each affected system) are required to examine each configuration/combinations of equipment for which the applicant seeks credit.

33.7.7.3.3 At least three Type II beams should be included in the evaluation.

33.7.7.3.4 When relatively minor changes are made to the approach control laws or when a different display (i.e., flight director instrument) is used with the system, approximately 9 approaches (total for each affected system) have been found to be sufficient (i.e., 3 each on 3 different ILS beams).

33.7.7.3.5 The approaches should be made in conditions chosen to show that the performance is satisfactory within the permitted extremes of weight, CG, wind speed, localizer capture angles, glideslope captures from below and above (if appropriate) the beam, captures at various ranges from runway threshold, etc.

33.7.7.4 If approval is sought for ILS approaches initiated with one engine inoperative, and with the airplane trimmed at the point of glide path intercept, the automatic flight control system should be capable of conducting the approach without further manual trimming. For airplanes with three or more engines, the loss of a second critical engine should not cause a rate of lateral deviation from the ILS course greater than 3° per second (averaged over a 5-second period), or produce hazardous attitudes.

33.7.7.5 Unless it is shown that failure of the automatic pilot system to disengage during the approach, when the pilot operates the quick release control on the control wheel, is improbable, then it should be demonstrated that the pilot can control the airplane manually without operating any of the other disengagement controls.

33.7.7.6 It is possible that many of the above tests can be performed in a simulator.

33.7.8 Procedures: FGS Control Wheel Steering (CWS).

33.7.8.1 It should be possible for the pilot to overpower the automatic pilot system, and achieve the maximum available control surface deflection, without using forces that exceed the pilot control force limits specified in § 25.143(d).

33.7.8.2 The maximum bank and pitch attitudes that could be achieved without overpowering the automatic pilot system should be limited to those necessary for the normal operation of the airplane. Typically, these attitudes are ±35° in roll and +20° to -10° in pitch.

33.7.8.3 It should be possible to carry out all normal maneuvers and to counter normal changes of trim due to change of configuration etc., within the range of flight conditions in which control wheel steering may be used, without encountering excessive discontinuities in control force that might adversely affect the flight path.

33.7.8.4 The stall and stall recovery characteristics of the airplane should remain acceptable with control wheel steering in use.

33.7.8.5 In showing compliance with § 25.143(f), account should be taken of such adjustment to trim as may be carried out by the automatic pilot system in the course of maneuvers that can reasonably be expected. Some alleviation may be acceptable in the case of unusually prolonged maneuvers, provided the reduced control forces would not be hazardous.

33.7.8.6 If the use of this mode for takeoff and landing is to be permitted, it should be shown that:

- Sufficient control, both in amplitude and rate, is available without encountering force discontinuities;
- Reasonable mishandling is not hazardous (e.g., engaging the autopilot while the pitch or roll controls are held in an out-of-trim position); and
- Runaway rates and control forces are such that the pilot can readily overpower the automatic pilot with no significant error in flight path.

33.7.9 Procedures: Environmental Conditions.

33.7.9.1 Some environmental conditions have created operational problems during FGS operations. The flight demonstration program should expose the FGS to a range of environmental conditions as the opportunity presents itself. These include winds, mountain-wave, turbulence, icing, etc. However, some specific test conditions may have to be flown to find operational conditions that are not readily achieved during the normal flight test program.

33.7.9.2 FGS use in icing conditions may mask the onset of an airplane condition (e.g., out of trim condition) that would present the pilot with handling difficulties if the FGS is disengaged, particularly if the FGS suddenly disengages automatically. The opportunity should be taken during the flight test program to evaluate the FGS during natural icing conditions, including during shedding of the ice, as applicable. The operation of the FGS should also be evaluated during basic airplane performance and handling qualities compliance flight tests with simulated ice accretions installed. (See AC 25-25 for examples of a flight test program for evaluating airplane performance and handling qualities in icing conditions and for guidance on ice accretions to use for flight testing.) The following test conditions should also be considered for evaluating FGS performance in icing conditions:

33.7.9.2.1 Low Speed Protection.

1. With all high lift devices retracted, slow down at a rate not to exceed 1 knot per second until either the autopilot automatically disengages (with an associated alert) or a low speed protection function engages (which may be a low speed alert).
2. Recovery should be initiated no less than three seconds after the onset of an appropriate alert.
3. The airplane should exhibit no hazardous characteristics.

33.7.9.2.2 Coupled Approach.

If the autopilot has the ability to fly a coupled instrument approach and go-around, the following test conditions should be evaluated:

1. Instrument approach, using all normal flap selections.
2. Go-around, using all normal flap selections.
3. Glideslope capture from above the glidepath.

33.7.9.2.3 If the airplane accretes or sheds ice asymmetrically, it should be possible to disengage the autopilot at any time without unacceptable out-of-trim forces.

33.7.9.2.4 General maneuverability should be assessed, including normal turns, and the maximum angle of bank commanded by the FGS in one direction followed by a rapid reversal of command reference to the maximum FGS angle of bank in the other direction.

33.7.10 Procedures: Failure Modes/Malfunction Tests.

33.7.10.1 **General.**

33.7.10.1.1 Failure conditions of the system should be simulated in such a manner as to represent the overall effect, and worse case effect, of each failure condition about all axes. The test method for most failure conditions will require some type of fault simulation technique with controls that provide for controlled insertion and removal of the type of fault. The insertion point will typically be at a major control or guidance point on the airplane (for example, a control surface command, guidance command, or power/thrust command).

33.7.10.1.2 Investigations should include the effects of any failure conditions identified for validation by a system safety assessment conducted to show compliance with § 25.1309(d).

33.7.10.1.3 The safety assessment process may identify vulnerabilities to failure conditions involving hardovers, slowovers, or oscillatory behavior. The various types of effect will result in differing airplane responses and cues to alert the flightcrew to the failure condition. The recognition point should be that at which a line pilot in non-visual conditions may be expected to recognize the need to take action. Recognition of the malfunction may be through the behavior of the airplane or a reliable alerting system. The recognition point should be identified by the test pilot. Control column or wheel movements alone should not be used for recognition.

33.7.10.1.4 After the recognition point, action by the test pilot should be delayed to simulate the time it would take for a line pilot to take control after recognizing the need for action. The test condition is considered completed when a stable state is reached as determined by the test pilot. A three-second delay added to the measured time increment between pilot recognition of an automatic pilot malfunction and pilot corrective action has been considered acceptable for climb, cruise, and descent phases of flight. A one-second delay is considered appropriate for flight phases where the crew is expected to be closely monitoring FGS control inputs, such as during approach, and for FGS use during takeoff from shortly after liftoff through flap retraction. For control wheel steering (CWS) mode of operation during takeoff, go-around, and landing, and for autoland and go-around mode hardovers, no delay time need be applied.

33.7.10.1.5 Satisfactory airplane response to autopilot hardovers should be shown throughout the entire certificated airspeed/altitude flight envelope. Since loading limitations of the test airplane preclude investigation of the entire flight envelope for which certification is requested, simulation results may be used to validate response in the unreachable CG versus weight combinations.

33.7.10.1.6 The nominal worst-case weight/CG combinations achievable by the test airplane, as predicted by simulation results, should be flight tested. The justification for selection of the weight/CG combinations proposed for testing should be submitted for FAA review prior to type inspection authorization (TIA) issuance.

33.7.10.1.7 The analysis should also present a comprehensive exploration of airplane "g" responses throughout the weight-CG-airspeed-altitude flight envelope, including worst case and envelope boundary conditions. The analysis should include flight test and simulator responses adjusted for the presence of worst-case system tolerance effects.

33.7.10.1.8 During recovery from an automatic pilot system malfunction, the pilot may overpower the autopilot or disengage it. The pilot should be able to return the airplane to its normal flight attitude under full manual control, without exceeding the loads or speed limits appropriate to the flight condition, without engaging in any dangerous maneuver during recovery, and without control forces exceeding the values given in § 25.143(d).

33.7.10.1.9 If an autothrottle is installed, the malfunctions should be examined with and without the autothrottle operating.

33.7.10.1.10 The airplane should be instrumented such that parameters appropriate to the tests are recorded (e.g., normal acceleration, airspeed, altitude, pitch and roll attitude, automatic pilot engagement discrete).

33.7.10.2 **Oscillatory Tests.**

33.7.10.2.1 An investigation should be made to determine the effects of an oscillatory signal of sufficient amplitude to saturate the servo amplifier of each device that can move a control surface. The investigation should cover the range of frequencies that can be induced by a malfunction of the automatic pilot system and systems functionally connected to it, including an open circuit in a feedback loop. The investigated frequency range should include the highest frequency that results in apparent movement of the system driving the control surface to the lowest elastic or rigid body response frequency of the airplane. Frequencies less than 0.2 Hz may, however, be excluded from consideration. The investigation should also cover the normal speed and configuration ranges of the airplane. The results of this investigation should show that the peak loads imposed on the parts of the airplane by the application of the oscillatory signal are within the limit loads for these parts. Flight guidance systems that contain integral performance envelope limiting cut-out functions may be exempt from this requirement, provided the monitor is demonstrated to have sufficient integrity.

33.7.10.2.2 The investigation may be accomplished largely through analysis with sufficient flight data to verify the analytical studies, or largely through flight tests with analytical studies extending the flight data to the conditions that impose the highest percentage of limit load to the parts.

33.7.10.2.3 When flight tests are conducted in which the signal frequency is continuously swept through a range, the rate of frequency change should be slow enough to permit determination of the amplitude of response of any part under steady frequency oscillation at any critical frequency within the test range.

33.7.10.3 **Climb, Cruise and Descent Flight Regimes.**

33.7.10.3.1 The more critical of the following should be induced into the FGS. If autothrottles are installed, they should be operating, and vertical gyro mechanical failures should not be considered:

1. A signal about any axis equivalent to the cumulative effect of any single failure, including autotrim, if installed.
2. The combined signals about all affected axes, if multiple axis failures can result from the malfunction of any single component.

33.7.10.3.2 Corrective action should not be initiated until three-seconds after the pilot has become aware, either through the behavior of the airplane or a reliable failure warning system, that a malfunction has occurred.

33.7.10.3.3 The simulated failure and the subsequent corrective action should not result in accelerations normal to the flight path below zero g or above 2 g, speeds beyond V_{FC}/M_{FC}, or result in dangerous dynamic conditions or deviations from the flight path. The positive "g" limitation may be increased up to the positive design limit maneuvering load factor, provided adequate analysis and flight test measurements are conducted to establish that no resultant airplane load is beyond limit loads for the structure, including a critical assessment and consideration of the effects of structural loading parameter variations, (i.e., CG, load distribution, control system variations, etc.). Analysis alone may be used to establish that limit loads are not exceeded where the airplane loads are in the linear range of loading, (i.e., aerodynamic coefficients for the flight condition are adequately established and no significant nonlinear air loading exists). If significant nonlinear effects could exist (e.g., buffet loads), flight loads survey measurements may be necessary to substantiate that the limit loads are not exceeded.

33.7.10.3.4 The power or thrust for climb should be the most critical of that used:

- In the performance climb demonstrations;
- In the longitudinal stability tests; or
- For normal operational speeds.

33.7.10.3.5 The altitude loss for the cruise condition is the difference between the observed altitude at the time the malfunction is introduced, and the lowest altitude observed in the recovery maneuver.

33.7.10.4 **Maneuvering Flight.**

33.7.10.4.1 Maneuvering flight tests should include turns with the malfunctions introduced when maximum bank angles for normal operation of the system have been established, and in the critical airplane configuration and stages of flight likely to be encountered when using the automatic pilot.

33.7.10.4.2 A one second delay time following pilot recognition of the malfunction, through the behavior of the airplane or a reliable failure warning system, should be used for maneuvering flight malfunction testing.

33.7.10.4.3 The altitude loss, for maneuvering flight testing, is the difference between the observed altitude at the time the malfunction is introduced, and the lowest altitude observed in the recovery maneuver.

33.7.10.5 **Approach.**

There are two types of approach operations to consider—an approach with vertical path reference and one without vertical path reference. The approach with vertical path reference should be assessed against ground-based criteria using a deviation profile assessment. A height loss assessment should be used for approaches without vertical path reference.

33.7.10.5.1 <u>Fault Demonstration Process.</u>

First determine the worst-case malfunction for each vertical flight path mode that may be used to conduct an approach (e.g., ILS, MLS, GLS, flight management system/RNAV, vertical speed, flight path angle), based on factors such as the following:

- Failure conditions identified by the system safety assessment.
- System characteristics such as variations in authority or monitor operation.
- Mitigation provided by any system alerts.
- Aircraft flight characteristics relevant to failure recognition.

33.7.10.5.2 Once the worst-case malfunction has been determined, flight tests of the worst-case malfunction should be flown in representative conditions (for example, coupled to an ILS), with the malfunction being initiated at a safe height. The pilot should not initiate recovery from the malfunction until one second after the recognition point. The delay is intended to simulate the variability in response to effectively a “hands off” condition. It is expected that the pilot will follow through on the controls until the recovery is initiated.

33.7.10.5.3 Assessment of Approach with Vertical Path Reference.

Figure 33-2 depicts the deviation profile method. The first step is to identify the deviation profile from the worst-case malfunction. The next step is to “slide” the deviation profile down the glidepath, until it is tangential to the 1:29 line or the runway. The failure condition contribution to the minimum use height (MUH)-approach may be determined from the geometry of the airplane wheel height determined by the deviation profile, relative to the 1:29 line intersecting a point 15 feet above the threshold.

Note: The MUH-approach is based on the recovery point for the following reasons: (1) it is assumed that in service the pilot will be “hands off” until the autopilot is disengaged at the MUH in normal operation; (2) the test technique assumes a worst-case based on the pilot being “hands off” from the point of malfunction initiation to the point of recovery; and (3) a failure occurring later in the approach than the point of initiation of the worst-case malfunction described above is therefore assumed to be recovered earlier and in consequence to be less severe.

33.7.10.5.4 Assessment of Approach without Vertical Path Reference.

Figure 33-3 depicts the height loss method. A descent path of 3°, with nominal approach speed, should be used unless the autopilot is to be approved for significantly steeper descents. The vertical height loss is determined by the deviation of the aircraft wheel height relative to the nominal wheel flight path.

Figure 33-2. Deviation Profile Method

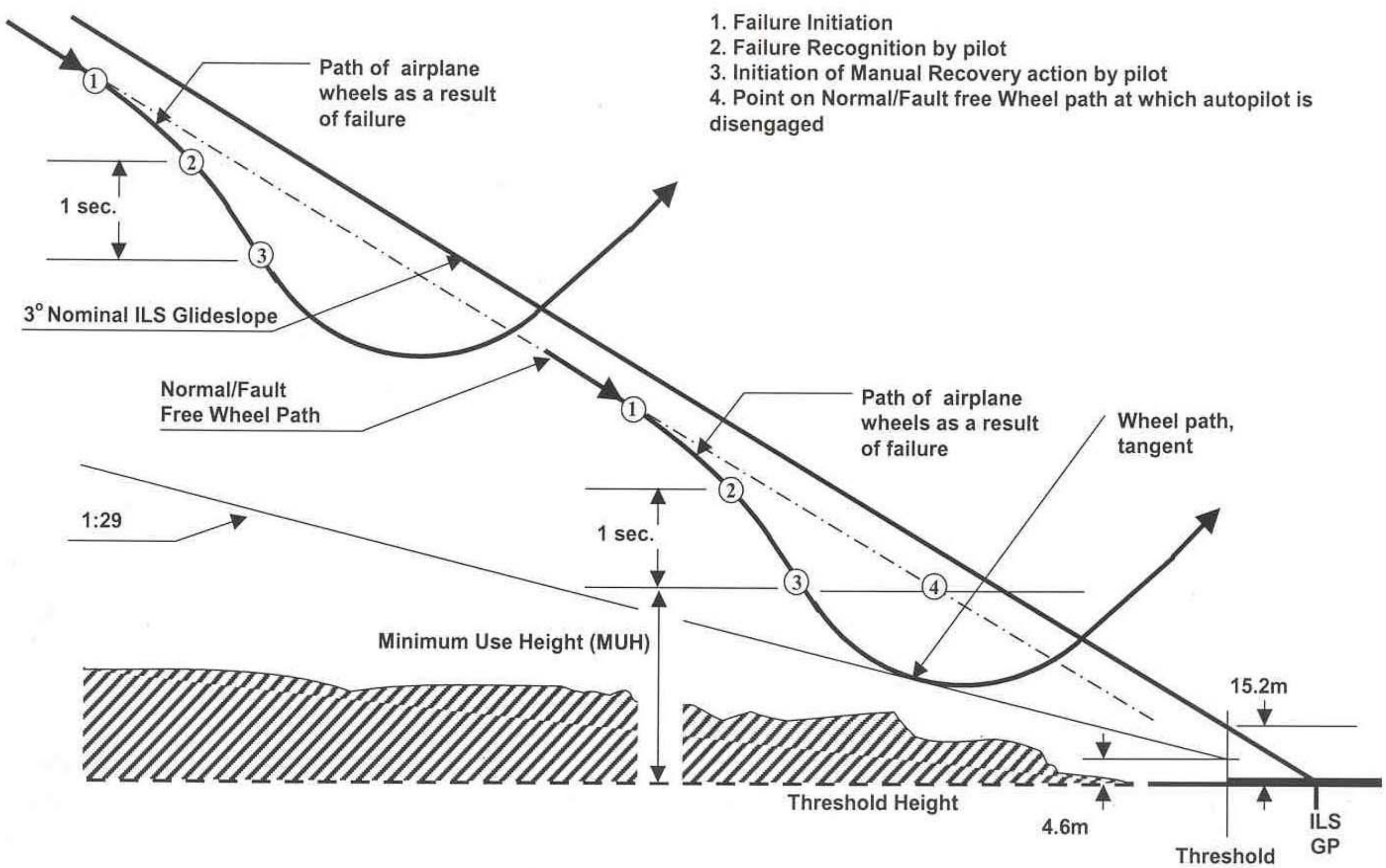
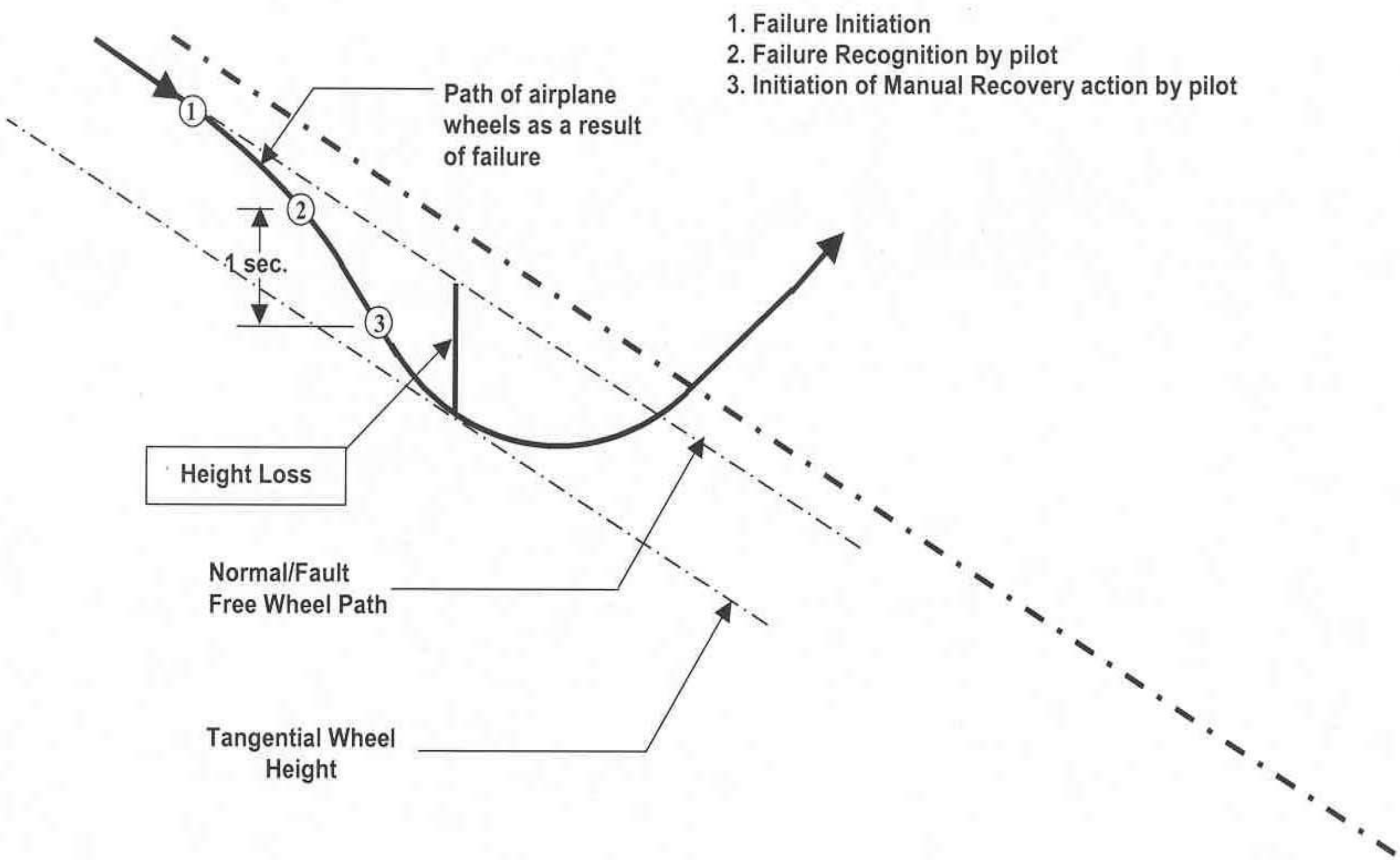


Figure 33-3. Height Loss Method



33.7.10.6 **Autopilot Override.**

33.7.10.6.1 Initial Tests.

The initial tests to demonstrate compliance should be accomplished at an intermediate altitude and airspeed, e.g., 15,000 feet MSL and 250 knots. With the autopilot engaged in Altitude Hold, the pilot should apply a low force to the control wheel (or equivalent) and verify that the automatic trim system does not produce motion resulting in a hazardous condition.

33.7.10.6.2 Automatic Disengagement.

Disengagement caused by flightcrew override should be verified by applying an input on the control wheel (or equivalent) to each axis for which the FGS is designed to disengage, that is, the pitch and roll yoke, or the rudder pedals (if applicable). The pilot should gradually increase the applied force to the control wheel (or equivalent) until the autopilot disengages. When the autopilot disengagement occurs, observe the transient response of the airplane. Verify that the transient response is no more than minor as required by § 25.1329(d). The inputs by the pilot should increase for each test case to a point where the input is sharp and forceful, so that the FGS can immediately be disengaged for the flightcrew to assume manual control of the airplane.

33.7.10.6.3 Non-Automatic Disengagement.

If the autopilot is designed such that it does not automatically disengage during an autopilot override—and instead provides a flight deck alert to mitigate any potentially hazardous conditions—the timeliness and effectiveness of this alert should be evaluated. The pilot should follow the evaluation procedure identified above until such time as an alert is provided. At that time, the pilot should respond to the alert in a responsive manner consistent with the level of the alert (that is, a caution, a warning) and with the appropriate flightcrew procedure defined for that alert. When the autopilot is manually disengaged, observe the transient response of the airplane and verify that the transient response is no more than minor as required by § 25.1329(d).

33.7.10.6.4 Repeated Test Conditions.

After the initial tests have been successfully completed, the above tests should be repeated at higher altitudes and airspeeds until reaching M_{MO} at high cruise altitudes.

33.7.11 Procedures: Airplane Flight Manual Information.

The following information should be provided in the AFM:

33.7.11.1 Operating Limitations Section: Airspeed and other applicable operating limitations for use with the autopilot.

33.7.11.2 Operating Procedures Section: The normal operation information.

33.7.11.3 Non-Normal/Emergency Operating Procedures Section: A statement of the maximum altitude loss experienced during malfunction tests in the cruise and maneuvering flight regimes. A statement of the altitude loss should be provided. Further, it should be stated that a 3-degree glideslope was used, and the altitude loss was measured from the glideslope path to a point where maximum vertical deviation from the glideslope exists.

CHAPTER 34. EQUIPMENT: ELECTRICAL SYSTEMS AND EQUIPMENT

34.1 **General—§ 25.1351.**

34.1.1 Explanation.

Section 25.1351(a) requires that the electrical generating capacity, and number and kinds of power sources, be determined by an electrical load analysis, and meet the requirements of § 25.1309.

34.1.2 Procedures: § 25.1351(a)—Electrical System Capacity.

Section 25.1351(a) requires the generating capacity, and number and kinds of power sources, to be determined by an electrical loads analysis and meet the requirements of § 25.1309. Additionally, verify by flight test that cooling is satisfactory to maintain component temperatures within the manufacturer's limits, both on the ground and in flight, with the electrical system operating at maximum limit load.

34.1.3 Procedures: § 25.1351(b)(1)—Electrical Power Configuration.

34.1.3.1 Verify that electrical power sources function properly when independent and when connected in combination.

34.1.3.2 For airplanes with autoland capability, verify proper electrical power reconfiguration for each available autoland mode.

34.1.3.3 Verify that no hazardous airplane systems reaction occurs, to a partial loss of the electrical distribution system by simulating loss of individual busses. Simulate loss of individual busses by opening circuit breakers/relays.

34.1.3.4 Verify proper transfer of electrical power between the different power sources (i.e., external power, APU, engines).

34.1.4 Procedures: § 25.1351(b)(2)—Failure of Power Source.

Verify proper operation of system during simulated power failures by flight test functional demonstrations. The applicant must show by design analysis or laboratory demonstration, that no failure or malfunction of any power source, including the battery can create a hazard or impair the ability of remaining sources to supply essential loads.

34.1.5 Procedures: § 25.1351(b)(3)—System Voltage and Frequency.

For probable operating conditions, verify that system voltage and frequency, as applicable, at the terminals of all essential load equipment can be maintained within the limits for which the equipment is designed. This may be accomplished in a laboratory environment.

34.1.6 Procedures: § 25.1351(b)(4)—System Transients.

The applicant must show by design analysis, laboratory demonstration, and/or flight demonstration that system transients due to switching, fault clearing, or other causes during normal operations do not make essential loads inoperative, and do not cause a smoke or fire hazard. Flight test recordings may be useful to verify laboratory demonstrations of system transients and electromagnetic interference (EMI) during normal operations.

34.1.7 Procedures: § 25.1351(b)(5)—Power Source Disconnection.

34.1.7.1 Verify that there are means accessible in flight, to the appropriate crewmembers, for the individual and collective disconnection of the electrical power sources from the system.

34.1.7.2 Demonstrate that the airplane can be flown with one less generator than allowed by the MMEL. Also verify that prior to switching off the non-essential electrical loads specified in the AFM, the remaining generators' short-term (up to 5 minutes) capacity is not exceeded.

34.1.8 Procedures: § 25.1351(b)(6)—Power Source Indicators.

34.1.8.1 Verify that there are means to indicate, to the appropriate crewmembers, the generating system quantities essential for the safe operation of the system, such as the voltage and current supplied by each power source, if appropriate to type of aircraft, i.e., glass cockpit design may provide information on multi-function display (MFD), electronic centralized aircraft monitor (ECAM), engine indicating and crew alerting system (EICAS), etc.)

34.1.8.2 Verify proper operation of electrical power system warning, caution, and advisory indications, if any, and that these indications comply with §§ 25.1309(c) and 25.1322.

34.1.9 Procedures: § 25.1351(c)—External Power.

If provisions are made for connecting external power to the airplane, and that external power can be electrically connected to equipment other than that used for engine starting, verify that a means is provided to ensure that no external power supply having a reverse polarity, a reverse phase sequence, overvoltage, or reverse phase/neutral can supply power to the airplane's electrical system. This demonstration may be accomplished in a laboratory environment.

34.1.10 Procedures: § 25.1351(d)—Operation without Normal Electrical Power.

The applicant must demonstrate that the airplane can be operated safely in visual flight rules (VFR) conditions, for a period of not less than five minutes, with the normal electrical power (electrical power sources excluding the battery) inoperative, with critical type fuel (from the standpoint of flameout and restart capability), and with the airplane initially at the maximum certificated altitude.

34.1.11 Procedures: Emergency Electrical Power System.

34.1.11.1 For airplanes with a type certification basis that includes amendment 25-23, the FAA has applied a general policy that following total failure of the electrical power system, if not shown to be extremely improbable, emergency electrical power should be available to power instrument displays, systems, equipment, or parts of the airplane essential for safety of flight during IMC operations for at least 30 minutes. It may also be advisable to check that in the event when normal operation is reestablished following the use of emergency power devices, such devices can withstand, or at least do not adversely affect, the subsequent reversion to "normal" operation.

34.1.11.2 **Thirty-Minute Requirement Test.**

34.1.11.2.1 Accomplish ground and/or flight testing to verify that the main battery/non time-limited power source (e.g., auxiliary power unit (APU), ram air turbine, pneumatic or hydraulic motor, etc.) is sufficient to power the essential loads required for safety of flight during IMC operations for at least 30 minutes. If the emergency power is provided by a non-time-limited power source, the main battery capacity should be sufficient for at least 5 minutes to show compliance with § 25.1351(d). Essential loads for safety of flight during IMC operations are considered to include the following:

- Those essential for continued safe flight and landing during visual meteorological conditions (VMC) operations.
- One display of attitude, direction, airspeed and altitude as specifically stated in § 25.1333(b), a free-air temperature indicator, and pitot/static heat capability, if required.
- Communication, intercommunication, and navigation capability (for IMC operations) necessary cockpit and instrument lighting, and any other instrument displays, systems, equipment, or parts of the airplane that are necessary to safely complete the flight.

34.1.11.2.2 Perform a VMC approach and landing with the airplane powered with emergency electrical power only. Verify acceptable operation of the emergency equipment.

34.1.11.2.3 Perform a simulated night IMC approach and landing with the airplane powered with emergency electrical power only. Verify acceptable visibility and operation of the emergency equipment. This test can be accomplished on a simulator.

34.1.11.3 **Electrical Attitude, Altitude, Direction, and Airspeed Systems Using Battery Standby Power.**

34.1.11.3.1 The FAA has published additional policy that applies to certification of flight instrument installations where: (1) all displays of any of the essential flight information (e.g., altitude, attitude, airspeed, or direction) require electrical power; and (2) the back-up source of electrical power is time-limited. See Policy Statement PS-ANM100-2001-116, "*Policy Statement with respect to All Electrical Attitude, Altitude, Direction and Airspeed Systems using Battery Standby Power*," dated April 27, 2001.

34.1.11.3.2 Flight evaluations of such installations should be used to make sure that all the essential safety related flight instrument parameters are displayed, that the pilots do not have to take any action to display them when normal power is lost, and that the standby display(s) can be effectively used for all flight tasks required for safe flight and landing.

34.2 Electrical Equipment and Installations—§ 25.1353. [Reserved]

34.3 Distribution System—§ 25.1355.

34.3.1 Explanation.

Section 25.1355(a) defines the distribution system, including the distribution busses, their associated feeders, and each control and protective device.

34.3.2 Procedures: Section 25.1355(c)—Independent Power Sources.

For equipment or systems that are required to have two independent sources of electrical power, verify by airplane demonstration that in the event of a failure of one power source for such equipment or system, another power source (including its separate feeder) is automatically provided or can be manually selected to maintain equipment or system operation.

34.4 Circuit Protective Devices—§ 25.1357.

34.4.1 Explanation.

If the ability to reset a circuit breaker or replace a fuse is essential to safety in flight, § 25.1357(d) requires that the applicant locate and identify the circuit breaker (this includes solid state circuit breakers) or fuse so that the flightcrew can readily reset or replace them in flight. For airplane systems for which the ability to remove or reset power during normal operations is necessary, § 25.1357(f) requires that the applicant design the system so that circuit breakers are not the primary means to remove or reset power during normal operations unless the circuit breaker is specifically designed for use as a switch.

34.4.2 Reference.

See AC 25.1357-1A for additional guidance.

34.4.3 Procedures.

34.4.3.1 For compliance with § 25.1357(d), AC 25.1357-1A defines a circuit protective device (e.g., a circuit breaker or fuse) as essential to safety in flight if its disconnection would result in a major, hazardous, or catastrophic failure condition using the definitions of failure condition classifications according to that AC. AC 25.1357-1A also states that an "accessible" circuit protective device is one that a flightcrew member can readily reset or replace without leaving his or her seat, and that is the intent of the rule.

34.4.3.2 For compliance with § 25.1357(f), the applicant should evaluate procedures for normal operation to ensure they do not call for using circuit protective devices as the means to remove or reset system power unless the device is specifically designed for use as a switch.

34.4.3.3 The applicant should minimize the use of non-normal or emergency procedures involving flightcrew use of circuit breakers. Non-normal or emergency procedures should not call for pulling circuit breakers or resetting or replacing circuit protective devices in flight, except as part of an approved fault-clearing and isolation procedure. The applicant should evaluate, during ground and/or flight tests, the location and identification of circuit protective devices whose actuation is called for in non-normal or emergency procedures to confirm their accessibility as part of the review and approval of those procedures.

34.5 Electrical System Tests—§ 25.1363.

34.5.1 Explanation.

Laboratory tests are conducted to verify that the control, regulation, protection, and automatic operation of the electrical system comply with §§ 25.1351 through 25.1357. Laboratory tests must be conducted on a mockup using the same type and length of feeder wires, and generating equipment that will be installed in the airplane. Additionally, the generator drives must simulate the actual prime movers on the airplane with respect to their reaction to generator loading, including loading due to faults. Section 25.1363(b) states that for each flight condition that cannot be adequately simulated in the laboratory or by ground tests on the airplane, a flight test must be conducted.

34.5.2 Procedures: Negative Acceleration Performance.

Verify that no hazardous malfunctions of the electrical power system occur when the airplane is operated at the negative accelerations within the flight envelope prescribed in § 25.333. This should be shown for the greatest duration expected for the acceleration.

This test is normally conducted in conjunction with the engine negative acceleration test to comply with § 25.943.

CHAPTER 35. EQUIPMENT: LIGHTS

35.1 **Instrument Lights—§ 25.1381.**

35.1.1 Explanation.

None.

35.1.2 Procedure.

Under actual or simulated nighttime conditions, evaluate instrument lighting for the following characteristics:

35.1.2.1 Illumination of adequate intensity is provided for all appropriate cockpit instruments/controls/equipment.

35.1.2.2 Illumination is of appropriate color, intensity is evenly distributed, and is free of objectionable flicker, glare, or reflection.

35.1.2.3 Dimming capability allows smoothly adjustable illumination intensity between appropriate limits.

35.2 **Landing Lights—§ 25.1383.**

35.2.1 Explanation.

None.

35.2.2 Procedure.

The landing lights should be evaluated to determine that they are:

35.2.2.1 Aimed properly, provide sufficient intensity to facilitate night landings, and are acceptable at different pitch attitudes during landing approach with various CG, flap settings and airspeed;

35.2.2.2 Not a source of objectionable glare or halation; and

35.2.2.3 Functional in MMEL configurations and during operations in adverse weather.

35.3 **Position Light System Installation—§ 25.1385.**

35.3.1 Explanation.

Section 25.1385(a) requires the position light system to comply with detailed technical specifications contained in §§ 25.1387 through 25.1397. These sections define location, color, visibility, and intensity requirements with considerable precision. An in depth examination of the installed position light system with regard to these requirements is not necessarily considered appropriate or within the scope of a flight test evaluation, unless it becomes apparent while accomplishing the following procedures that further examination is warranted.

35.3.2 Procedures.

35.3.2.1 Operate the position light system. Verify that general locations and color are as prescribed in § 25.1385(b) and (c).

35.3.2.2 Verify that position light illumination does not cause objectionable glare to the flightcrew.

35.4 Anti-Collision Light System—§ 25.1401.

35.4.1 Explanation.

35.4.1.1 Section 25.1401(a)(2) requires the anti-collision light system to comply with the detailed specifications contained in § 25.1401(b) through (f). These sections define coverage, color, flash rate, and intensity requirements with some precision. An in depth examination of the installed anti-collision system, with regard to all of these requirements, is not necessarily considered appropriate or within the scope of a flight test evaluation, unless it becomes apparent while accomplishing the following procedures that further examination is warranted.

35.4.1.2 Policy statement ANM-111-06-001, *Modifications Which Impact Airplane Exterior Lighting*, dated May 14, 2007, specifies that applicants need to perform an analysis for airplane modifications involving external antenna installations in order to evaluate compliance to § 25.1401. The analysis should include an evaluation of the impact of the new installation on the anti-collision light system and its associated master minimum equipment list (MMEL) dispatch relief.

35.4.2 Procedures.

35.4.2.1 Operate the anti-collision light system. Verify that one or more red or white lights are installed in locations that appear to provide the required visibility and which flash at the appropriate rates.

35.4.2.2 Verify that the anti-collision lights are not a source of objectionable glare or halation, to the flightcrew.

35.4.2.3 Evaluate anti-collision lights during flight in clouds.

35.5 Wing Icing Detection Lights—§ 25.1403.

35.5.1 Explanation.

If the airplane is intended to be certificated for night flight into known icing conditions, a means for visually or otherwise determining the extent of icing on critical surfaces must be provided.

35.5.2 Procedures.

35.5.2.1 The wing icing detection lights, if required, should be evaluated to determine that they:

35.5.2.2 Are aimed properly toward the appropriate surfaces, and are of sufficient intensity for required illumination.

35.5.2.3 Are not a source of objectionable glare, reflection, or halation.

CHAPTER 36. SAFETY EQUIPMENT [RESERVED]

CHAPTER 37. MISCELLANEOUS EQUIPMENT

37.1 Electronic Equipment—§ 25.1431.

37.1.1 Explanation.

Section 25.1431(d) requires verification that any electronic equipment will not cause essential loads to become inoperative as a result of electrical power supply transients or transients from other causes. Although this requirement explicitly addresses electrical power supply transients, this requirement is also implicit in other part 25 requirements, specifically:

37.1.1.1 Section 25.1310(a) (Power source capacity and distribution), which states that each installation whose functioning is required and that requires a power supply is considered an "essential load" on the power supply. It requires that the power sources and the system be able to continue to supply power loads under probable critical operating combinations and for probable durations;

37.1.1.2 Section 25.1351(b) (Electrical systems and equipment—General), which requires that electrical generating systems be designed so that no failure or malfunction of any power source can create a hazard or impair the ability of remaining sources to supply essential loads; and

37.1.1.3 Section 25.1353(a) (Electrical equipment and installations), which requires that electrical equipment and controls be installed so that operation of any one unit or system of units will not adversely affect the simultaneous operation of any other electrical unit or system essential to safe operation.

37.1.2 Procedures.

37.1.2.1 Evaluate the possibility of interaction between different systems of communications and navigation equipment. Momentary deflection or flicker can be permitted if it does not result in any deviation to the aircraft flight path when flying a coupled navigation mode. (Flicker frequencies above 55 Hertz for stroke symbology or non-interlaced raster and 30/60 Hertz for interlaced raster are generally satisfactory.) Loss of required function of the usable and assigned frequencies in the national airspace system should be considered unacceptable.

37.1.2.2 Equipment sensitivity to a variety of transient signal conditions is accomplished during laboratory environmental testing (usually accomplished per the methods contained in RTCA Document No. RTCA/DO-160). However, equipment sensitivity to normal airplane systems electrical transients should be evaluated during flight testing. This can be accomplished by observing the operation of flight essential equipment while:

37.1.2.2.1 Reconfiguring the electrical generating and distributing system (e.g., opening/closing bus-tie breakers, supplying the various electrical busses with other source of power, e.g., right main bus from left integrated drive generator, etc.).

37.1.2.2.2 Switching on/off high current demand systems such as galley ovens, hydraulic pumps, cabin lighting, in-flight entertainment systems, power supply systems for portable electronic devices, seat actuators, and

37.1.2.2.3 Any other high-current airplane system that would normally be operated during flight.

37.2 Equipment Standards for Oxygen Dispensing Units—§ 25.1447.

37.2.1 Explanation.

37.2.1.1 Section 25.1447(c)(2)(i) requires that each flightcrew member be provided with an oxygen dispensing unit that can be taken from its ready position and placed on the face using one hand, properly secured, sealed, and supplying oxygen upon demand within five seconds without disturbing eyeglasses or causing delay in accomplishing emergency duties.

37.2.1.2 Showing compliance with this rule involves measuring human performance, which is inherently variable. In order to take variations in human performance into account, multiple tests of donning each oxygen mask should be conducted. In determining whether compliance has been shown, it is important to consider both the average mask donning time and the variation in donning times as noted below:

37.2.1.2.1 The average time to don the mask should indicate that the 5-second requirement is met.

37.2.1.2.2 Even if the average donning time is five seconds or less, it may take longer than 5 seconds to don the mask for 50 percent or more of the tests. Therefore, it is also important to establish a criterion regarding the distribution of test results in order to ensure that the mask can be consistently donned within five seconds.

37.2.2 Procedures.

37.2.2.1 A donning test should be conducted from each required flight crewmember station whenever the oxygen mask, storage location, or means of stowing the mask is established or changed. Each donning test should consist of at least five donning events. The donning tests may be conducted in an airplane, a simulator, or a flight deck mockup that accurately reflects the proposed design.

37.2.2.2 The test should be witnessed by an FAA or designated engineering representative (DER) test pilot. It is acceptable, but not required, to use appropriately qualified flight crewmembers as test subjects.

37.2.2.3 Prior to starting each mask-donning event at each pilot station, the pilot should be seated at the design eye reference position with the seat belt and shoulder harness fastened. One hand should be on the control wheel and the other on the throttles. For other flight crewmember duty positions (e.g., flight engineer), appropriate seating and hand positions may be determined on a case-by-case basis. Either hand may be used to don the mask.

37.2.2.4 Since § 25.1447(c)(2)(i) requires the five second donning criterion to be met without disturbing eyeglasses, the test subjects must wear glasses during the test. Daytime lighting conditions may be used, unless flight deck arrangement and lighting systems suggest that locating and retrieving the mask may be difficult in nighttime lighting conditions.

37.2.2.5 Timing should begin when the start of the test event is announced by the test director, and end when the mask is properly sealed on the pilot’s face with eyeglasses in place. The method of initiating the test event and determining when the mask is sealed is at the discretion of the test participants. A stopwatch, or other means shown to be reasonably accurate, may be used to time the tests.

37.2.2.6 For each donning test:

37.2.2.6.1 At least 80 percent of the donning events should be completed in 5 seconds or less.

37.2.2.6.2 The average time for each donning test should be five seconds or less.

CHAPTER 38. OPERATING LIMITATIONS AND INFORMATION: GENERAL [RESERVED]

CHAPTER 39. OPERATING LIMITATIONS AND INFORMATION: OPERATING LIMITATIONS [RESERVED]

CHAPTER 40. OPERATING LIMITATIONS AND INFORMATION: MARKINGS AND PLACARDS [RESERVED]

CHAPTER 41. OPERATING LIMITATIONS AND INFORMATION: AIRPLANE FLIGHT MANUAL

41.1 General—§ 25.1581.

41.1.1 Explanation.

The primary purpose of the AFM is to provide an authoritative source of information considered to be necessary for safe operation of the airplane. Since the flightcrew is most directly concerned with operation of the airplane, the language and presentation of the flight manual should be directed principally to the needs and convenience of the flightcrew, but should not ignore the needs of other contributors to safe operation of the airplane in accordance with the applicable operating regulations.

41.1.1.1 Section 25.1501 requires that the operating limitations specified in §§ 25.1503 through 25.1533, and other information necessary for safe operation, be included in the AFM, be expressed in markings and placards, and also be made available by any other means that will convey the necessary information to the crew members.

41.1.1.2 Information and data that are mandatory for an acceptable AFM are prescribed in §§ 25.1581 through 25.1587. The material required by 14 CFR parts 25 and 36 must be included in the AFM. At the option of the applicant, the AFM may be expanded to contain additional FAA approved information.

41.1.1.3 The manufacturer or operator may include other “unapproved” data in a separate and distinctively identified portion of the AFM.

41.1.2 Reference.

See AC 25.1581-1, Change 1, for detailed guidance on the required content and general structure of the AFM.

41.2 [Reserved.]

CHAPTER 42. AIRWORTHINESS: MISCELLANEOUS ITEMS

42.1 Design and Function of Artificial Stall Warning and Identification Systems.

42.1.1 Applicable Regulations.

Sections 25.103, 25.201, 25.203, and 25.207.

42.1.2 Explanation.

Some airplanes require artificial stall warning systems to compensate for a lack of clearly identifiable natural aerodynamic stall warning to show compliance with the stall warning requirements of § 25.207. A stick shaker is a recommended method of providing such a warning, regardless of whether or not the natural aerodynamic stall warning is clearly identifiable. Similarly, some airplanes require a stall identification device or system (e.g., stick pusher,) to compensate for an inability to meet the stalling definitions of § 25.201 or the stall characteristics requirements of § 25.203. In addition to compliance with the flight test requirements prescribed in paragraph 8.1 of this AC, certain system design and function criteria should also be addressed during the certification process of these airplanes. Included are system arming and disarming, preflight checks, failure indications and warnings, and system reliability and safety. The reliability of these systems can be evaluated in terms of the probability of the system not operating when required, and the safety aspects in terms of the probability of the system operating inadvertently. The required reliability and safety of stall warning and identification systems should be defined as a function of how critical their respective functioning is to safety of flight.

42.1.3 Arming and Disarming.

42.1.3.1 Stall warning systems should be armed any time the airplane is in flight (i.e. from main gear liftoff to touchdown). However, up to the end of the takeoff rotation (i.e., until the takeoff pitch attitude is attained), any phase advance feature of the stall warning system (i.e., the portion of the algorithm for activating the stall warning system that responds to the rate of change in angle-of-attack) can be inhibited.

42.1.3.1.1 Arming of stall warning systems has typically been accomplished by a ground/air logic circuit, which requires the nose and/or main gear squat switches to sense air mode before the system is armed. A pitch angle threshold during rotation has also been used to arm the stall warning system. These types of system arming schemes provide stall warning protection during liftoff and initial climb, where a stall would most probably have catastrophic consequences. They also provide protection against nuisance warnings during the takeoff roll, where the angle-of-attack (AOA) sensor vanes may be misaligned. Service history, however, has shown that systems armed around the liftoff point have caused pilots to abort takeoffs due to false alerts resulting from stall warning system faults or failures. In some cases, these high-energy rejected takeoffs have resulted in overruns. Therefore, system faults and failures that would lead to a false stall warning near liftoff should be made evident as early in the takeoff as practicable.

42.1.3.1.2 In accordance with the requirements of § 25.207(b), if a stall warning system is required for any normal combination of flap and landing gear position, it must be used for all combinations of flap and landing gear positions. The purpose of this requirement is to provide a standard, consistent warning to the flightcrew of an operational flight envelope limit.

42.1.3.2 Stall identification systems should be armed any time the airplane is in flight.

42.1.3.2.1 The arming should take place automatically and may be provided by the same ground/air sensing system used for arming the stall warning system. The stall identification system may be inhibited during the takeoff rotation, but should become functional immediately after main gear liftoff. For airplanes with both stall warning and stall identification systems, it is permissible to have the stall identification system armed by operation of the stall warning system, provided the resulting probability of the stall identification not to operate when required is not greater than that specified in paragraph 42.1.5 below.

42.1.3.2.2 Stall identification systems may incorporate automatic disarming in flight regimes where the risk of stalling is extremely remote or where their unwanted operation would pose a threat to continued safe flight; examples of such inhibits would be high airspeed, and “g” cutouts (typically 0.5 g), and while the pilot is following windshear recovery flight director guidance.

42.1.3.2.3 A means to quickly deactivate the stall identification system should be provided and be available to both pilots. It should be effective at all times, and should be capable of preventing the system from making any input to the longitudinal control system. It should also be capable of canceling any input that has already been applied, from either normal operation or from a failure condition.

42.1.3.2.4 If a stall identification system is required to show compliance with the stall requirements of part 25 in one (or some) airplane configuration(s), it does not have to be used for stall identification in configurations where compliance can be demonstrated without it. Unlike stall warning, the stall point, be it aerodynamic or artificially induced, represents an end-point outside the in-service operational envelope of the airplane, and, therefore, does not need to be provided by the same means for all flap and landing gear configurations. Additionally, the added system complexity, and increased exposure to malfunctions and failures, would not warrant the use of a stall identification system for configurations where it is not required.

42.1.4 Indicating and Warning Devices.

42.1.4.1 A method should be provided to allow the pilot to determine that the stall warning and stall identification systems are operating properly prior to takeoff. This method should be described in the operating procedures section of the AFM.

42.1.4.2 Warning that the associated systems for operating the stall warning or stall identification devices has failed should be provided. As far as is practicable, this warning should cover all system failure modes.

42.1.4.3 A clear and distinctive cockpit indication should be given when the stall identification system has been deactivated by the flightcrew (see paragraph 42.1.3.2.3 above). This indication should be present as long as the system is deactivated.

42.1.4.4 Any related limitations, and normal and emergency operating procedures, together with any information found necessary for safety during operation of the stall warning and identification systems, should be included in the AFM and supplemented by such markings and placards as deemed necessary.

42.1.5 System Reliability and Safety.

When stall warning and/or stall identification systems are installed to show compliance with the stalling requirements of §§ 25.201, 25.203, and 25.207, engineering data should be supplied to satisfy the following criteria, determined in accordance with § 25.1309.

42.1.5.1 **Reliability.**

Probability of artificial stall warning and stall identification systems not operating when required:

42.1.5.1.1 If stall warning is not clearly identifiable by natural characteristics, the loss of artificial stall warning should be improbable (not greater than 10^{-5} per flight hour). This reliability requirement is normally met by using dual, independent stall warning systems.

42.1.5.1.2 If the natural stall characteristics are unacceptable, the combination of failure of the stall identification system to operate and entry into a stall should be extremely improbable (not greater than 10^{-9} per flight hour). A stall identification system with a failure rate not greater than 10^{-4} per flight hour will satisfy this requirement.

42.1.5.1.3 If the stall identification system is installed solely for the purposes of identifying the stall, and the stall characteristics would otherwise meet the requirements of Subpart B with the stall identification system disabled, a maximum failure rate of 10^{-3} per flight hour will be acceptable.

42.1.5.2 **Safety.**

Probability of artificial stall warning and stall identification systems operating inadvertently:

42.1.5.2.1 The probability of inadvertent operation of artificial stall warning systems, during critical phases of flight, should not be greater than 10^{-5} per flight hour.

42.1.5.2.2 To ensure that inadvertent operation of the stall identification system does not jeopardize safe flight, and to maintain crew confidence in the system, it should be shown that:

- No single failure will result in inadvertent operation of the stall identification system; and
- The probability of inadvertent operation from all causes is improbable (not greater than 10^{-5} per flight hour).

42.1.5.2.3 Stall identification systems should be designed so that flight in turbulence will not result in inadvertent operation.

Note: In making the assessments of paragraphs 42.1.5.2.4, 42.1.5.2.5, and 42.1.5.2.6 below, it should be assumed that in the climb, cruise, and descent flight regimes, corrective pilot action will not be initiated until three seconds after unwanted operation has been recognized. During takeoff and final approach, this time delay may be reduced to one second.

42.1.5.2.4 If inadvertent operation of the stall identification system would result in limit loads being exceeded in any part of the airplane structure, the probability of inadvertent operation should not be greater than 10^{-7} per flight hour.

42.1.5.2.5 If inadvertent operation of the stall identification system would result in ultimate loads being exceeded in any part of the airplane structure, the probability of inadvertent operation should be extremely improbable (not greater than 10^{-9} per flight hour).

42.1.5.2.6 Inadvertent operation of the stall identification system should not cause catastrophic ground contact. This should be achieved by limiting the effect of the stall identification system to that necessary for stall identification purposes, without undue flight path deviation (e.g., by limiting the stroke of a stick pusher). Alternatively, if inadvertent operation could result in catastrophic ground contact according to § 25.1309(b)(1), the probability of inadvertent operation must be extremely improbable. Inhibition of the system close to the ground (e.g., for a fixed time after liftoff or below a radar altitude) would not normally be an acceptable means of compliance with this requirement.

42.1.6 System Functional Requirements.

42.1.6.1 Operation of the stall identification system should reduce the airplane's angle-of-attack far enough below the point for its activation that inadvertent return to the stall angle-of-attack is unlikely.

42.1.6.2 The characteristics of stall identification systems, which by design are intended to apply an abrupt nose-down control input (e.g., a stick pusher), should make it unlikely that a flightcrew member will prevent or delay its operation. The required stick force, rate of application, and stick travel will depend on the airplane's stall and stick force characteristics, but a force of 50 to 80 lbs applied virtually instantaneously has previously been accepted as providing this characteristic.

42.1.6.3 Normal operation of the stall identification system should not result in the total normal acceleration of the airplane becoming negative.

42.1.6.4 The longitudinal maneuvering capability of an airplane equipped with stall identification systems, at all speeds likely to be encountered in normal operations, should be substantially the same as would be expected for an airplane with acceptable aerodynamic stall characteristics.

42.1.7 System Tolerances.

See paragraph 8.1.9 for additional considerations regarding compliance with stall-related regulatory requirements, including how to address tolerances for stall speed (§ 25.103) and stall characteristics (§ 25.203) testing. See paragraph 8.1.6.2.6 for how to address tolerances of the stall warning and stall identification systems during testing to show compliance with the stall warning requirements (§ 25.207).

42.2 Reduced and Derated Power or Thrust Takeoff Operations.

42.2.1 Explanation.

The use of derated and reduced power or thrust for takeoff operations can produce substantial reductions in operating costs due to lower fuel consumption and increased operating margins. With the appropriate limitations and operating procedures applied, these operations can also offer safety benefits. Three methods have been approved by the FAA for derated and reduced power or thrust takeoff operations. These methods are as follows:

42.2.1.1 Derated power or thrust approvals entail the use of completely new takeoff power or thrust setting charts and AFM performance information. The new power or thrust settings are less than the engine manufacturer's approved takeoff power or thrust settings, and the AFM performance is based on the power or thrust developed at these new, lower power or thrust settings.

42.2.1.2 A constant reduced power or thrust increment can be used for all operating conditions. In this method the engine parameter by which power or thrust is set is reduced by a constant, such as an engine pressure ratio increment (ΔEPR) of 0.02. A method is supplied to determine the airplane's takeoff performance, at this reduced power or thrust level, from the AFM data representative of full takeoff power or thrust.

42.2.1.3 The assumed temperature method of reduced power or thrust takeoff operations entails using takeoff performance information determined for an "assumed" temperature above ambient, but not above the temperature at which the takeoff weight would be limited by the takeoff field length available for a particular airport runway or by FAA climb requirements. Engine power or thrust settings, takeoff speed schedules, takeoff field lengths, and climb performance are determined at the assumed temperature. This assumed temperature method is the most flexible in its application and the most widely used by transport category airplane manufacturers and operators.

42.2.2 Procedures.

Because there is a reduction in the takeoff performance level when any of the derated or reduced power or thrust methods are used, the FAA has certain limitations on the use of these reduced power or thrust levels. The appropriate guidance for derated and reduced power or thrust approvals, including limitations and procedures, is presented in AC 25-13.

42.3 Runway Gradients Greater than ±2 Percent.

42.3.1 Applicable Regulations.

Sections 25.105, 25.115, 25.119, 25.121, 25.125, 25.1533, and 25.1587.

42.3.2 Explanation.

The sections of part 25, referenced above, require accounting for the effects of runway gradient. Typically, performance limitations and information are determined for runway gradients up to ±2 percent in the AFM expansion of test data. Though these gradient extremes are adequate for addressing the majority of runways, there are a number of airports frequented by transport category airplanes that have runway slopes greater than ±2 percent. Consequently, approvals have been granted for operations on runways with slopes exceeding ±2 percent with specific testing and analysis validation for the effects of the higher slopes. Additional concerns, beyond runway slope effect on acceleration and braking and proper accounting of elevations during obstacle clearance analysis, include takeoff flare from liftoff to 35 feet, minimum takeoff climb gradients, minimum approach and landing climb gradients, landing flare distances, and unique operating procedures.

42.3.3 Procedures.

42.3.3.1 **Takeoff Flare from Liftoff to 35 Feet.**

The AFM expansion of the takeoff data should account for the effect of the runway slope on the portion of the takeoff distance after liftoff. At climb performance-limiting thrust-to-weight ratios, the average gradient of climb will be on the order of 2.0 to 3.0 percent. On a downhill runway of sufficient magnitude, the airplane could attain a height of 35 feet above the runway and have a positive gradient of climb relative to it, but its flight path may continue to descend beyond that point. The transition from liftoff to climbing flight, in the sense of an ascending flight path, should be adequately addressed with respect to obstacle clearance analysis data.

42.3.3.2 **Minimum Takeoff Climb Gradients.**

At limiting thrust-to-weight ratios, the transition to free air (i.e., out of ground effect) takeoff climb could result in steep uphill runways rising faster than the airplane’s ability to climb. The minimum second segment takeoff climb gradient should maintain the same margin, relative to the increased maximum uphill runway slope, that exists between the minimum gradient specified in § 25.121 and a two percent uphill runway.

42.3.3.3 **Minimum Approach and Landing Climb Gradients.**

Balked landing go-arounds, at climb limited landing weights, could also result in an uphill runway rising faster than the airplane’s ability to climb. The minimum approach and landing climb gradients should maintain the same margins, relative to the increased maximum uphill runway slope, that exist between the minimum gradients specified in §§ 25.119 and 25.121 and a two percent uphill runway.

42.3.3.4 **Landing Technique and Distance.**

Final approaches to steep uphill runways will require early flare initiation, to avoid hard landings, and landing flare air distances will be increased for approaches to steep downhill runways using normal approach descent angles. The AFM operating procedures should describe any special piloting technique required for landing on steep runways. The AFM expansion of landing distances should account for the effect of runway gradient, including any expected increase in flare distances, from 50 feet to touchdown, for steep downhill runways.

42.3.3.5 **Operating Procedures.**

Operating procedures should be provided in the AFM for operations on runways with gradients greater than ±2 percent. Guidance should be provided on takeoff rotation and landing flare techniques.

42.3.3.6 **Operational Considerations.**

For runway slopes greater than ±3 percent, the specific airport(s) should be investigated relative to runway lengths and surrounding terrain and obstacles. Airport-specific operating limitations may be necessary, such as: direction of takeoff and landing, takeoff flap restrictions, prohibition of overspeed takeoffs on downhill runways, requirement for the anti-skid system to be operative and on, and restrictions on engine bleed air and power extraction.

42.3.3.7 **Flight Test Requirements.**

For approval of certification data for runway slopes exceeding ±3 percent, operational flight tests should be conducted to verify the proposed procedures and performance information.

42.4 Criteria for Approval of Steep Approach to Landing.

42.4.1 <u>Applicable Regulations.</u>

Sections 25.119, 25.121, 25.125, and 25.143.

42.4.2 <u>Explanation.</u>

42.4.2.1 **Airworthiness Approval.**

The standard approach angle assumed as part of the type certification of transport category airplanes is 3°, which coincides with the nominal ILS approach angle. Those evaluations are considered adequate to address approach angles of less than 4.5°. The criteria listed below represent FAA policy for airworthiness approval of steep approach landing capability using an approach angle of 4.5° or more. Additions or deletions to these criteria may be needed to address specific design features. It should be noted in the AFM that the presentation of the steep approach limitations, procedures, and performance information reflects the capability of the airplane to perform steep approaches, but does not constitute operational approval.

42.4.2.2 **Operational Approval.**

Operational approval to conduct steep approaches in the United States is the exclusive responsibility of FAA Flight Standards Service, and cannot be delegated to FAA Aircraft Certification Service employees, designees, or to foreign civil aviation authorities. FAA Flight Standards Service has assigned this responsibility to the Flight Standardization Board (FSB) with oversight for the airplane type in question. Operational approval will, in part, be based on the results of the airworthiness testing described in this section. Additional testing, for operational concerns, may be combined with the airworthiness testing. Ideally, the testing for operational approval would be conducted by the Flight Standardization Board during the test program for airworthiness certification of steep approach capability.

42.4.3 General Criteria.

42.4.3.1 If approval is sought to conduct steep approaches in icing conditions, compliance with the part 25 requirements applicable to steep approach operations identified below should also be shown for icing conditions.

42.4.3.2 The following criteria apply when showing compliance with § 25.125 for steep approaches:

42.4.3.2.1 The airplane should be in the landing configuration used for steep approaches.

42.4.3.2.2 Compliance with the requirement that a stable approach be conducted to a height of 50 feet with a speed not less than V_{REF} (§ 25.125(b)(2)) should be shown with an approach path angle not exceeding the maximum for which approval is sought. The V_{REF} used for steep approaches may be different than the V_{REF} used for normal approaches.

42.4.3.2.3 If the parametric method of determining the landing distance is used (see paragraph 4.11.2.3 of this AC), approach angles should be appropriate to the steep approach path angle desired, and the touchdown sink rate for data expansion should be limited to 6 feet per second.

42.4.3.3 The landing distance established under § 25.125(a) begins at a point 50 feet above the landing surface. If an applicant proposes to use a different height for the beginning of the steep approach landing distance, this must be done through an equivalent level of safety finding, in accordance with § 21.21(b)(1), or an exemption, in accordance with part 11. This has been done in some steep approach certifications to take advantage of precision approach guidance at an airport that guides the airplane to a height over the runway threshold of less than 50 feet.

42.4.3.4 Compliance with §§ 25.119 and 25.121(d) should be shown using the configurations and speeds established for steep approach operations.

42.4.4 Test Conditions for Reasonably Expected Variations in Approach Speed and Path Angle.

The following additional criteria should be applied to show that the airplane is safely controllable and maneuverable during landing (§ 25.143(a)(5)):

42.4.4.1 Under calm air conditions, demonstrate that it is possible to complete an approach, touchdown, and stop without displaying any hazardous characteristics in the following conditions:

42.4.4.1.1 An approach path angle 2° steeper than the steepest approach path angle for which approval is sought at the V_{REF} established for a steep approach; and

42.4.4.1.2 The steepest approach path angle for which approval is sought at a speed 5 knots lower than the V_{REF} established for a steep approach.

42.4.4.2 For both conditions in paragraphs 42.4.4.1.1 and 42.4.4.1.2 above:

42.4.4.2.1 The airplane should be loaded to the most critical weight and CG combination;

42.4.4.2.2 The airplane should be in the steep approach configuration;

42.4.4.2.3 The rate of descent should be reduced to no more than 3 feet per second at touchdown;

42.4.4.2.4 Below a height of 200 feet, no action should be taken by the pilot to increase power or thrust, apart from those small changes needed to maintain an accurate approach;

42.4.4.2.5 After initiating the flare, the longitudinal control should not be used to depress the nose apart from those small changes necessary to maintain a continuous and consistent flare flight path;

42.4.4.2.6 The flare, touchdown, and landing should not require exceptional piloting skill, alertness, or strength; and

42.4.4.2.7 To ensure adequate capability for a go-around or down path adjustment, the engines should remain above flight idle power or thrust when stabilized on the approach path.

Note: The 2° steeper approach path angle demonstration is to account for tailwinds on the approach and to take into account necessary corrections back to the desired approach path after inadvertent excursions. The purpose of the test at V_{REF} minus 5 knots is to account for an unnoticed speed decrease during the approach, hence the requirement in paragraph 42.4.4.2.4 for no power or thrust increase to account for the slower speed.

42.4.4.3 For flight test safety reasons, when conducting the 2° steeper approach path angle test condition of paragraph 42.4.4.1.1, the pilot may begin to flare the airplane (or reduce the approach angle) at a reasonable height somewhat higher than the normal steep approach flare height. If this is done, it should be shown by analysis that there is sufficient pitch control to arrest the descent rate if the flare were to be initiated at the normal steep approach flare height, keeping in mind the criteria in paragraphs 42.4.4.2.3 and 42.4.4.2.6.

42.4.4.4 Compliance with § 25.143(b)(1) should be assessed as follows: Demonstrate that the airplane can both safely land and safely transition to a go-around following a failure of the critical engine at any point in the approach under the following conditions:

42.4.4.4.1 The steepest approach angle for which approval is sought;

42.4.4.4.2 The V_{REF} established for a steep approach; and

42.4.4.4.3 The most critical combination of weight and CG; and

42.4.4.4.4 For propeller powered airplanes, the propeller of the inoperative engine should be in the position it would normally assume without any action taken by the pilot following an engine failure.

42.4.4.5 The height loss experienced during the maneuver described in paragraph 42.4.4.3 should be determined.

42.4.5 One-Engine-Inoperative Steep Approach.

If approval is sought for one-engine-inoperative steep approach capability, the following criteria should be met at the most critical weight and CG position, using the configuration and speed established for a one-engine-inoperative steep approach:

42.4.5.1 The demonstrations identified in paragraph 42.4.4 above; and

42.4.5.2 Demonstrate that the airplane can safely transition to a go-around during a one-engine-inoperative steep approach.

42.4.6 Airplane Flight Manual.

In accordance with §§ 25.1581, 25.1583, 25.1585, and 25.1587, the following information must be provided in the AFM:

42.4.6.1 Limitations, operating procedures, and performance information necessary for steep approach operations, including the configuration(s), speeds and flight path angle(s) approved for conducting a steep approach; and

42.4.6.2 Operating limitations prohibiting initiation of a steep approach:

42.4.6.2.1 With one engine inoperative, unless the airplane is approved for one-engine-inoperative steep approaches; and

42.4.6.2.2 In forecast or known icing conditions unless the airplane is approved for conducting steep approaches in icing conditions.

42.4.6.3 A statement in the limitations section that the steep approach limitations, procedures, and performance information reflect the capability of the airplane to perform a steep approach, but do not constitute operational approval to conduct steep approach operations.

42.4.6.4 The height loss determined in accordance with paragraph 42.4.4.4.

42.5 Takeoff and Landing on Unpaved Runways.

42.5.1 Explanation.

There are no specific regulatory requirements or established guidance material pertaining to transport category airplane airworthiness certification for operations on runway surfaces other than smooth and hard. However, several transport category airplanes have been certificated by the FAA for operation on various kinds of unpaved runways, including sod, dirt, and gravel. The following general guidance for airplane certification, for operation on unpaved surfaces, reflects the experience and policy developed during those certification programs.

42.5.2 Procedures.

The considerations described in paragraphs 42.5.2.1 through 42.5.2.6 below should be addressed in obtaining approval for operation of transport category airplanes on unpaved runways.

42.5.2.1 **Surface Definition.**

Each type of surface should be defined so that it can be recognized, controlled, and maintained in service. The definition should include specification characteristics of the surface necessary for safe operation, such as:

42.5.2.1.1 Surface and sub-base bearing strength, usually expressed in terms of California bearing ratio (CBR). Measurements wet and dry every 500 feet along the runway centerline and 15 to 30 feet either side of the centerline have been used. Other means of defining the suitability of a runway surface to the operation of a particular airplane exist that classify runways based on their load bearing capability; one example is the Aircraft Classification Number (ACN) employed by the International Civil Aviation Organization (ICAO).

42.5.2.1.2 Thickness, aggregate size, and depth of the surface material.

42.5.2.1.3 Presence of rutting.

42.5.2.1.4 Drainage.

42.5.2.1.5 Presence of surface vegetation.

42.5.2.2 **Airplane Performance.**

If special equipment (e.g., low pressure tires, shields, deflectors) or special procedures are required, the effect of such equipment and/or procedures on airplane performance should be determined and presented in the AFM; for example, landing gear retraction time may increase if deflectors are installed on the landing gear, necessitating changes to AFM first segment climb data.

42.5.2.2.1 Takeoff, accelerate-stop, and landing performance should be demonstrated and scheduled in accordance with the appropriate airworthiness requirements based on each type of unpaved runway surface for which approval is requested. The flight test demonstrations should be conducted on both wet and dry surfaces. An abbreviated series of test conditions, relative to the test requirements of a conventional smooth, hard-surface runway test program, may be acceptable if reliable adjustments for all flap settings can be established to derive these data from the smooth, hard surface performance data. However, a minimum of four conditions each for takeoff, accelerate-stop, and landing should be conducted, and the heaviest weight demonstrated for takeoff and landing will establish the weight limitations for those modes of operation.

42.5.2.2.2 The test runway should be the actual runway for which approval is requested or be chosen to represent the worst characteristics (i.e., high rolling friction, low braking friction, etc.) of each type of unpaved runway for which approval is sought. In this regard, it may not be sufficient to conduct these tests from a runway with a low CBR. Previous tests have shown that rolling friction is primarily a function of CBR, but braking friction is primarily a function of runway surface characteristics and largely independent of CBR and, in some cases, whether the surface is wet or dry. The effects of other variables such as airplane weight and tolerances on recommended tire pressure should also be determined.

42.5.2.2.3 A V_{MCG} demonstration should be conducted. Rudder pedal nose wheel steering may be used, provided the runway surface for the test represents the worst case anticipated for operation. The aerodynamic moment applied to the airplane by the rudder, combined with the use of rudder pedal nose wheel steering, may result in the nose wheel plowing the unpaved runway surface. This can result in the runway surface elements impacting critical airframe and powerplant surfaces. The test should be closely monitored to ensure this damage source does not exist. If the test is conducted with rudder pedal nose wheel steering:

- Credit may be taken for any performance benefit provided; and
- Dispatch without it is prohibited, regardless of whether credit for any performance benefit is taken.

42.5.2.2.4 Landing flare and touchdown characteristics should be evaluated during the landing performance tests.

42.5.2.2.5 Climb performance should account for any additional drag or power/thrust loss due to special equipment installations.

42.5.2.3 **Airplane Handling.**

Airplane handling characteristics must meet the appropriate airworthiness requirements in each configuration specified for operation. Any special procedures or techniques associated with unpaved runway operation, such as use of thrust reversers, brakes, nose wheel steering, etc., should be identified.

42.5.2.4 **Systems, Engine, and Structure.**

42.5.2.4.1 It should be demonstrated that systems whose normal functions may be affected by operation from unpaved runways (e.g., anti-skid, nose wheel steering) continue to perform their intended function under all conditions for which approval is requested.

42.5.2.4.2 It should be determined that the airplane can be operated on each defined surface without hazard from likely impingement or engine ingestion of gravel or other surface material. In demonstrating that there is no hazard, consideration should be given to immediate effects such as mechanical damage, and to longer term effects, such as accumulation of loose runway material. These accumulations could cause jamming of flight controls, prevent configuration changes, or cause blockage of cooling ducts or drains. Also, sandblasting effects, from materials thrown by the tires, on the wings, propellers, and fuselage may result in surface erosion that, in time, may lead to more serious structural damage. To address these concerns, the test airplane, its engines, and any relevant systems should be inspected for surface damage after each accelerate-stop test and each takeoff/landing cycle.

42.5.2.4.3 The effect on landing gear fatigue life, due to operation on unpaved runway surfaces, should be determined.

42.5.2.4.4 It should be demonstrated that any special equipment, such as gravel deflectors or low pressure tires, does not adversely affect any of the AFM performance or ground handling characteristics previously established for the airplane on hard surface runways (e.g., water spray ingestion characteristics of the airplane).

42.5.2.5 **Maintenance.**

42.5.2.5.1 Any revised airplane maintenance procedures, such as increased frequency of inspections considered necessary to ensure safe operation of the airplane, should be determined and scheduled.

42.5.2.5.2 Runway maintenance procedures specific to the unpaved surface should be determined and scheduled (e.g., grading and sanding at, and just beyond, the touchdown point, and in the area where takeoff power or thrust is set, if those areas may be contaminated with ice or compact snow).

42.5.2.6 **Airplane Flight Manual.**

42.5.2.6.1 The limitations, procedures, and performance information for unpaved runway operation should be presented in an AFM appendix or supplement.

42.5.2.6.2 The limitations section should include runway surface definitions as established under paragraph 42.5.2.1 above, for which the airplane has been approved to operate and for which suitable performance data has been determined and scheduled in accordance with paragraph 42.5.2.2 above. Approved airplane configurations, including any special equipment required, along with system limitations, should also be included. The following takeoff and landing limitations should be stated:

- Reduced power or thrust takeoffs are prohibited.
- Dispatch with an inoperative anti-skid system is prohibited.
- Dispatch with inoperative spoilers/lift dumpers is prohibited.
- Use of continuous ignition is required during the takeoff.

42.5.2.6.3 The procedures section should include any special procedures (e.g., use of thrust reversers, nose wheel steering, rolling takeoff, air conditioning/pressurization configuration).

42.5.2.6.4 The performance section should include the performance determined and approved under paragraph 42.5.2.2 above, accounting for any special procedures required. No credit for clearway and/or stopway should be allowed.

42.6 Accounting for Performance Effects of Minor Design Changes and Configuration Deviation List Items.

42.6.1 Explanation.

Minor changes to the type design that involve changes to the exterior of the airplane (e.g., installation of wing tip-mounted emblem lights) and configuration deviation list (CDL) items (e.g., missing flap hinge covers) have aerodynamic effects and therefore can adversely affect airplane performance. These effects should be assessed and performance decrements identified as applicable.

42.6.2 Procedures.

The methods described below have been found acceptable for assessing the performance decrement that should be applied. These methods are considered as being a conservative alternative to a complete flight test analysis.

42.6.2.1 Analytically assess the performance degradation of an aerodynamic configuration change by estimating the drag value and then doubling that value. The resulting degradations in takeoff performance, en route climb, and approach/landing climb capability should be determined in terms of airplane weight. For airplanes with maximum takeoff gross weights not exceeding 20,000 lbs, performance weight decrements less than 0.5 percent of maximum takeoff weight for the takeoff and en route cases (or 0.5 percent of maximum landing weight for the approach/landing climb cases) may be considered negligible. For airplanes with maximum takeoff gross weights greater than 20,000 lbs, performance weight decrements of 100 lbs or less may be considered negligible. The AFM supplement or CDL appendix should identify those type design changes or CDL items that result in a negligible performance degradation. If the performance degradation is not considered negligible, the appropriate performance penalty (in terms of a weight and/or climb gradient capability, as appropriate) should be provided. For design changes, this information should be provided as a limitation in the AFM supplement. For CDL items, this information should be provided in the CDL appendix, along with the information described under *General Limitations* in paragraph 42.7.3 of this AC.

42.6.2.2 An alternative method of analytically assessing the performance degradation is to implement conservatism throughout the analysis through conservative round offs and chart readings, using worst-case assumptions, etc. The performance weight decrements are then implemented as noted in paragraph 42.6.2.1 above.

42.7 Configuration Deviation List.

42.7.1 Explanation.

The parts and/or combinations of parts permitted to be missing, and the associated performance decrements and other limitations, must be determined and presented in the AFM CDL.

42.7.2 Procedures.

42.7.2.1 The effect of the missing part should be evaluated to determine if an airplane performance decrement and/or other limitation(s) must be applied to ensure that there is no safety effect. A missing part that affects structural safety, results in damage to other parts, or causes the loss of required safety features is ineligible to be included in the CDL. For example, access panels that, if missing, could affect fire detection, extinguishing, and containment characteristics, are not eligible for listing as CDL items.

42.7.2.2 Performance decrements should be computed as described in paragraph 42.6 of this AC. A single decrement applicable to all AFM performance limitations may be presented; or, subject to the following restrictions, performance decrements may be presented for different flight phases:

42.7.2.2.1 Only a single performance decrement for takeoff and a single performance decrement for landing will be permitted. For takeoff, the decrement should be the greatest decrement considering takeoff field length, first, second, and final segment climbs, and takeoff flight path. For landing, the decrement should be the greatest decrement considering approach climb, landing climb, and landing field length.

42.7.2.2.2 Only a single weight decrement for the one-engine-inoperative and two-engine-inoperative en route climb performance will be permitted.

42.7.2.2.3 The CDL should contain explanations of the takeoff performance decrement, the landing performance decrement, and the en route performance decrement, as appropriate for the airplane, when the three decrements are used.

42.7.2.3 No reduction in V_{MO}/M_{MO} will be needed if it can be shown by flight test that: (1) no significant changes of flight characteristics or other adverse airworthiness effects exist up to V_{MO}/M_{MO}; and (2) a rational analysis is made for speeds up to V_D/M_D to show no deterioration of airplane control characteristics. The rational analysis should be based primarily on the proximity of the missing part to aerodynamic surfaces. If a reduction in V_{MO}/M_{MO} is needed, the maximum allowable airspeed indicator and aural warning, required by § 25.1303(b)(1) and (c)(1), must be rescheduled for the reduced speed.

42.7.3 General Limitations.

The following information should be presented in the CDL appendix:

42.7.3.1 When the airplane is operated using the CDL, it must be operated in accordance with the limitations specified in the AFM, as amended in the CDL.

42.7.3.2 Any associated operating limitations (e.g., speed, altitude, or performance limitations) should be listed on a placard affixed in the cockpit in clear view of the pilot in command and other appropriate crewmember(s).

42.7.3.3 For operations using a dispatch or flight release not prepared by the pilot in command, the pilot in command should be notified of each operation with a missing part(s) by listing the missing part(s) in the flight or dispatch release.

42.7.3.4 The operator should list in the airplane logbook an appropriate notation covering the missing part(s) on each flight.

42.7.3.5 If an additional part is lost in flight, the airplane may not depart the airport at which it landed following this event, until it again complies with the limitations of the CDL. This, of course, does not preclude the issuance of a ferry permit to allow the airplane to be flown to a point where the necessary repairs or replacements can be made.

42.7.3.6 No more than one part for any one system (e.g., one engine pylon fairing) may be missing, unless specific combinations of parts are included in the CDL. Unless otherwise specified, parts from different systems may be missing. The performance penalties are cumulative, unless specifically designated penalties are indicated for the combination of missing parts.

42.7.3.7 No more than three parts that have each been determined to cause a negligible performance degradation may be missing for takeoff without applying a performance penalty. When more than three such parts are missing, a performance penalty of either 0.5 percent of the maximum takeoff weight or 100 lbs, whichever is less, should be applied for takeoff, en route, and landing for each missing part.

42.7.3.8 Takeoff performance penalties should be applied to the takeoff weights that are limited by performance considerations (i.e., takeoff field length, first, second, or final segment climb, or takeoff flight path). If the performance-limited takeoff weight is greater than the maximum certified takeoff weight, the takeoff performance penalties should be applied to the maximum certified takeoff weight to ensure compliance with the noise requirements.

42.7.3.9 Landing performance penalties should be applied to the landing weights that are limited by performance considerations (i.e., landing field length, landing climb, or approach climb). If the performance-limited landing weight is greater than the maximum certified landing weight, the landing performance penalties should be applied to the maximum certified landing weight to ensure compliance with the noise requirements.

42.7.3.10 En route performance penalties apply only to operations that are limited by the one- or two-engine(s)-inoperative en route climb performance.

42.7.3.11 The numbering and designation of systems in the CDL appendix should be based on an Air Transport Association (ATA) Specification. The parts within each system should be identified by functional description and, when necessary, by part numbers.

42.8 Spare Engine Pod.

42.8.1 Explanation.

When a spare engine pod is installed, this is considered a major change to the type design. The airplane's performance and flight characteristics that are affected by the installation should be evaluated as part of the approval process required by § 21.97(a)(2).

42.8.2 Procedures.

The drag increment due to the spare engine pod installation is normally determined by the drag polar method described in paragraph 4.9.2.1.2 of this AC. Check climbs are performed to verify the performance penalties derived from the drag data. These check climbs will normally be conducted in the airplane configuration corresponding to the limiting takeoff performance segment. Performance stalls should be conducted for a minimum of one takeoff and one landing flap setting to determine any effect of the spare engine pod installation on stall speeds and handling characteristics in the stalling maneuver. Vibration and buffeting (§ 25.251), flutter (§ 25.629), and the maximum operating limit speed (§ 25.1505) may also require flight demonstration with the spare engine and pod installed. Longitudinal control (§ 25.145), directional and lateral control (§ 25.147), and ability to trim (§ 25.161) should be demonstrated with the spare engine and pod installed.

42.9 Authorization for Ferry Flight with One Engine Inoperative—§ 91.611.

42.9.1 Explanation.

Section 91.611 provides an allowance for the ferry flight of "a four-engine airplane or a turbine-engine-powered airplane equipped with three engines, with one engine inoperative, to a base for the purpose of repairing that engine…." This allowance is provided for airplanes operated in accordance with parts 121 and 125. Section 91.611 also provides performance and operating criteria, including references to sections of part 25 that must be met in order to obtain a one-engine-inoperative ferry flight permit.

42.9.2 Procedures.

Section 91.611(a)(1) requires the subject airplane be flight tested to show satisfactory compliance with the requirements of § 91.611(b) or (c) for reciprocating and turbine engine powered airplanes, respectively. Deviations from the flight tested configuration may be approved, based on a conservative analysis as described in paragraph 42.6 of this AC. An example of such a deviation would be a turbojet powered airplane with a one-engine-inoperative ferry flight approval, based on a flight test with the inoperative engine windmilling being subsequently approved for flight with a locked rotor. Though the one-engine-inoperative ferry is an operational approval and not a change in the type design, the airplane performance with the locked rotor should be treated in the same manner as a "minor design change," and the associated drag increment computed conservatively as described in paragraph 42.6. The pertinent regulatory sections are described below.

42.9.2.1 Section 91.611(a)(2) requires the approved AFM to contain limitations, operating procedures, and performance information, including a description of the configuration of the inoperative propeller (i.e., engine).

42.9.2.2 Section 91.611(c)(1) and (2) require flight tests to be conducted, in the propeller (i.e., engine) configuration desired for approval, to determine takeoff speeds and distances for one-engine-inoperative ferry operations.

42.9.2.3 Section 91.611(c) refers to the general performance requirements of § 25.101, the takeoff speed requirements of § 25.107, and the climb requirements of § 25.121, thus tying the one engine inoperative ferry performance to the type design criteria.

42.9.2.4 Section 91.611(c)(5) states the airplane must be satisfactorily controllable in a climb with two critical engines inoperative and the climb performance "may be shown by calculations based on, and equal in accuracy to, the results of testing."

42.9.2.5 Section 25.21(a)(1) states the same allowance for calculated performance if it is "based on, and equal in accuracy to, the results of testing." Based on this statement, and the previously noted references of § 91.611 to sections of part 25, it is permissible to calculate one-engine-inoperative ferry performance for a configuration that differs from that flight tested. In such cases the conservative methods described in paragraph 42.6 of this AC should be used.

42.10 **Instrument Landing System Weather Minima.**

42.10.1 Explanation.

The all-weather categories, as presented by the ICAO, are defined as follows:

42.10.1.1 Category I—200 feet (60 meters) ceiling, 2600 feet (800 meters) runway visual range (RVR).

42.10.1.2 Category II—100 feet (30 meters) ceiling, 1200 feet (400 meters) RVR.

42.10.1.3 Category III.

42.10.1.3.1 Category IIIA—No decision height, 700 feet (200 meters) RVR.

42.10.1.3.2 Category IIIB—No decision height, no external reference and 150 feet (50 meters) RVR.

42.10.1.3.3 Category IIIC—No decision height, no external reference for landing or taxi.

42.10.2 Procedures.

The criteria for airworthiness certification of Category I and II all weather operations are contained in AC 120-29A. The criteria for airworthiness certification of Category III all weather operations are contained in AC 120-28D.

42.11 Takeoff Performance Credit for Alternate Forward Center of Gravity Limits.

42.11.1 Applicable Regulations.

Sections 25.23, 25.103, 25.105, 25.107, 25.109, 25.111, 25.113, 25.115, and 25.121.

42.11.2 Explanation.

42.11.2.1 In the early 1970s, approvals were granted for one alternate forward CG limit per manufacturer's airplane model (e.g., DC-10 series 40, B737-300, A300-600, etc.). These approvals included AFM performance information that took credit for the improved takeoff performance available with a further aft forward CG limit. The effect of this was that all operators of a particular airplane model (e.g., B737-300) would have the same alternate forward CG limit, which may or may not be useable by any particular operator, depending on that operator's interior configuration, loading, and route structure.

42.11.2.2 Since those early approvals, the commercial aviation market has changed considerably, with many transport category airplanes capable of fulfilling more than one mission requirement in an operator's fleet. This is particularly true for modern extended range operation two-engine airplanes, most of which were derived from an earlier medium range version of the same airplane type. When these airplanes are used in long range operations, the CG can be considerably aft of the forward limit due to large fuel loadings. The advent of integral horizontal stabilizer fuel tanks has also led to a further shift aft of the CG. Some operators use these same long range airplanes on short to medium length routes, with the CG further forward than that of the long range operations, but still significantly aft of the forward CG limit.

42.11.2.3 The operational flexibility of many of today's transport category airplanes can be enhanced by taking credit for the improvements in takeoff performance afforded by a CG that is aft of the forward limit. The reductions in stall speeds and airplane drag result in increased takeoff weights for a given field length and takeoff flight path profile. The approval of takeoff performance for two alternate forward CG limits would provide operators with increased flexibility in operating the same airplane model on both long and short to medium range routes.

42.11.2.4 The concept of having alternate forward CG limits, with associated improvements in takeoff performance, does not conflict with any of the airworthiness or operational requirements of the federal aviation regulations. Section 25.103(b)(5) requires stall speeds to be based on the CG position that results in the highest value of reference stall speed. Section 25.117 states that compliance with the climb performance requirements must be shown with the “most unfavorable CG” position. Historically, this has been interpreted as a requirement to conduct the associated performance flight testing at the most forward CG limit, and present the resulting AFM performance for that same extreme forward CG limit. However, there is no requirement that prevents operating limitations from being used to establish multiple forward CG limits.

42.11.2.5 The primary concern in granting performance credit for forward CG limits that are aft of the extreme forward limit is the reduction in the conservative performance margin that results from usually operating with the CG aft of the extreme forward limit that the takeoff performance is based on. With the availability of alternate forward CG limits, this safety margin will be decreased, and on a statistical basis, completely eliminated more often. Consequently, emphasis should be put on maintaining accurate weight and balance records, implementing accurate loading plans, and providing the necessary training and operating procedures for ground and dispatch personnel.

42.11.2.6 Flightcrew training is also a concern for alternate forward CG limit operations. With many of today’s transport category airplanes incorporating high levels of cockpit automation, it is important that the flightcrew be aware of when an alternate forward CG limit is being used as the basis for computing takeoff performance data. This is most important when an alternate forward CG limit is used in conducting a performance-limited takeoff.

42.11.3 Procedures.

Approval may be granted for as many as two alternate forward CG limits (for a total of three forward CG limits), with associated takeoff performance data, using the following certification criteria:

42.11.3.1 No more than two alternate forward CG limits (three total) should be approved per operator-specific variant of a particular airplane type and model. “Airplane type” refers to those airplanes of similar design as identified on the type certificate; “airplane model” refers to different versions of an airplane type as reflected on the type certificate. An “operator specific variant” is an airplane type and model outfitted to a particular customer’s requirements (e.g., engine type, seat pitch, galley locations, etc.). For control purposes, airplanes that are classified as an “operator specific variant” should be clearly identifiable as such; this can be accomplished by definitive AFM document numbering systems and AFMs tied to specific airplane serial numbers.

42.11.3.2 The alternate forward CG limits should be sufficiently different that they will be treated as discrete limits and not result in confusion when determining takeoff performance adjustments.

42.11.3.3 The CG range that results from the use of an alternate forward CG limit should be of sufficient magnitude to be practical and allow for expected variations in operational loading.

42.11.3.4 The alternate forward CG limits should be identified as such and presented on the weight and CG chart in the limitations section of the basic AFM. That chart should also provide a reference to a separate appendix to the AFM that contains the related airplane performance adjustments.

42.11.3.5 To minimize the impact on crew training and standardization of cockpit procedures, onboard systems that use or provide weight and balance information (e.g., Flight Management Systems, Electronic Flight Bags, etc.) should include the performance and fuel management data associated with the alternate forward CG limits. If they do not include such information, a limitation should be added to the AFM that prohibits the use of such systems when using an alternate forward CG limit.

42.11.3.6 The AFM performance associated with alternate forward CG limit operations must be substantiated by flight test data per § 25.21(a)(2). This does not mean that flight test data needs to be obtained at every alternate forward CG limit; the intent is for the applicant to verify the analytical predictions of CG effect with flight test data collected at different CGs.

42.11.3.7 All affected cockpit placards and displays should be revised to reflect the alternate forward CG limits.

42.12 Airplane Backing Using Reverse Thrust.

42.12.1 <u>Explanation.</u>

Where compliance with applicable airworthiness requirements has been demonstrated, operational approval has been granted for the use of reverse thrust to back airplanes away from airport gates in lieu of a tug pushback. The applicable airworthiness requirements are prescribed in paragraph 42.12.2 below. Note that compliance with these requirements only demonstrates the capability of the airplane, and does not constitute operational approval. Operational approval should be coordinated with the applicable FAA Flight Standards office.

42.12.2 <u>Procedures.</u>

To obtain airworthiness approval for reverse thrust backing, compliance should be demonstrated with the criteria prescribed below. Since operational approvals for reverse thrust backing specify the applicable airplanes, airports, and gates, some of these tests will be site specific and should be coordinated with the applicable FAA Flight Standards office.

42.12.2.1 Both the airplane and engine manufacturer should determine the applicability of the maneuver and provide appropriate limitations for the procedure. These limitations should include:

- Engine power or thrust setting and operating parameter limits,
- Minimum and maximum allowable weights,
- CG limits,
- Ramp slope limits,
- Use of wheel brakes,
- Atmospheric conditions (see Note below), and
- Any other factor unique to the proposed operation.

Note: The use of reverse thrust backing with snow, ice, or slush on the ramp, or during periods of heavy rain, is not considered good operating practice.

42.12.2.2 All limitations, and any normal or abnormal operating procedures, associated with reverse thrust backing should be included in the AFM. Any procedures related to ground crew functions should also be included in the AFM.

42.12.2.3 Testing should be conducted to verify that the reverser efflux does not have a detrimental effect on the powerplant installations. Items to be considered include:

- Foreign object damage (FOD),
- Effects on engine cooling,
- Inlet flow distortion,
- Re-ingestion of exhaust gases, and
- Any effects on engine mounted accessories.

42.12.2.4 Testing should be conducted to verify that the reverser efflux does not have a detrimental effect on other airplane systems such as air conditioning system inlets, APU inlets and exhausts, overboard drains, etc.

42.12.2.5 It should be verified that cockpit and cabin air will not be contaminated.

Note: It is acceptable to have a limitation prohibiting the operation of the air conditioning packs during reverse thrust backing to avoid cockpit and cabin air contamination.

42.12.2.6 Reverse thrust backing demonstrations should be conducted to evaluate the associated procedures. These demonstrations should be conducted at:

- Maximum ramp weight with the CG at the aft limit, and
- Any other weight that may be critical with the CG at the aft limit.

42.12.2.7 The reverse thrust backing demonstrations of paragraph 42.12.2.6 above should be evaluated to determine:

42.12.2.7.1 The amount of aft pitching moment, including its effect on nose wheel steering;

42.12.2.7.2 The effect of inadvertent heavy/emergency braking action;

42.12.2.7.3 Adequate cockpit visibility and ground crew function;

42.12.2.7.4 An area around the airplane that should be free of ground crew personnel and ground support equipment throughout the reverse backing maneuver;

Note: This evaluation should also consider the effects of the reverser efflux on airplanes at adjacent gates.

42.12.2.7.5 The adequacy of procedures for transitioning from reverse to forward thrust;

42.12.2.7.6 The effect of thrust asymmetry due to failure of an engine to enter reverse, or recover forward thrust mode;

42.12.2.7.7 The effects of low tire pressures;

42.12.2.7.8 The effect of ramp slope and surface condition;

42.12.2.7.9 The effects of ambient atmospheric temperature; and

42.12.2.7.10 The effect of flap/slat configuration.

APPENDIX A. ACRONYMS, ABBREVIATIONS, SYMBOLS, AND DEFINITIONS

Table A-1. Terms and Definitions

Term	Definition
AC	Advisory Circular
ACARS	Aircraft Communications Addressing and Reporting System
ACO	Aircraft Certification Office
ACN	Aircraft Classification Number
ADC	Air Data Computer
ADF	Automatic Direction Finder
ADQ	Adequate
AEO	All-Engines-Operating
AFM	Airplane Flight Manual
AGL	Above Ground Level
AHRS	Attitude and Heading Reference System
AOA	Angle of Attack
APU	Auxiliary Power Unit
AR	Authorization Required
ARSR	Air Route Surveillance Radar
ARTCC	Air Route Traffic Control Center
ASR	Airport Surveillance Radar
ATA	Air Transport Association
ATC	Air Traffic Control
ATCRBS	Air Traffic Control Radar Beacon System

Table A-1. Terms and Definitions (continued)

Term	Definition
ATS	Automatic Throttle System
ATT REF	Attitude Reference
ATTCS	Automatic Takeoff Thrust Control System
C	Celsius
CAR	Civil Air Regulations
CAS	Calibrated Airspeed
CAT	Category
CAWS	Central Aural Warning System
CBR	California Bearing Ratio
CDL	Configuration Deviation List
CDU	Cockpit Display Unit
CFR	Code of Federal Regulations
CG	Center of Gravity
C_L	Lift Coefficient
CMM	Component Maintenance Manual
C_N	Yawing Moment Coefficient
COM	Communications
CON	Controllable
CRT	Cathode Ray Tube
CVR	Cockpit Voice Recorder
CWS	Control Wheel Steering

Table A-1. Terms and Definitions (continued)

Term	Definition
dB	Decibel
DER	Designated Engineering Representative
DFDR	Digital Flight Data Recorder
DG	Directional Gyros
DH	Decision Height
DME	Distance Measuring Equipment
ECAM	Electronic Centralized Aircraft monitor
EFCS	Electronic Flight Control System
EGT	Exhaust Gas Temperature
EICAS	Engine Indicating and Crew Alerting System
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EPR	Engine Pressure Ratio
ESDU	Engineering Sciences Data Unit
F	Fahrenheit
F&R	Function and Reliability
FGS	Flight Guidance System
FMEA	Failure Modes and Effects Analysis
FMS	Flight Management System
FOD	Foreign Object Damage
F_S	Longitudinal Control (Stick) Force

Table A-1. Terms and Definitions (continued)

Term	Definition
FSB	Flight Standardization Board
F_S/g	Stick Force per g
ft	Foot or Feet
FWC	Flight Warning Computer
g or G	Acceleration Due to Gravity at the Earth’s Surface
GLS	GNSS Landing System
GNSS	Global Navigation Satellite System
HF	High Frequency
HGS	Head-Up Guidance System
HQ	Handling Qualities
HQRM	Handling Qualities Rating Method
HSI	Horizontal Situation Indicator
HUD	Head-Up Display
Hz	Hertz (cycles per second)
IAS	Indicated Airspeed
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
IKE	Initial Kinetic Energy
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
INS	Inertial Navigation System
IRS	Inertial Reference System

Table A-1. Terms and Definitions (continued)

Term	Definition
ITT	Interstage Turbine Temperature
IVSI	Instantaneous Vertical Speed Indicator
KE	Kinetic Energy
lbs	Pounds
LF	Low Frequency
LFE	Limit Flight Envelope
LNAV	Lateral Navigation
LODA	Letter of Design Approval
M	Mach Number
MAC	Mean Aerodynamic Chord
MCS	Master Caution System
MCT	Maximum Continuous Thrust
M_D	Design Dive Mach
MDA	Minimum Descent Altitude
M_{DF}	Demonstrated Flight Diving Mach
MEL	Minimum Equipment List
MF	Medium Frequency
M_{FC}	Maximum Mach for Stability Characteristics
MFD	Multi-Function Display
min	Minute(s)
M_{LRC}	Long Range Cruise Mach

Table A-1. Terms and Definitions (continued)

Term	Definition
MLS	Microwave Landing System
MMEL	Master Minimum Equipment List
M_{MO}	Maximum Operating Mach
MSL	Mean Sea Level
MWS	Master Warning System
MUH	Minimum Use Height
N_1	Rotational Speed of Low Pressure Compressor (Turbine Engine)
N_2	Rotational Speed of High Pressure Compressor (Turbine Engine)
NAS	National Airspace System
NAV	Navigate
NM	Nautical Mile(s)
NFE	Normal Flight Envelope
OAT	Outside Air Temperature
OEW	Operating Empty Weight
OFE	Operational Flight Envelope
PA	Public Address
PFC	Porous Friction Course
PIO	Pilot Induced Oscillation
Q	Dynamic Pressure
R/A	Radio Altimeter
RFI	Radio Frequency Interference

Table A-1. Terms and Definitions (continued)

Term	Definition
RPM	Revolutions per Minute
RMI	Radio Magnetic Indicator
RNAV	Area Navigation
RNP	Required Navigation Performance
RTO	Rejected Takeoff
RVP	Reid Vapor pressure
RVR	Runway Visual Range
SAS	Stability Augmentation System
SAT	1. Static Air Temperature 2. Satisfactory (when used with the handling qualities rating method)
SATCOM	Satellite Communications
secs	Seconds
SELCAL	Selective Calling System
S/F	Slow/Fast
SR	Special Regulation
STC	Supplemental Type Certificate
STOL	Short Takeoff and Landing
SWC	Stall Warning Computer
TAT	Total Air Temperature
TAWS	Terrain Awareness and Warning System
TCAS	Traffic Collision Avoidance System
TCDS	Type Certificate Data Sheet

Table A-1. Terms and Definitions (continued)

Term	Definition
TIA	Type inspection Authorization
TIR	Type Inspection Report
TOW	Takeoff Warning
TSO	Technical Standard Order
T/W	Thrust-to-Weight Ratio
UNSAT	1. Unsatisfactory 2. Failed
V_1	Maximum speed in the takeoff at which the pilot must take the first action (e.g., apply brakes, reduce thrust, deploy speed brakes) to stop the airplane within the accelerate-stop distance. It also means the minimum speed in the takeoff, following a failure of the critical engine at V_{EF}, at which the pilot can continue the takeoff and achieve the required height above the takeoff surface within the takeoff distance.
V_2	Takeoff safety speed
V_{2MIN}	Minimum takeoff safety speed
V_{35}	Speed at a height of 35 feet above the takeoff surface
V_D	Design diving speed
V_{DF}	Demonstrated flight diving speed
V_{EF}	Speed at which the critical engine is assumed to fail during takeoff
V_{FC}	Maximum speed for stability characteristics
V_{FE}	Maximum flap extended speed
VFR	Visual Flight Rules
VG	Vertical Gyros

Table A-1. Terms and Definitions (continued)

Term	Definition
VHF	Very High Frequency
V_{LE}	Maximum landing gear extended speed
V_{LO}	Maximum landing gear operating speed
V_{LOF}	Lift off speed
VMC	Visual Meteorological Conditions
V_{MC}	Minimum control speed with the critical engine inoperative
V_{MCA}	Minimum control speed in the air
V_{MCG}	Minimum control speed on the ground
V_{MCL}	Minimum control speed during approach and landing with all engines operating
$V_{MCL(1\ out)}$	Minimum control speed during approach and landing with one engine inoperative
V_{MCL-2}	Minimum control speed during approach and landing with one critical engine inoperative (for airplanes with three or more engines)
$V_{MCL-2(2\ out)}$	Minimum control speed during approach and landing with two engines inoperative (for airplanes with three or more engines)
V_{MO}	Maximum operating limit speed
V_{MU}	Minimum unstick speed
VNAV	Vertical Navigation
VOR	Very High Frequency Omnidirectional Range
VORTAC	Very High Frequency Omnidirectional Range Tactical Air Navigation
V_{REF}	Reference landing speed
V_S	Stalling speed or the minimum steady flight speed at which the airplane is controllable

Table A-1. Terms and Definitions (continued)

Term	Definition
V_{S0}	Stalling speed or the minimum steady flight speed in the landing configuration
V_{S1}	Stalling speed or the minimum steady flight speed in a specific configuration
V_{SR}	Reference stall speed
V_{SR0}	Reference stall speed in the landing configuration
V_{SR1}	Reference stall speed in a specific configuration
V_{SW}	Speed at which the onset of natural or artificial stall warning occurs
WAT	Weight, Altitude, Temperature
W/δ	Weight/Delta

Table A-2. Symbols and Definitions

Symbol	Definition
Δ	Incremental change in value
δ	Ratio of atmospheric pressure at any altitude to the pressure at sea level
μ_{max}	Maximum friction coefficient available between a tire and the runway surface

APPENDIX B. FUNCTION AND RELIABILITY (F&R) TESTS

B.1 Explanation.

B.1.1 Section 21.35(b)(2) requires applicants for a type certificate (including an amended type certificate, supplemental type certificate (STC), or amended STC) to conduct all flight tests that the FAA finds necessary to determine whether there is reasonable assurance that the airplane, its components, and its equipment function properly (i.e., perform their intended function without introducing safety hazards) and are reliable (i.e., will continue to function properly in service).

Note: In order to obtain wider experience, manufacturers are encouraged to cooperate with operators in operating airplanes with provisional type certificates under service conditions.

B.1.2 However, the applicant must discontinue flight testing until appropriate corrective action has been taken, in accordance with § 21.35(e)(2), when it finds items of non-compliance with requirements that may make additional test data meaningless or that would make further testing unduly hazardous. The applicant must address any non-compliance with the functionality or reliability standards in the applicable airworthiness standards and any unsafe feature or characteristic identified during the test program prior to approval of the design under § 21.21(b)(1) and (2). Additional compliance demonstration testing and/or F&R testing may be necessary if the applicant introduces a design change.

B.1.3 Section 21.35(b)(2) applies to all type certification programs (except those covered under §§ 21.24 through 21.29), including those involving new type certificates, amended type certificates (including type design changes), STCs, and amended STCs.

B.2 Procedures.

The principal FAA flight test pilot for the project will act as coordinator of all flight activities during the official program, and that pilot (or a designated alternate) will participate in all flights. Other FAA personnel will not board the F&R airplane(s) during these activities unless authorized by the flight test pilot. The manufacturer's pilot should be in command of all flights, but FAA pilots will fly the airplane to determine compliance with § 21.35(b)(2). Other FAA personnel (e.g., representatives of other divisions and specialists) will participate in the flight tests, when deemed necessary, to accomplish the purpose of the tests.

B.2.1 Test Time.

It is highly desirable that the FAA administer F&R test programs uniformly so that the program and flight time for similar projects will be approximately the same, regardless of which ACO administers the project. This can be difficult to achieve without establishing fixed test times that would be contrary to the FAA's intent that § 21.35 (b)(2) be a performance-based standard. The applicant should use the following procedure as a guide for developing F&R test programs:

B.2.1.1 For a new or changed turbine engine-powered airplane incorporating engines of a type not previously used on a type certificated airplane, § 21.35(f)(1) requires an F&R test program of at least 300 hours. ("Engines of a type not previously used on a type certificated airplane" means engines of a new or changed type design that require a substantially complete investigation of compliance with the applicable regulations, regardless of whether a new engine type certificate was issued.) Though some F&R test requirements can be completed concurrently with certification testing (if relevant design conformity can be shown), experience has indicated the desirability of obtaining at least 150 hours of the minimum required 300 hours of F&R test time as dedicated F&R test time on a production configured airplane for these types of certification programs. However, § 21.35(f)(1) requires the applicant to perform a minimum of 300 hours of F&R time on a full complement of engines installed on the airplane that fully conform to the production configuration. To accomplish the intent of the reliability demonstration required by § 21.35(b)(2), the applicant must use the same full complement (single ship set) of engines for at least 300 airplane test hours.

B.2.1.2 For a new turbine engine-powered airplane (i.e., a new type certificate program) that is conventional with regard to complexity and design features, and does not incorporate "engines that have not been previously used on a type certificated airplane" as defined above, the FAA has found that F&R can normally be proven by less than 300 hours of testing. The ACO can reduce the amount of required F&R test time below 300 hours by granting credit for certain types of component testing (see paragraph B.2.5.2 of this appendix) and for supplementary experience (see paragraph B.2.1.4.3 of this appendix). However, the test time may not be reduced below the minimum 150 hours required by § 21.35(f)(2). More than 150 hours of F&R testing may be necessary if difficulties are encountered or for unusual cases of complexity.

B.2.1.3 For airplanes incorporating design changes, the FAA can give full or partial credit for F&R testing performed previously on sufficiently similar configurations of that aircraft type. The FAA should require an amount of new dedicated F&R testing commensurate with the level of change made to the airplane design, the potential effect of the change on the F&R of the airplane, the amount of flight testing performed to show compliance with airworthiness requirements, and the configuration of the aircraft used in the flight testing performed to show compliance with airworthiness requirements. The FAA may choose to give the applicant credit, reducing the amount of dedicated F&R test time, for test time from the flight testing compliance demonstration for type certification, provided that:

- The changed and potentially affected areas of the airplane conform to the production configuration, and

- The test activities are consistent with the intent of the F&R testing required for the design change.

B.2.1.4 When satisfactory supplementary experience gained from operators' route proving tests; or from the applicant's or operator's ferry flights, customer demonstration flights, or training flights; is available and taken into account, the following allowances should be used as a guide and applied with judgment in reducing the official flight test time. However, in any case, the official F&R test program should provide sufficient time to accomplish the objective of paragraph B.1 in accordance with the procedures described in paragraphs B.2.5.3 and B.2.5.4.

1. Intensive Experience. When the allowance is based on the total time of any one airplane in airline crew training and similar intensive operations, two hours of such operation may be considered equivalent to one hour of official testing.
2. For Miscellaneous Experience. When the allowance is based on the total time of any one airplane, five hours of such experience may be considered equivalent to one hour of official testing.
3. Reduction for Supplementary Experience. Whenever a reduction of official test time is desired on the basis of supplementary experience, such experience should be adequately recorded and submitted to the responsible FAA aircraft certification office as described in paragraph B.2.6.2 of this appendix.

B.2.1.5 The FAA should only consider giving credit for F&R test activities or test time required under § 21.35(b)(2) for compliance demonstration testing performed under § 21.35(b)(1) when:

- The changed and potentially affected areas of the airplane conform to the production configuration, and
- The test activities are consistent with the intent of the F&R testing determined to be required for the design change.

B.2.2 <u>Test Airplane.</u>

To facilitate completion of the type certification procedure, the applicant should use one airplane, in production configuration or equivalent, for the official F&R tests and use another airplane (or airplanes) for the compliance demonstration tests for type certification. In this case, the test time on at least one airplane would be sufficient to accomplish the reliability demonstration objective of § 21.35(b)(2). That is, the applicant should perform the reliability demonstration (normally either 150 or 300 hours, but potentially longer if problems are discovered) on a single airplane as implied by § 21.35(c). All engines of the F&R test airplane are required, in accordance with § 21.35(f)(1), to fully conform to the production configuration for all credited F&R test time. This engine conformity requirement was specifically discussed in the preamble to amendment 21-40.

B.2.3 Modified Types.

The procedure outlined in paragraph B.2.4 below applies to new type designs. When a design employs components (parts) identical to those used in previous designs, the applicant may receive credit for the supplementary experience available for such components. When a design is modified (e.g., one certification program covers several versions of the same basic type with different engines, propellers, etc.), the modified features and components should be rechecked in accordance with paragraph B.2.5.6 below.

B.2.4 Test Program.

The project engineers of the responsible FAA ACO will propose guidelines for developing an F&R test program at the preflight type board meeting (prior to commencement of FAA certification flight tests) and coordinate this with the airplane manufacturer. Near the conclusion of the type certification tests, the FAA certification engineers will again meet with the manufacturer to review the experience gained in those tests, review changes made in the design, consider any additional supplementary experience, and revise the proposed F&R test program accordingly. In application, there is generally considerable overlap of the certification and F&R test programs, thus making a definite transition point indiscernible.

B.2.5 Planning and Execution of Test Program.

The following points should be considered:

B.2.5.1 The test program should be sufficiently well planned to enable its execution in an efficient manner without overlooking important items. Documentation should focus on the test objective(s) but does not necessarily require the type of detail maintained for type certification testing. The FAA project engineers will review the design features and equipment (appliances) with respect to the general objective and prepare a list showing:

- Components and systems to be checked in accordance with the procedures described in the paragraph B.2.5.4 below.
- A brief description of the operations to be performed, where these are not obvious (referencing any necessary operating instructions).
- Special checks or likely critical conditions.
- Estimated flight time required.

B.2.5.2 Allowance may be made for those functional tests whose requirements are covered by part 25 type certification tests. Allowance may also be made for qualification-type testing of new features and equipment; however, the flight test program should be planned to determine the adequacy of these tests and the accuracy of the simulated operating environment (e.g., to determine whether the actual environmental conditions such as temperature variation, etc., are covered by the test simulations) when these may be critical, and to determine whether the installation and connected systems are satisfactory. This does not imply that flight tests must be conducted under the most severe outside air temperatures likely to be encountered in service. It should normally be possible to determine the effects of extreme outside temperatures on local temperatures by extrapolation or by suitable correction factors. The FAA project engineers will then make a consolidated estimate of the total flight time required, allowing for overlapping, and adjust this in accordance with the *Test Time* outlined in the paragraph B.2.1 above.

B.2.5.3 This program will be arranged to permit the principal FAA flight test pilot to become thoroughly familiar with the operational aspects of the airplane in its anticipated service environment.

B.2.5.4 All components of the airplane should be intensively operated and studied under all operating conditions expected in service and obtainable within the time and geographical limitations of the tests. Intensive operation means repeated operation of components in various sequences and combinations likely to occur in service. Particular attention should be given to potential sources of crew error, excessive crew workload or coordination, and the procedures that would be required in the event of malfunction of any component. The testing should also include an evaluation of operations with various MEL items declared/simulated inoperative. This intensive type of testing should be conducted in all cases, but the length of time for which it is continued will depend upon the supplementary experience available for the particular type, as outlined in paragraph B.2.1 above.

B.2.5.5 Ground inspections should be made at appropriate intervals during the test program to determine whether there are any failures or incipient failures in any of the components that might be a hazard to safe flight. The normal maintenance procedures should be employed during the F&R program and carefully documented for review.

B.2.5.6 When design changes are made during the course of the test, or when the designated test airplane differs from those on which supplementary experience is obtained, the modified items will be rechecked on the designated F&R test airplane in accordance with the above procedures. Every effort should be made to include such items in the program in such a way as to avoid unduly extending the overall test time. To this end, the Administrator may accept, in lieu of additional flight tests:

- Special tests of the original and revised components in which the conditions causing failure are intensified.
- Ground qualification tests of differing components when the test methods have been validated as being representative of actual flight conditions.

B.2.6 Reports and Records.

B.2.6.1 Either the FAA or the applicant should keep a log of all flights, according to agreements made prior to start of the F&R test program. The log should include accurate and complete records of all defects, difficulties, and unusual characteristics and sources of crew error discovered during the tests, and of the recommendations made and action(s) taken. If the applicant is responsible for keeping the flight logs, the applicant will report to the responsible ACO all items for which design changes may be required.

B.2.6.2 If supplementary experience is to be taken into account, the applicant should submit records of such experience to the responsible ACO, together with a list of the differences between the airplane on which the experience was obtained and the official test airplane. When supplementary experience is obtained on a large fleet of airplanes (for example, military operations) of the same or a comparable type (see paragraph B.2.5.6 above), these records may consist of statistical summaries in lieu of complete records for each individual airplane.

B.2.6.3 At the conclusion of the official tests, a summary report should be prepared and made a part of the type inspection report. Either the FAA or the applicant may prepare the report, according to agreements made prior to start of the F&R test program.

APPENDIX C. HISTORICAL DEVELOPMENT OF ACCELERATE-STOP TIME DELAYS

C.1 Explanation.

C.1.1 As the rules pertaining to transport category airplane accelerate-stop distances have developed over the years, the interpretation of those rules, with regard to pilot actions, recognition times, and delay times, has also changed. The paragraphs below provide a historical perspective on the application of pilot recognition and delay times, with references to the applicable part 25 amendment number.

C.1.2 In accordance with § 21.101 (a) and (b) the certification basis for a derivative airplane type may be the regulations specified in the type certificate of the basic airplane, depending upon the extent and nature of the changes to the airplane. For those cases where the original certification basis can be retained, the guidance presented in paragraphs C.2.1 and C.2.2 below may be used to show compliance with the appropriate regulations. (For more information related to determining a derivative airplane's certification basis, see AC 21.101-1B.)

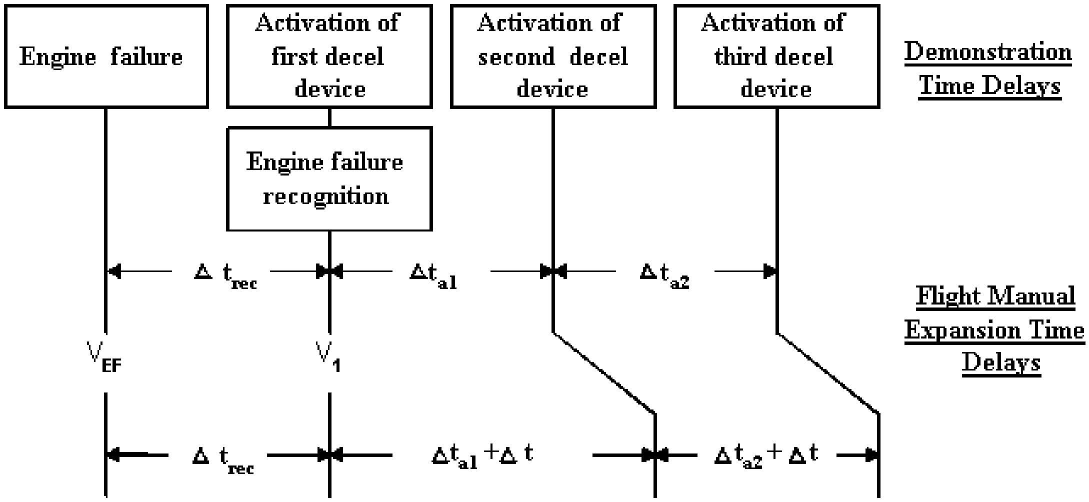
C.1.3 Regardless of the certification basis, the effects of brake wear state on energy absorption capability and stopping performance must be addressed in order to comply with § 21.21(b)(2). The responsible FAA ACO should be contacted to establish the applicable brake wear criteria for a specific airplane type.

C.2 Procedures.

C.2.1 <u>Pre-Amendment 25-42 Accelerate-Stop Time Delays.</u>

Parts 1 and 25 of 14 CFR, prior to amendments 1-29 and 25-42, respectively, defined V_1 as the critical engine failure speed. When this definition of V_1 was applied to the accelerate-stop criteria of § 25.109 and the V_1 criteria of § 25.107(a)(2), the implication was that engine failure and engine failure recognition could occur simultaneously. It was recognized that this simultaneous occurrence could not be achieved in actual operations, and that defining V_1 as the engine failure speed resulted in a conflict with § 25.101(h), which requires allowance for time delays in execution of procedures. In order to resolve this conflict, V_1 was applied as the engine failure recognition speed, and appropriate time delays were developed for showing compliance with § 25.101(h). Figure C-1 shows a pictorial representation of the accelerate-stop time delays that were considered acceptable for compliance with § 25.101(h) before amendment 25-42 (effective March 1, 1978). Paragraph C.2.1.7 of this appendix provides guidance on reflecting these time delays in the AFM accelerate-stop distances.

Figure C-1. Accelerate-Stop Time Delays (Pre-Amendment 25-42)



C.2.1.1 Δt_{rec} = engine failure recognition time. The demonstrated time from engine failure to pilot activation of the first deceleration device, this action indicating recognition of the engine failure. For AFM data expansion purposes, in order to provide a recognition time increment that can be executed consistently in service, it has been found practical to use the demonstrated time or 1 second, whichever is greater. If the airplane incorporates an engine failure warning light, the recognition time includes the time increment necessary for the engine to spool down to the point of warning light activation, plus the time increment from light "on" to pilot action indicating recognition of engine failure.

C.2.1.2 Δt_{a1} = the demonstrated time interval between activation of the first and second deceleration devices.

C.2.1.3 Δt_{a2} = the demonstrated time interval between activation of the second and third deceleration devices.

C.2.1.4 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 that are approved for performance credit for AFM data expansion, established times determined during certification testing may be used without the application of the additional time delays required by this paragraph.

C.2.1.5 The sequence for activation of deceleration devices may be selected by the applicant in accordance with § 25.101(f). If, on occasion, the desired sequence is not achieved during testing, the test need not be repeated;

however, sufficient tests should be conducted to establish acceptable values of Δt_a.

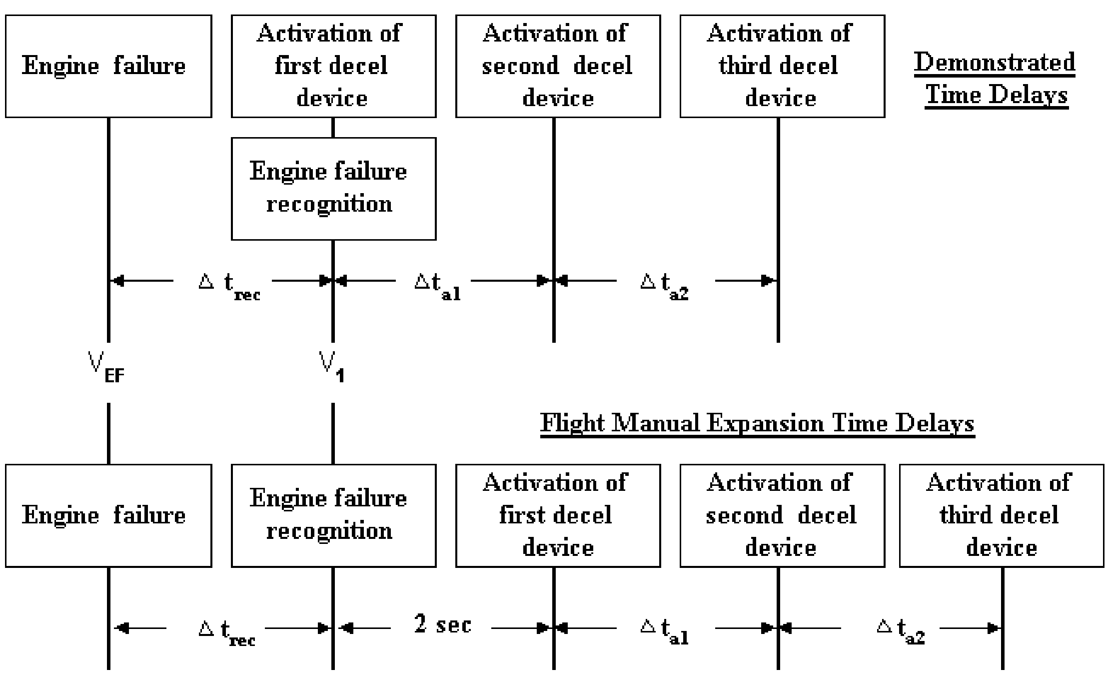
C.2.1.6 If additional devices are used to decelerate the airplane, their respective demonstrated times, plus any additional required time delays, should be included until the airplane is in the full braking configuration.

C.2.1.7 For the purpose of flight manual calculations, the 1-second delay for each action may be added at the end of the total demonstrated time. Regardless of the manner in which the time delays are applied, the flight manual calculations should assume the airplane does not decelerate during the delay time increments.

C.2.2 Amendment 25-42 through Amendment 25-91, Accelerate-Stop Time Delays.

Amendment 25-42, effective March 1, 1978, introduced several new requirements affecting accelerate-stop distance determination. One of the most significant changes of amendment 25-42 was the requirement to determine an all-engines-operating accelerate-stop distance to account for the many rejected takeoffs that were not the result of an engine failure. Amendment 25-42 also introduced into the regulations an engine-failure speed, V_{EF}; redefined the takeoff decision speed, V_1; revised the accelerate-stop distance criteria to correspond to the V_{EF} and V_1 definitions; and added a 2-second time delay between V_1 and the first action to decelerate the airplane during which the airplane continues accelerating with the operating engines at takeoff thrust. Figure C-2 shows a pictorial representation of the accelerate-stop time delays in accordance with the provisions of part 25, including amendment 25-42:

Figure C-2. Accelerate-Stop Time Delays (Amendment 25-42 through Amendment 25-91)



C.2.2.1 Δt_{rec} - § 25.107 defines the relationship between V_{EF} and V_1 as follows: "V_{EF} is the calibrated airspeed at which the critical engine is assumed to fail. V_{EF} must be selected by the applicant, but may not be less than V_{MCG} determined under § 25.149(e). V_1, in terms of calibrated airspeed, is the takeoff decision speed selected by the applicant; however, V_1 may not be less than V_{EF} plus the speed gained with the critical engine inoperative during the time interval between the instant at which the critical engine is failed, and the instant at which the pilot recognizes and reacts to the engine failure, as indicated by the pilot's application of the first retarding means during accelerate-stop tests."

C.2.2.2 Demonstrated engine failure recognition times less than 1 second should be carefully reviewed to assure the conditions under which they were obtained were representative of that which may reasonably be expected to occur in service. A sufficient number of demonstrations should be conducted using both applicant and FAA test pilots to assure that the time increment is representative and repeatable. The pilot's feet should be on the rudder pedals, not brakes, during demonstration tests.

C.2.2.3 Δt_{a1} = the demonstrated time interval between activation of the first and second deceleration devices.

C.2.2.4 Δt_{a2} = the demonstrated time interval between activation of the second and third deceleration devices.

C.2.2.5 If a command is required for another crewmember to activate a deceleration device, a 1-second delay, in addition to the delays specified in paragraphs C.2.2.3 and C.2.2.4 above, should be applied for each action. For automatic deceleration devices which are approved for performance credit for AFM data expansion, established system times determined during certification testing may be used. These established times cannot be assumed to start until after the pilot action that triggers them; that is, they cannot be triggered before the first pilot action and, hence, cannot begin until at least 2 seconds after V_1.

C.2.2.6 The sequence for activation of deceleration devices may be selected by the applicant in accordance with § 25.101(f). If, on occasion, the desired sequence is not achieved during testing, the test need not be repeated; however, sufficient tests should be conducted to establish acceptable values of Δt_a.

C.2.2.7 Figure C-2 shows a pictorial representation of how to apply time delays with up to three deceleration devices. If more than three devices are used to decelerate the airplane, the respective demonstrated time plus a 1-second reaction time delay should be included for each device beyond that represented pictorially in figure C-2 until the airplane is in the full braking configuration.

APPENDIX D. HISTORY OF JET TRANSPORT PERFORMANCE STANDARDS

D.1 Overview.

D.1.1 When the first jet transport airplanes were certificated in the late 1950s, the applicable transport category airworthiness regulations were contained in part 4b of the Civil Air Regulations (CAR 4b). The airworthiness requirements of CAR 4b were developed from years of experience with propeller-driven airplanes powered by reciprocating engines. The different powerplant operating principles, and expanded speed and altitude envelopes, of the first generation jet-powered airplanes required comprehensive changes to the performance requirements of CAR 4b. Special Civil Air Regulation No. SR-422 was adopted in July 1957 as a supplement to CAR 4b, containing airworthiness and operational requirements that were applicable to transport category airplanes powered by turbine engines (turbojet and turbopropeller).

D.1.2 As experience was gained, SR-422 was amended in July 1958 (SR-422A) and July 1959 (SR-422B) to better reflect the operating environment of these new airplane designs. These special civil air regulations, presented in this appendix, formed the basis for the current transport category airworthiness and operating performance regulations of parts 25, 121, and 135. Though the number of operational airplanes that were certificated to these requirements is continually decreasing, these special civil air regulations, and the related preamble material, still provide a worthwhile perspective on many of the issues behind the development of today's regulations, and are therefore preserved for future reference in this appendix.

D.2 Special Civil Air Regulation No. SR-422.

Effective: August 27, 1957
Adopted: July 23, 1957

Turbine-Powered Transport Category Airplanes of Current Design

Part 4b of the Civil Air Regulations contains rules governing the design of transport category airplanes. For a number of years, this part has established airworthiness requirements for this category of airplanes by prescribing detailed provisions to be met for the issuance of a type certificate. However, the advent of turbine-powered airplanes (jets, turbo-props, etc.) has brought about operations at considerably higher speeds and altitudes than those involving reciprocating engine airplanes. These higher speeds and altitudes as well as certain inherent characteristics of turbine engines have introduced numerous new technical and design problems and have necessitated re-evaluation and amendment of many provisions in part 4b.

In recent years the Board has amended part 4b by introducing numerous technical provisions more specifically applicable to turbine-powered airplanes. These were included in amendments pertaining to structural, flight characteristic, powerplant installation, and other provisions. It is believed that part 4b as now written is applicable to turbine-powered airplanes with but one exception; namely, airplane performance. In the future, further amendments to this part, other than those relating to performance, will be comparatively minor in nature mainly reflecting the latest experience in the certification and operation of these airplanes.

The performance requirements presently in part 4b were first promulgated almost twelve years ago. They are now considered by the Board to be in a form not suitable for direct application to turbine-powered airplanes.

The administrator of Civil Aeronautics is in receipt of a large number of applications for type certification of turbine-powered airplanes. However, the so-called “non-retroactive” clause of section 4b.11(a) of part 4b does not make applicable to a particular airplane type any amendment which is adopted after an application is filed by the manufacturer for type certification of that airplane. Thus, most of these airplanes are not now required to meet some of the latest effective provisions of part 4b unless the Board prescribes otherwise. With so many applications for type certificates pending, it is essential that the Board establish adequate requirements which will effectively apply to the type certification of turbine-powered transport category airplanes. This Special Civil Air Regulation is being promulgated for that purpose.

This Special Civil Air Regulation is being made effective with respect to all turbine-powered transport category airplanes not yet certificated. In essence, it prescribes a revised set of performance requirements for turbine-powered airplanes and incorporates such of the recent amendments to part 4b as the Administrator finds necessary to insure that the level of safety of turbine-powered airplanes is equivalent to that generally intended by part 4b.

The performance requirements contained herein include not only the performance requirements necessary for the certification of an airplane, but also the complementary performance operating limitations as applicable under Parts 40, 41, and 42 of the Civil Air Regulations. In promulgating this new performance code, the Board intends that the resulting level of safety will be generally similar to the level of safety established by the performance code as expressed by the provisions now contained in Parts 4b and 40 (or 41 or 42 as appropriate) for reciprocating engine airplanes. To attain this, many of the performance provisions have been modified for better applicability to turbine-powered airplanes, some in the direction of liberalization, others in the direction of improvement in the required performance.

A significant change being made is the introduction of full temperature accountability in all stages of performance, except the landing distances required. The introduction of full temperature accountability will insure that the airplane’s performance is satisfactory irrespective of the existing atmospheric temperature. The performance requirements heretofore applicable did not give sufficient assurance in this respect.

The reason for omitting the direct application of temperature accountability in the requirement for landing distances is that this stage of performance always has been treated in a highly empirical fashion whereby temperature effects are taken into account indirectly together with the effects of other operational factors. Long range studies on rationalization of airplane performance so far have not yielded a satisfactory solution to the landing stage of performance. The Board hopes, however, that continued studies will result in a solution of this problem in the near future.

The introduction of full temperature accountability has necessitated a complete re-evaluation of the minimum climb requirements. Since the prescribed climb must now be met at all temperatures rather than to be associated with standard temperature, the specific values of climb have been altered. In each instance, the change has been in the downward direction because, although the previous values were related to standard temperature, a satisfactory resultant climb performance was attained at temperatures substantially above standard. While values of minimum climb performance specified in the new code will tend to increase the maximum certificated weights of the airplane for the lower range of temperatures, they will limit these weights for the upper range of temperatures, giving adequate assurance of satisfactory climb performance at all temperatures.

In considering the various stages of flight where minimum values of climb have been heretofore established, the Board finds that in two of the stages (all-engines-operating en route and one-engine-inoperative en route) the establishment of minimum values of climb is unnecessary because, in the case of the all-engines-operating stage, it has been found not to be critical and the case of the one-engine-inoperative stage is now more effectively covered by the en route performance operating limitations.

Considering that the minimum climbs being prescribed affect mainly the maximum certificated weights of the airplane but not the maximum operating weights, the Board, in adopting the new performance code, places considerable emphasis on the ability of the airplane to clear obstacles on take-off and during flight. To this end, criteria for the take-off path, the en route flight paths, and the transition from take-off to the en route stage of flight have been prescribed to reflect realistic operating procedures. Temperature is fully accounted for in establishing all flight paths and an expanding clearance between the take-off path and the terrain or obstacles is required until the en route stage of flight is reached.

In order to insure that the objectives of the prescribed performance are in fact realized in actual operations, the manufacturer is required to establish procedures to be followed in the operation of the airplane in the various conditions specified in the regulation. These procedures, each designed for a specific airplane, will permit the operator to utilize the full performance capabilities of the airplane more readily than if the regulations prescribed all-inclusive procedures. The use of these procedures in determining compliance with the requirements governing take-off, en route, and landing stages, will also add considerable flexibility to the regulation.

The new performance requirements established more clearly than heretofore which of the performance limitations are conditions on the airworthiness certificate of the airplane. In addition to the maximum certificated take-off and landing weights, there are included limitations on the take-off distances and on the use of the airplane within the ranges of operational variables, such as altitude, temperature, and wind. Since these limitations are in the airworthiness certificate, they are applicable to all type operations conducted with the airplane.

The new performance code contains values for minimum climb expressed as gradients of climb, in percent, rather than as rates of climb, in feet per minute, as has been the case heretofore. The Board believes that the gradient of climb is more direct in expressing the performance margins of the airplane. Use of the gradient eliminates the influence of the stalling speed on the required climb. Heretofore, higher rates of climb were required for airplanes with higher stalling speeds. The only differentiation in the new code with respect to the required climb is between two and four-engine airplanes. This type of differentiation is of long standing in the regulations, being applicable to the one-engine-inoperative stage of flight. It is now being expanded to the take-off and approach stages.

The new performance requirements contained herein are based on the best information presently available to the Board. It is realized, however, that due to the present limited operating experience with turbine-powered transport airplanes, improvement in the requirements can be expected as a result of the direct application of the code to specific designs of new airplanes. There are certain areas in the new requirements where additional refinement of details might be advisable. This is so particularly in the case of the requirements pertaining to the landing stage of flight. It is anticipated that, after further study of the regulation and especially after its application in the design, certification, and operation of forthcoming turbine-powered airplanes, the desirability of changes may become more apparent. It is the intent of the Board to consider without delay such changes as might be found necessary. Only after the provisions of this Special Civil Air Regulation are reasonably verified by practical application will the Board consider incorporating them on a more permanent basis into Parts 4b, 40, 41, and 42 of the Civil Air Regulations.

This Special Civil Air Regulation is not intended to compromise the authority of the Administrator under section 4b.10 to impose such special conditions as he finds necessary in any particular case to avoid unsafe design features and otherwise to insure equivalent safety.

Interested persons have been afforded an opportunity to participate in the making of this regulation (21 F.R. 6091), and due consideration has been given to all relevant matter presented.

In consideration of the foregoing, the Civil Aeronautics Board hereby makes and promulgates the following Special Civil Air Regulation, effective August 27, 1957.

Contrary provisions of the Civil Air Regulations notwithstanding, all turbine-powered transport category airplanes for which a type certificate is issued after the effective date of this Special Civil Air Regulation shall comply with the following:

1. The provisions of part 4b of the Civil Air Regulations, effective on the date of application for type certificate; and such of the provisions of all subsequent amendments to part 4b, in effect prior to the effective date of this special regulation, as the Administrator finds necessary to insure that the level of safety of turbine-powered airplanes is equivalent to that generally intended by part 4b.

2. In lieu of sections 4b.110 through 4b.125, and 4b.743 of part 4b of the Civil Air Regulations, the following shall be applicable:

Performance

4T.110 *General*.

(a) The performance of the airplane shall be determined and scheduled in accordance with, and shall meet the minima prescribed by, the provisions of sections 4T.110 through 4T.123. The performance limitations, information, and other data shall be given in accordance with section 4T.743.

(b) Unless otherwise specifically prescribed, the performance shall correspond with ambient atmospheric conditions and still air. Humidity shall be accounted for as specified in paragraph (c) of this section.

(c) The performance as affected by engine power and/or thrust shall be based on a relative humidity of 80 percent at and below standard temperatures and on 34 percent at and above standard temperatures plus 50 °F. Between these two temperatures the relative humidity shall vary linearly.

(d) The performance shall correspond with the propulsive thrust available under the particular ambient atmospheric conditions, the particular flight conditions, and the relative humidity specified in paragraph (c) of this section. The available propulsive thrust shall correspond with engine power and/or thrust not exceeding the approved power and/or thrust less the installational losses and less the power and/or equivalent thrust absorbed by the accessories and services appropriate to the particular ambient atmospheric conditions and the particular flight condition.

4T.111 *Airplane configuration, speed, power, and/or thrust; general*.

(a) The airplane configuration (setting of wing and cowl flaps, air brakes, landing gear, propeller, etc.), denoted respectively as the take-off, en route, approach, and landing configurations, shall be selected by the applicant except as otherwise prescribed.

(b) It shall be acceptable to make the airplane configurations variable with weight, altitude, and temperature, to an extent found by the Administrator to be compatible with operating procedures required in accordance with paragraph (c) of this section.

(c) In determining the accelerate-stop distances, take-off flight paths, take-off distances, and landing distances, changes in the airplane's configuration and speed, and in the power and/or thrust shall be in accordance with procedures established by the applicant for the operation of the airplane in service, except as otherwise prescribed. The procedures shall comply with the provisions of subparagraphs (1) through (3) of this paragraph.

(1) The Administrator shall find that the procedures can be consistently executed in service by crews of average skill.

(2) The procedures shall not involve methods or the use of devices which have not been proven to be safe and reliable.

(3) Allowance shall be made for such time delays in the execution of the procedures as may be reasonably expected to occur during service.

4T.112 ***Stalling speeds*.**

The minimum steady flight speed at which the airplane is controllable, in

(a) The speed V_{S0} shall denote the calibrated stalling speed, in knots, with:

(1) Zero thrust at the stalling speed, or engines idling and throttles closed if it is shown that the resultant thrust has no appreciable effect on the stalling speed;

(2) If applicable, propeller pitch controls in the position necessary for compliance with subparagraph (1) of this paragraph;

(3) The airplane in the landing configuration;

(4) The c.g. in the most unfavorable position within the allowable landing range;

(5) The weight of the airplane equal to the weight in connection with which V_S is being used to determine compliance with a particular requirement.

(b) The speed V_{S1} shall denote the calibrated stalling speed, or the minimum steady flight speed at which the airplane is controllable, in knots, with:

(1) Zero thrust at the stalling speed, or engines idling and throttles closed if it is shown that the resultant thrust has no appreciable effect on the stalling speed;

(2) If applicable, propeller pitch controls in the position necessary for compliance with subparagraph (1) of this paragraph; the airplane in all other respects (flaps, landing gear, etc.) in the particular configuration corresponding with that in connection with which V_{S1} is being used;

(3) The weight of the airplane equal to the weight in connection with which V_{S1} is being used to determine compliance with a particular requirement.

(c) The stall speeds defined in this section shall be the minimum speeds obtained in flight tests conducted in accordance with the procedure of subparagraphs (1) and (2) of this paragraph.

(1) With the airplane trimmed for straight flight at a speed of 1.4 V_S and from a speed sufficiently above the stalling speed to insure steady conditions, the elevator control shall be applied at a rate such that the airplane speed reduction does not exceed one knot per second.

(2) During the test prescribed in subparagraph (1) of this paragraph, the flight characteristics provisions of section 4b.160 of part 4b of the Civil Air Regulations shall be complied with.

4T.113 ***Take-off; general***

(a) The take-off data in sections 4T.114 through 4T.117 shall be determined under the conditions of subparagraphs (1) and (2) of this paragraph.

(1) At all weights, altitudes, and ambient temperatures within the operational limits established by the applicant for the airplane.

(2) In the configuration for take-off (see sec. 4T.111).

(b) Take-off data shall be based on a smooth, dry, hard-surfaced runway, and shall be determined in such a manner that reproduction of the performance does not require exceptional skill or alertness on the part of the pilot. In the case of seaplanes or float planes, the take-off surface shall be smooth water, while for skiplanes it shall be smooth dry snow. In addition, the take-off data shall be corrected in accordance with subparagraphs (1) and (2) of this paragraph for wind and for runway gradients within the operational limits established by the applicant for the airplane.

(1) Not more than 50 percent of nominal wind components along the take-off path opposite to the direction of take-off, and not less than 150 percent of nominal wind components along the take-off path in the direction of take-off.

(2) Effective runway gradients.

4T.114 ***Take-off speeds*.**

(a) The critical-engine-failure speed V_1, in terms of calibrated air speed, shall be selected by the applicant, but shall not be less than the minimum speed at which controllability by primary aerodynamic controls alone is demonstrated during the take-off run to be adequate to permit proceeding safely with the take-off using average piloting skill, when the critical engine is suddenly made inoperative.

(b) The minimum take-off safety speed V_2, in terms of calibrated air speed, shall be selected by the applicant so as to permit the gradient of climb required in section 4T.120(a) and (b), but it shall not be less than:

(1) 1.2 V_{S1} for two-engine propeller-driven airplanes and for airplanes without propellers which have no provisions for obtaining a significant reduction in the one-engine-inoperative power-on stalling speed.

(2) 1.15 V_{S1} for propeller-driven airplanes having more than two engines and for airplanes without propellers which have provisions for obtaining a significant reduction in the one-engine-inoperative power-on stalling speed;

(3) 1.10 times the minimum control speed V_{MC}, established in accordance with section 4b.133 of part 4b of the Civil Air Regulations.

(c) If engine failure is assumed to occur at or after the attainment of V_2, the demonstration in which the take-off run is continued to include the take-off climb, as provided in paragraph (a) of this section, shall not be required.

4T.115 ***Accelerate-stop distance.***

(a) The accelerate-stop distance shall be the sum of the following:

(1) The distance required to accelerate the airplane from a standing start to the speed V_1;

(2) Assuming the critical engine to fail at the speed V_1, the distance required to bring the airplane to a full stop from the point corresponding with the speed V_1.

(b) In addition to, or in lieu of, wheel brakes, the use of other braking means shall be acceptable in determining the accelerate-stop distance, provided that such braking means shall have been proven to be safe and reliable, that the manner of their employment is such that consistent results can be expected in service, and that exceptional skill is not required to control the airplane.

(c) The landing gear shall remain extended throughout the accelerate-stop distance.

4T.116 ***Take-off path.*** The take-off path shall be considered to extend from the standing start to a point in the take-off where a height of 1,000 feet above the take-off surface is reached or to a point in the take-off where the transition from the take-off to the en route configuration is completed and a speed is reached at which compliance with section 4T.120(c) is shown, whichever point is at a higher altitude. The conditions of paragraphs (a) through (i) of this section shall apply in determining the take-off path.

(a) The take-off path shall be based upon procedures prescribed in accordance with section 4T.111(c).

(b) The airplane shall be accelerated on or near the ground to the speed V_2 during which time the critical engine shall be made inoperative at speed V_1 and shall remain inoperative during the remainder of the take-off.

(c) Landing gear retraction shall not be initiated prior to reaching the speed V_2

(d) The slope of the airborne portion of the take-off path shall be positive at all points.

(e) After the V_2 speed is reached, the speed throughout the take-off path shall not be less than V_2 and shall be constant from the point where the landing gear is completely retracted until a height of 400 feet above the take-off surface is reached.

(f) Except for gear retraction and propeller feathering, the airplane configuration shall not be changed before reaching a height of 400 feet above the take-off surface.

(g) At all points along the take-off path starting at the point where the airplane first reaches a height of 400 feet above the take-off surface, the available gradient of climb shall not be less than 1.4 percent for two-engine airplanes and 1.8 percent for four-engine airplanes.

(h) The take-off path shall be determined either by a continuous demonstration take-off, or alternatively, by synthesizing from segments the complete take-off path.

(i) If the take-off path is determined by the segmental method, the provisions of subparagraphs (1) through (4) of this paragraph shall be specifically applicable.

(1) The segments of a segmental take-off path shall be clearly defined and shall be related to the distinct changes in the configuration of the airplane, in power and/or thrust, and in speed.

(2) The weight of the airplane, the configuration, and the power and/or thrust shall be constant throughout each segment and shall correspond with the most critical condition prevailing in the particular segment.

(3) The segmental flight path shall be based on the airplane's performance without ground effect.

(4) Segmental take-off path data shall be checked by continuous demonstrated take-offs to insure that the segmental path is conservative relative to the continuous path.

4T.117 ***Take-off distance.*** The take-off distance shall be the horizontal distance along the take-off path from the start of the take-off to the point where the airplane attains a height of 35 feet above the take-off surface as determined in accordance with 4T.116.

4T.118 ***Climb; general.*** Compliance shall be shown with the climb requirements of sections 4T.119 and 4T.120 at all weights, altitudes, and ambient temperatures, within the operational limits established by the applicant for the airplane. The airplane's c.g. shall be in the most unfavorable position corresponding with the applicable configuration.

4T.119 ***All-engine-operating landing climb.*** In the landing configuration, the steady gradient of climb shall not be less than 4.0 per cent, with:

(a) All engines operating at the available take-off power and/or thrust;

(b) A climb speed not in excess of 1.4 V_{S0}.

4T.120 ***One-engine-inoperative climb.***

(a) *Take-off; landing gear extended*. In the take-off configuration at the point of the flight path where the airplane's speed first reaches V_2, in accordance with section 4T.116 but without ground effect, the steady gradient of climb shall be positive with:

(1) The critical engine inoperative, the remaining engine(s) operating at the available take-off power and/or thrust existing in accordance with section 4T.116 at the time the airplane's landing gear is fully retracted;

(2) The weight equal to the airplane's weight existing in accordance with section 4T.116 at the time retraction of the airplane's landing gear is initiated;

(3) The speed equal to the speed V_2.

(b) *Take-off; landing gear retracted*. In the take-off configuration at the point of the flight path where the airplane's landing gear is fully retracted, in accordance with section 4T.116 but without ground effect, the steady gradient of climb shall not be less than 2.5 percent for two-engine airplanes and not less than 3.0 percent for four-engine airplanes, with:

(1) The critical engine inoperative, the remaining engine(s) operating at the take-off power and/or thrust available at a height of 400 feet above the take-off surface and existing in accordance with section 4T.116;

(2) The weight equal to the airplane's weight existing in accordance with section 4T.116 at the time the airplane's landing gear is fully retracted;

(3) The speed equal to the speed V_2.

(c) *Final take-off*. In the en route configuration, the steady gradient of climb shall not be less than 1.4 percent for two-engine airplanes and not less than 1.8 percent for four-engine airplanes, at the end of the take-off path as determined by section 4T.116, with:

(1) The critical engine inoperative, the remaining engine(s) operating at the available maximum continuous power and/or thrust;

(2) The weight equal to the airplane's weight existing in accordance with section 4T.116 at the time retraction of the airplane's flaps is initiated;

(3) The speed equal to not less than 1.25 V_{S1}.

(d) *Approach*. In the approach configuration such that V_{S1} does not exceed 1.10 V_{S0}, the steady gradient of climb shall not be less than 2.2 percent for two-engine airplanes and not less than 2.8 percent for four-engine airplanes, with:

(1) The critical engine inoperative, the remaining engine(s) operating at the available take-off power and/or thrust;

(2) The weight equal to the maximum landing weight;

(3) A climb speed in excess of 1.5 V_{S1}.

4T.121 *En route flight paths.* With the airplane in the en route configuration, the flight paths prescribed in paragraphs (a) and (b) of this section shall be determined at all weights, altitudes, and ambient temperatures within the limits established by the applicant for the airplane.

(a) *One engine inoperative*. The one-engine-inoperative net flight path data shall be determined in such a manner that they represent the airplane's actual climb performance diminished by a gradient of climb equal to 1.4 percent for two-engine airplanes and 1.8 percent for four-engine airplanes. It shall be acceptable to include in these data the variation of the airplane's weight along the flight path to take into account the progressive consumption of fuel and oil by the operating engine(s).

(b) *Two engines inoperative*. For airplanes with four engines, the two-engine-inoperative net flight path data shall be determined in such a manner that they represent the airplane's actual climb performance diminished by a gradient of climb equal to 0.6 percent. It shall be acceptable to include in these data the variation of the airplane's weight along the flight path to take into account the progressive consumption of fuel and oil by the operating engines.

(c) *Conditions*. In determining the flight paths prescribed in paragraphs (a) and (b) of this section, the conditions of subparagraphs (1) through (4) of this paragraph shall apply.

(1) The airplane's c.g. shall be in the most unfavorable position.

(2) The critical engine(s) shall be inoperative, the remaining engine(s) operating at the available maximum continuous power and/or thrust.

(3) Means for controlling the engine cooling air supply shall be in the position which provides adequate cooling in the hot-day condition.

(4) The speed shall be selected by the applicant.

4T.122 *Landing distance.* The landing distance shall be the horizontal distance required to land and to come to a complete stop (to a speed of approximately 3 knots in the case of seaplanes or float planes) from a point at a height of 50 feet above the landing surface. Landing distances shall be determined for standard temperatures at all weights, altitudes, and winds within the operational limits established by the applicant for the airplane. The conditions of paragraphs (a) through (f) of this section shall apply.

(a) The airplane shall be in the landing configuration. During the landing, changes in the airplane's configuration, in power and/or thrust, and in speed shall be in accordance with procedures established by the applicant for the operation of the airplane in service. The procedures shall comply with the provisions of section 4T.111(c).

(b) The landing shall be preceded by a steady gliding approach down to the 50-foot height with a calibrated air speed of not less than 1.3 V_{S0}.

(c) The landing distance shall be based on a smooth, dry, hard-surfaced runway, and shall be determined in such a manner that reproduction does not require exceptional skill or alertness on the part of the pilot. In the case of seaplanes or float planes, the landing surface shall be smooth water, while for skiplanes it shall be smooth dry snow. During landing, the airplane shall not exhibit excessive vertical acceleration, a tendency to bounce, nose over, ground loop, porpoise, or water loop.

(d) The landing distance shall be corrected for not more than 50 percent of nominal wind components along the landing path opposite to the direction of landing and not less than 150 percent of nominal wind components along the landing path in the direction of landing.

(e) During landing, the operating pressures on the wheel braking system shall not be in excess of those approved by the manufacturer of the brakes, and the wheel brakes shall not be used in such a manner as to produce excessive wear of brakes and tires.

(f) If the Administrator finds that a device on the airplane other than wheel brakes has a noticeable effect on the landing distance and if the device depends upon the operation of the engine and the effect of such a device is not compensated for by other devices in the event of engine failure, the landing distance shall be determined by assuming the critical engine to be inoperative.

4T.123 *Limitations and information*.

(a) *Limitations*. The performance limitations on the operation of the airplane shall be established in accordance with subparagraphs (1) through (4) of this paragraph. (See also sec. 4T.743.)

(1) *Take-off weights*. The maximum take-off weights shall be established at which compliance is shown with the generally applicable provisions of this regulation and with section 4T.120(a), (b), and (c) for altitudes and ambient temperatures within the operational limits of the airplane (see subparagraph (4) of this paragraph).

(2) *Landing weights*. The maximum landing weights shall be established at which compliance is shown with the generally applicable provisions of this regulation and with sections 4T.119 and 4T.120(d) for altitudes and ambient temperatures within the operational limits of the airplane (see subparagraph (4) of this paragraph).

(3) *Take-off and accelerate-stop distances*. The minimum distances required for take-off shall be established at which compliance is shown with the generally applicable provisions of this regulation and with sections 4T.115 and 4T.117 for weights, altitudes, temperatures, wind components, and runway gradients, within the operational limits of the airplane (see subparagraph (4) of this paragraph).

(4) *Operational limits*. The operational limits of the airplane shall be established by the applicant for all variable factors required in showing compliance with this regulation (weight, altitude, temperature, etc.). (See secs. 4T.113(a)(1) and (b), 4T.118, 4T.121, and 4T.122.)

(b) *Information*. The performance information on the operation of the airplane shall be scheduled in compliance with the generally applicable provisions of this regulation and with sections 4T.116, 4T.121, and 4T.122 for weights, altitudes, temperatures, wind components, and runway gradients, as these may be applicable, within the operational limits of the airplane (see subparagraph (a)(4) of this section). In addition, the performance information specified in subparagraphs (1) through (3) of this paragraph shall be determined by extrapolation and scheduled for the ranges of weights between the maximum landing and maximum take-off weights established in accordance with subparagraphs (a) (1) and (a) (2) of this section. (See also sec. 4T.743.)

(1) Climb in the landing configuration (see sec. 4T.119);

(2) Climb in the approach configuration (see sec. 4T.120(d));

(3) Landing distance (see sec. 4T.122).

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4T.743 *Performance limitations, information, and other data*.

(a) *Limitations*. The airplanes' performance limitations shall be given in accordance with section 4T.123(a).

(b) *Information*. The performance information prescribed in section 4T.123(b) for the application of the operating rules of this regulation shall be given together with descriptions of the conditions, air speeds, etc. under which the data were determined.

(c) *Procedures*. For all stages of flight, procedures shall be given with respect to airplane configurations, power and/or thrust settings, and indicated air speeds, to the extent such procedures are related to the limitations and information set forth in accordance with paragraphs (a) and (b) of this section.

(d) *Miscellaneous*. An explanation shall be given of significant or unusual flight or ground handling characteristics of the airplane.

3. In lieu of sections 40.70 through 40.78, 41-27 through 41.36(d), and 42.70 through 42.83, of Parts 40, 41, and 42 of the Civil Air Regulations, respectively, the following shall be applicable:

Operating Rules

40T.80 *Transport category airplane operating limitations*.

(a) In operating any passenger-carrying transport category airplane certificated in accordance with the performance requirements of this regulation, the provisions of sections 40T.80 through 40T.894 shall be complied with, unless deviations therefrom are specifically authorized by the Administrator on the ground that the special circumstances of a particular case make a literal observance of the requirements unnecessary for safety.

(b) The performance data in the AFM shall be applied in determining compliance with the provisions of sections 40T.81 through 40T.84. Where conditions differ from those for which specific tests were made compliance shall be determined by approved interpolation or computation of the effects of changes in the specific variables if such interpolations or computations give results substantially equaling in accuracy the results of a direct test.

40T.81 ***Airplane's certificate limitations*.**

(a) No airplane shall be taken off at a weight which exceeds the take-off weight specified in the AFM for the elevation of the airport and for the ambient temperature existing at the time of the take-off. (See sec. 4T.123(a)(1) and 4T.743(a).)

(b) No airplane shall be taken off at a weight such that, allowing for normal consumption of fuel and oil in flight to the airport of destination, the weight on arrival will exceed the landing weight specified in the AFM for the elevation of the airport of destination and for the ambient temperature anticipated there at the time of landing. (See secs. 4T.123(a) (2) and 4T.743(a).)

(c) No airplane shall be taken off at a weight which exceeds the weight shown in the AFM to correspond with the minimum distance required for take-off on the runway to be used. The take-off distance shall correspond with the elevation of the airport, the effective runway gradient, and the ambient temperature and wind component existing at the time of take-off. (See secs. 4T.123(a)(3) and 4T.743 (a).)

(d) No airplane shall be operated outside the operational limits specified in the AFM (See secs. 4T.123(a) (4) and 4T.742(a)).

40T.82 ***Take-off obstacle clearance limitations.*** No airplane shall be taken off at a weight in excess of that shown in the AFM to correspond with a take-off path which clears all obstacles either by at least a height equal to (35 + 0.01D) feet vertically, where D is the distance out along the intended flight path from the end of the runway in feet, or by at least 200 feet horizontally within the airport boundaries and by at least 300 feet horizontally after passing beyond the boundaries. In determining the allowable deviation of the flight path in order to avoid obstacles by at least the distances prescribed, it shall be assumed that the airplane is not banked before reaching a height of 50 feet as shown by the take-off path data in the AFM, and that a maximum bank thereafter does not exceed 15 degrees. The take-off path considered shall be for the elevation of the airport, the effective runway gradient, and for the ambient temperature and wind component existing at the time of take-off. (See secs. 4T.123(b) and 4T.743(b).)

40T.83 ***En route limitations*.**

(a) *One engine inoperative*. No airplane shall be taken off at a weight in excess of that which, according to the one-engine-inoperative en route net flight path data shown in the AFM, will permit compliance with either subparagraph (1) or subparagraph (2) of this paragraph at all points along the route. The net flight path used shall be for the ambient temperatures anticipated along the route. (See secs. 4T.123(b) and 4T.743(b).)

(1) The slope of the net flight path shall be positive at an altitude of at least 1,000 feet above all terrain and obstructions along the route within 5 miles on either side of the intended track.

(2) The net flight path shall be such as to permit the airplane to continue flight from the cruising altitude to an alternate airport where a landing can be made in accordance with the provisions of section 40T.84(b), the net flight path clearing vertically by at least 2,000 feet all terrain and obstructions along the route within 5 miles on either side of the intended track. The provisions of subdivisions (i) through (vii) of this paragraph shall apply.

(i) The engine shall be assumed to fail at the most critical point along the route.

(ii) The airplanes shall be assumed to pass over the critical obstruction following engine failure at a point no closer to the critical obstruction than the nearest approved radio navigational fix, except that the Administrator may authorize a procedure established on a different basis where adequate operational safeguards are found to exist.

(iii) The net flight path shall have a positive slope at 1,000 feet above the airport used as the alternate.

(iv) An approved method shall be used to account for winds which would otherwise adversely affect the flight path.

(v) Fuel jettisoning shall be permitted if the Administrator finds that the operator has an adequate training program, proper instructions are given to the flight crew, and all other precautions are taken to insure a safe procedure.

(vi) The alternate airport shall be specified in the dispatch release and shall meet the prescribed weather minima.

(vii) The consumption of fuel and oil after the engine becomes inoperative shall be that which is accounted for in the net flight path data shown in the AFM.

(b) *Two engines inoperative*. No airplane shall be flown along an intended route except in compliance with either subparagraph (1) or subparagraph (2) of this paragraph.

(1) No place along the intended track shall be more than 90 minutes away from an airport at which a landing can be made in accordance with the provisions of section 40T.84(b), assuming all engines to be operating at cruising power.

(2) No airplane shall be taken off at a weight in excess of that which, according to the two-engine-inoperative en route net flight path data shown in the AFM, will permit the airplane to continue flight from the point where two engines are assumed to fail simultaneously to an airport where a landing can be made in accordance with the provisions of section 40T.84(b), the net flight path having a positive slope at an altitude of at least 1,000 feet above all terrain and obstructions along the route within 5 miles on either side of the intended track or at an altitude of 5,000 feet, whichever is higher. The net flight path considered shall be for the

ambient temperatures anticipated along the route. The provisions of subdivision (i) through (iii) of this subparagraph shall apply. (See secs. 4T.123(b) and 4T.743(b).)

(i) The two engines shall be assumed to fail at the most critical point along the route.

(ii) If fuel jettisoning is provided, the airplane's weight at the point where the two engines are assumed to fail shall be considered to be not less than that which would include sufficient fuel to proceed to the airport and to arrive there at an altitude of at least 1,000 feet directly over the landing area.

(iii) The consumption of fuel and oil after the engines become inoperative shall be that which is accounted for in the net flight path data shown in the AFM.

40T.84 *Landing limitations*.

(a) *Airport of destination*. No airplane shall be taken off at a weight in excess of that which, in accordance with the landing distances shown in the AFM for the elevation of the airport of intended destination and for the wind conditions anticipated there at the time of landing, would permit the airplane to be brought to rest at the airport of intended destination within 60 percent of the effective length of the runway from a point 50 feet directly above the intersection of the obstruction clearance plane and the runway. The weight of the airplane shall be assumed to be reduced by the weight of the fuel and oil expected to be consumed in flight to the airport of intended destination. Compliance shall be shown with the conditions of subparagraphs (1) and (2) of this paragraph. (See secs. 4T.123(b) and 4T.743(b).)

(1) It shall be assumed that the airplane is landed on the most favorable runway and direction in still air.

(2) It shall be assumed that the airplane is landed on the most suitable runway considering the probable wind velocity and direction and taking due account of the ground handling characteristics of the airplane and of other conditions (i.e., landing aids, terrain, etc.). If full compliance with the provisions of this subparagraph is not shown, the airplane may be taken off if an alternate airport is designated which permits compliance with paragraph (b) of this section.

(b) *Alternate airport*. No airport shall be designated as an alternate airport in a dispatch release unless the airplane at the weight anticipated at the time of arrival at such airport can comply with the provisions of paragraph (a) of this section, provided that the airplane can be brought to rest within 70 percent of the effective length of the runway.

D.3 Special Civil Air Regulation No. SR-422A.

Adopted: July 2, 1958
Effective: July 2, 1958

Turbine-Powered Transport Category Airplanes of Current Design

On July 23, 1957, the Board adopted Special Civil Air Regulation No. SR-422 which sets forth airworthiness requirements applicable to the type certification and operation of turbine-powered transport category airplanes for which a type certificate is issued after August 27, 1957. Included in that regulation was a new set of performance requirements, with respect to which the Board indicated that consideration would be given to any changes found necessary as a result of further study and experience. The preamble to SR-422 contains the relevant considerations leading to its promulgation and is considered to provide the basic background for this regulation.

Since the adoption of SR-422, considerable study has been devoted to the new performance requirements by all interested parties. As a result of these studies and of further experience gained in the design, certification, and operation of turbine-powered airplanes, certain issues with respect to SR-422 require re-evaluation. This regulation reflects the resolution of most of the outstanding issues in the light of the best information presently available to the Board.

The following provisions of this regulation differ from, or are additional to, the provisions of SR-422; Introductory paragraph; item 1; sections 4T.111(c); 4T.112; 4T.114 (b), (b)(1), (b)(4), and (c); introductory paragraph of 4T.116; 4T.116 (b), (c), (e), and (g); 4T.117; 4T.117a; 4T.119; 4T.120 (a), (a)(1), (b), (b)(1), (c), (c)(2), (c)(3), (d), and (d)(3); 4T.121 (a) and (b); introductory paragraph of 4T.122; 4T.122 (b), (f), and (g); 4T.123 (a)(1), (a)(2), (a)(3), and (b); 4T.743(c); 40T.81 (b) and (c); 40T.82; 40T.83 (a)(2)(iii), (b)(2), and (b)(2)(ii); item 4; and item 5.

Of these provisions, the following differ from those proposed in Civil Air Regulations Draft Release No. 58-6: sections 4T.111(c); 4T.112(a)(4); 4T.114 (b)(4), (c), (c)(2), (c)(3), and (c)(4); 4T.116 (c) and (e); 4T.117 (b)(1) and (b)(2); 4T.119(a); 4T.120(a); 40T.81(c) and 43T.11(c).

With respect to the applicability of this regulation, experience with certification under SR-422 indicates that a lead time of about two months between the date of adoption of the regulation and the date of issuance of the type certificate should provide a reasonable period of time within which to show compliance with this regulation. In view of this, and in the interest of having uniform regulations applicable to most of the turbine-powered airplanes, it is considered advisable to have this regulation apply to all such airplanes for which a type certificate is issued after September 30, 1958. Turbine-powered transport category airplanes for which a type certificate is issued on or prior to September 30, 1958, may comply with the provisions of this regulation in lieu of SR-422. If this option is exercised, it is intended that compliance be shown with all the provisions of this regulation and it is not intended to permit a showing of compliance with portions of this regulation and portions of SR-422.

The provisions of this regulation involve the following technical issues:

A substantive change is made by introducing an all-engines-operating take-off in establishing the take-off distance. Presently, the take-off distance is based only on a one-engine-out take-off. To insure that an adequate margin of safety will exist for day-in and day-out operations, the minimum take-off distance is being related to both the one-engine-inoperative distance now prescribed and to the distance with all engines operating, with a factor of 1.15 being applied to the latter.

There are also included important changes with respect to the speeds applicable to the take-off path. The provisions of SR-422 prescribe that the airplane shall be accelerated on or near the ground to the speed V_2. This provision has been subject to varying interpretations having a marked difference in effect on the resultant level of performance. The issue in this matter is whether or not the airplane should be permitted to lift off the runway at some speed below V_2. Because of the increased acceleration of turbine-powered airplanes, the tendency to overshoot the lift-off speed will be greater than on piston-engine airplanes and this tendency increases with the reduction in weight of the airplane. To restrict lift-off to the minimum take-off safety speed V_2 would unduly extend the take-off distance in cases where such overshooting of speed occurs. Such a restriction would be unnecessarily conservative and would not reflect realistic take-off procedures. For these reasons this regulation permits the airplane to lift off the ground at a speed lower than the V_2 speed, but prescribes certain limiting conditions. The lift-off speed is related to a rotational speed VR which must not be less than 95 percent of the minimum V_2 speed and must be 10 percent greater than a speed at which no hazardous characteristics are displayed by the airplane, such as a relatively high drag condition or a ground stall. The V_2 speed has been re-defined to take into account the increment in speed arising from overshoot tendencies. Under the new definition, the minimum V_2 speed corresponds with the minimum take-off safety speed as now defined in SR-422. With respect to the take-off path, the V_2 speed is required to be attained prior to reaching a height of 35 feet above the take-off surface and thus is related to the selection of the rotational speed. Further, there is a revision which requires V_2 to be maintained as close as practicable at a constant value from the 35-foot point to a height of 400 feet above the take-off surface. This speed is the speed at which the prescribed minimum take-off gradients must be met.

There is introduced in this regulation the concept of unbalanced take-off field lengths. SR-422 does not preclude unbalancing of field lengths, provided that the unbalancing is within the length of the runway. Other countries have employed unbalancing with respect to so-ca1led "stopways" and "clearways." It appears that United States operators ultimately will find it advantageous to resort to the use of unbalancing, but probably not to the same extent as practiced in other countries. On the premise that only clearways will be utilized, the amendments have been formulated accordingly. Clearways, as defined herein, are areas not suitable for stopping the airplane in the event of an aborted take-off, but adequate to provide additional take-off distance for climb-out. To safeguard operations utilizing clearways, there is introduced the concept of a take-off run which operationally relates to the determination of the minimum runway length required. The take-off run is defined as the greater of the horizontal distances along the take-off path to a given point with one engine inoperative or with all engines operating, with a margin of 15 percent being added to the latter. The take-off run is measured from the beginning of take-off to a point equidistant between the point where the airplane lifts off and the point where a height of 35 feet is reached. The required runway length must not be less than the take-off run nor less than the accelerate stop distance.

According to the definition given, a clearway is subjected to the control of the airport authorities. It is not intended, however, that there be ownership by the airport authorities of the area in which the clearway lies. The objective for requiring control by the airport authorities is to insure that no flight will be initiated using a clearway unless it is determined with certainty that no movable obstacle will exist within the clearway when the airplane flies over.

It is anticipated that the introduction of clearways will offer further possibilities of increasing the utility of existing airport facilities in this country. When such areas can be integrated into existing facilities, economical benefits will accrue to the community and the operators. In addition, since clearways are presently available at some of the airports in other countries, United States operators will have the opportunity of taking advantage of such facilities.

There are included changes with respect to the prescribed minimum altitude of 1,000 feet relative to the take-off path and to the one-engine-inoperative and two-engine-inoperative requirements applicable to the vicinity of the airport. Heretofore, the Civil Air Regulations have incorporated the reference altitude of 1,000 feet in respect of performance criteria over the airport. Obscure as is the significance of this altitude operationally, the altitude of 1,500 feet has worldwide precedent of being used as the altitude above the airport at which, generally, IFR approaches are initiated and go-around procedures executed. For this reason, the changes made extend the take-off path to a minimum altitude of 1,500 feet and make this altitude applicable to the prescribed performance criteria above the airport for the one- and two-engine-inoperative en route requirements. It is not anticipated that these changes will create any problems with respect to the en route stages of flight; however, it is realized that a further extension of the take-off path might add to the problem of obtaining accurate data on obstacles relatively distant from the airport. The Board finds that the extension of the flight path to 1,500 feet is warranted in light of the operational significance of this altitude and because the extended flight paths will provide more fully for adequate terrain clearance at the end of the take-off path.

There is included a change with respect to the take-off path whereby the take-off flight path is established as starting from a 35-foot height at the end of the take-off distance and a net take-off flight is prescribed for operational use. This latter change is for consistency with the specification of net flight paths for the en route stages of flight and to simplify determination of obstacle clearances operationally. The net flight path is specified to be the actual flight path diminished by a gradient of 1.0 percent. It is intended that the net flight path be obtained from the gross flight path by simple geometric means.

The change in the altitude from 1,000 to 1,500 feet previously mentioned, as well as a reevaluation in other respects of some of the climb gradients in SR-422, justify certain changes. The gradients of 1.4 and 1.8 applicable to the take-off path and the final take-off climb are being reduced to 1.2 and 1.7 for two-engine and four-engine airplanes, respectively. In addition, the gradients 1.4 and 1.8 in the one-engine-inoperative en route case are being reduced to 1.1 and 1.6, respectively.

Changes are made with respect to the one-engine-inoperative take-off climb by interrelating more realistically the prescribed airplane configuration, weight, and power. These changes, in effect, permit meeting the prescribed gradients of climb at slightly higher airplane weights than would be possible under the presently effective provisions.

There is included a change to the provisions applicable to the one-engine-inoperative take-off climb with landing gear extended which increases the prescribed minimum gradient from substantially zero to 0.5 percent for four-engine airplanes. This change is made to attain consistency in the difference between gradients applicable to twins and fours.

Changes are incorporated in connection with the two-engine-inoperative en route requirement. Representations have been made that the gradient of 0.6 percent now prescribed is unduly conservative. On the other hand, it has been pointed out that the fuel requirements for this case are not realistically covered. Both of these contentions warrant consideration and changes are included which reduce the margin gradient from 0.6 to 0.5 percent, reduce the prescribed altitude from 5,000 to 2,000 feet, and require scheduling the flight so that there is sufficient fuel on board to reach the airport and subsequently to fly for 15 minutes at cruise power or thrust.

Changes are also made relative to the approach and landing stages of flight. There is a new provision which requires the establishment of procedures for the execution of missed approaches and balked landings. A question has been raised as to whether the speed limitation of 1.5 V_S applicable to the approach condition is realistically related to the normal day-in and day-out landing procedures. To insure that it will be so related, it is required that the speed used for demonstrating the approach climb be established consistent with the landing procedures, but that it not exceed 1.5 V_S. In addition, the approach gradient of 2.8 percent prescribed for four-engine airplanes is being reduced to 2.7 percent to obtain consistency in the differences between gradients applicable to twins and fours.

A change is made to the "all-engines-operating landing climb" provisions which now require a 4.0 percent gradient of climb in the landing configuration. On the premise that requiring the landing configuration during the climb after a balk is unduly conservative, consideration was given to a proposal to permit showing of compliance with the 4.0 percent gradient of climb in the configuration which would exist 5 seconds after the initiation of the climb. Further study of this proposal indicated that such a rule would tend to introduce complications in design and lead to less favorable operating procedures which ultimately would not contribute to safety. One of the most important factors in connection with this configuration is the response of the engines to throttle movement. Therefore, there is a provision which requires that the power used in showing compliance with the climb gradient be that power or thrust attained 8 seconds after initiation of movement of the power controls to the take-off position from the minimum flight idle position. In addition, for consistency with the procedures used for determining the landing distance, the speed limitation of 1.4 V_S is reduced to 1.3 V_S.

Concern has been indicated to the effect that any reduction in the prescribed gradient of 1.0 percent might not insure in all cases the ability of the airplane to continue a safe climb after a balk. To provide a further safeguard, the take-off weight-altitude-temperature limitations (WAT limitations stemming from the application of the one-engine-inoperative take-off climb requirements) are being made applicable to the maximum landing weight at the airport of landing. In the past, the landing weight limitations were applicable to the airport of destination but not to the weather alternates. This regulation makes both the take-off weight and landing weight limitations equally applicable to the airport of destination and the weather alternates. In view of the aforementioned changes, a reduction of the required climb gradient from 4.0 to 3.2 percent is justified and included in this regulation.

In addition to the substantive changes which have been discussed, there are three significant changes of a clarifying nature. The first deals with the determination of the landing distance as affected by devices or means other than wheel brakes. There is included a provision similar to the one applicable to the accelerate-stop distance for application to the landing distance. This provision permits the use of means other than wheel brakes in the determination of the landing distance. Additionally, there is a change to the provision which requires in some cases the determination of the landing distance with one engine inoperative. It is believed that the new requirement expresses the intent more clearly. One of the more obvious applications of this provision is in respect of turbo-propeller airplanes. Such airplanes usually are landed with the propellers in a relatively high drag position. If one of the engines becomes inoperative, its propeller would be expected to be in a relatively low drag position with the consequence of a longer landing distance than with all engines operating. In such a case it is required that the landing distance be determined with one engine inoperative unless use could be made by the crew of other means (e.g., reverse thrust not otherwise considered in determining the landing distance) which would reduce the landing distance at least to that determined for all-engine operation. The second clarification being included deals with the provision setting forth the procedures which must be included in the AFM. This provision in SR-422 does not make clear what procedures are involved and whether the procedures are considered to be limitations on the operation of the airplane. The clarification in language specifies that the procedures which are included with the performance limitations shall be considered only as guidance material.

The third clarification concerns the applicability of the performance limitations prescribed in SR-422. These consist of the “certificate limitations” and the “operating limitations.” The former relate to maximum take-off and landing weights, minimum take-off distances, accelerate-stop distances, and the operational limits imposed upon the airplane. These limitations, being part of the conditions of the type and airworthiness certificates, must be complied with at all times irrespective of the type of operation being conducted (e.g., air carrier, private, cargo). The “operating limitations,” distinct from the “certificate limitations,” are only applicable when required by the operating parts of the regulations (Parts 40, 41, and 42 require compliance for passenger operations). Although it appeared that previous Board pronouncements regarding this general principle as well as the explanation contained in the preamble to SR-422 would make the issue quite clear, it has come to the Board’s attention that there is still some misunderstanding of this matter. Apparently this misunderstanding stems from the fact that SR-422 prescribes operating rules for air carrier operations which contain both the “certificate limitations” and the “operating limitations” while no prescription is given to non-air-carrier operations; thus giving an impression that not even the “certificate limitations” are applicable to non-air-carriers. The inclusion of “certificate limitations” for air carrier operations with the “operating limitations” was meant only to provide the operators with the convenience of having together the complete prescription of the applicable performance limitations, notwithstanding that such an inclusion, in fact, duplicates the general requirement of compliance with the “certificate limitations” contained in the AFM. In view of the possible misunderstanding which might exist from the aforementioned inclusion, there are included in this regulation the same "certificate limitations" for application to all operations under the provisions of part 43 of the Civil Air Regulations.

In addition, other changes of a minor nature are included herein, the most significant of which is the generalization of the stall speed V_S, eliminating reference to V_{S0} and V_{S1}.

Of the changes to SR-422 made in this regulation, there are a number which might require further consideration as studies continue and as additional experience is gained with the application of these new rules. Several of these involve new concepts with which U.S. operators have had little or no experience. These entail the requirements relative to unbalanced field lengths with respect to clearways, to the rotational speed, and to the all-engine take-off distance. Strong representation has been made to the Board to the effect that the numerical factors applicable to the aforementioned rules are too high and should be reduced pending further experience. The Board considers that it would not be in the public interest to reduce any of these factors until such time as further experience indicates that they are in fact overly conservative. Realizing, however, that these issues are of considerable importance in prescribing a practicable level of performance, the Board stands ready to reconsider the relevant provisions of this regulation at such time as substantiating information is received.

There are areas other than those previously mentioned where additional refinement of details may be advisable. This is so particularly in the case of the requirements pertaining to the landing stage of flight, to the take-off lateral clearances, and to the two-engine inoperative en route gradient margin. It is anticipated that, after further study of the regulation and especially after its application in the design, certification, and operation of forthcoming turbine-powered airplanes, the desirability of changes may become more apparent. It is the intent of the Board to consider without delay such changes as might be found necessary. Only after the provisions of this Special Civil Air Regulation are reasonably verified by practical application will the Board consider incorporating them on a more permanent basis into Parts 4b, 40, 41, 42, and 43 of the Civil Air Regulations.

This Special Civil Air Regulation is not intended to compromise the authority of the Administrator under section 4b.10 to impose such special conditions as he finds necessary in any particular case to avoid unsafe design features and otherwise to insure equivalent safety.

Interested persons have been afforded an opportunity to participate in the making of this regulation (23 F.R.2139), and due consideration has been given to all relevant matter presented.

In consideration of the foregoing, the Civil Aeronautics Board hereby makes and promulgates the following Special Civil Air Regulation, effective July 2, 1958:

Contrary provisions of the Civil Air Regulations notwithstanding, all turbine-powered transport category airplanes for which a type certificate is issued after August 27, 1957, shall comply with Special Civil Air Regulation No. SR-422 or, alternatively, with the following provisions, except that those airplanes for which a type certificate is issued after September 30,1958, shall comply with the following provisions:

1. The provisions of part 4b of the Civil Air Regulations, effective on the date of application for type certificate; and such of the provisions of all subsequent amendments to part 4b, in effect prior to August 27, 1957, as the Administrator finds necessary to insure that the level of safety of turbine-powered airplanes is equivalent to that generally intended by part 4b.

2. In lieu of sections 4b.110 through 4b.125, and 4b.743 of part 4b of the Civil Air Regulations, the following shall be applicable:

Performance

4T.110 *General*.

(a) The performance of the airplane shall be determined and scheduled in accordance with, and shall meet the minima prescribed by, the provisions of sections 4T.110 through 4T.123. The performance limitations, information, and other data shall be given in accordance with section 4T.743.

(b) Unless otherwise specifically prescribed, the performance shall correspond with ambient atmospheric conditions and still air. Humidity shall be accounted for as specified in paragraph (c) of this section.

(c) The performance as affected by engine power and/or thrust shall be based on a relative humidity of 80 percent at and below standard temperatures and on 34 percent at and above standard temperatures plus 50° F. Between these two temperatures the relative humidity shall vary linearly.

(d) The performance shall correspond with the propulsive thrust available under the particular ambient atmospheric conditions, the particular flight condition, and the relative humidity specified in paragraph (c) of this section. The available propulsive thrust shall correspond with engine power and/or thrust not exceeding the approved power and/or thrust less the installational losses and less the power and/or equivalent thrust absorbed by the accessories and services appropriate to the particular ambient atmospheric conditions and the particular flight condition.

4T.111 *Airplane configuration, speed, power, and/or thrust; general*.

(a) The airplane configuration (setting of wing and cowl flaps, air brakes, landing gear, propeller, etc.), denoted respectively as the take-off, en route, approach, and landing configurations, shall be selected by the applicant except as otherwise prescribed.

(b) It shall be acceptable to make the airplane configurations variable with weight, altitude, and temperature, to an extent found by the Administrator to be compatible with operating procedures required in accordance with paragraph (c) of this section.

(c) In determining the accelerate-stop distances, take-off flight paths, take-off distances, and landing distances, changes in the airplane's configuration and speed, and in the power and/or thrust shall be in accordance with procedures established by the applicant for the operation of the airplane in service, except as otherwise prescribed. In addition, procedures shall be established for the execution of balked landings and missed approaches associated with the conditions prescribed in section 4T.119 and 4T.120(d), respectively. All procedures shall comply with the provisions of subparagraphs (1) through (3) of this paragraph.

(1) The Administrator shall find that the procedures can be consistently executed in service by crews of average skill.

(2) The procedures shall not involve methods or the use of devices which have not been proven to be safe and reliable.

(3) Allowance shall be made for such time delays in the execution of the procedures as may be reasonably expected to occur during service.

4T.112 ***Stalling speeds*.**

(a) The speed V_S, shall denote the calibrated stalling speed, or the minimum steady flight speed at which the airplane is controllable, in knots, with:

(1) Zero thrust at the stalling speed, or engines idling and throttles closed if it is shown that the resultant thrust has no appreciable effect on the stalling speed;

(2) If applicable, propeller pitch controls in the position necessary for compliance with subparagraph (1) of this paragraph; the airplane in all other respects (flaps, landing gear, etc.) in the particular configuration corresponding with that in connection with which V_S is being used;

(3) The weight of the airplane equal to the weight in connection with which V_S is being used to determine compliance with a particular requirement;

(4) The c.g. in the most unfavorable position within the allowable range.

(b) The stall speed defined in this section shall be the minimum speed obtained in flight tests conducted in accordance with the procedure of subparagraphs (1) and (2) of this paragraph.

(1) With the airplane trimmed for straight flight at a speed of 1.4 V_S and from a speed sufficiently above the stalling speed to insure steady conditions, the elevator control shall be applied at a rate such that the airplane speed reduction does not exceed one knot per second.

(2) During the test prescribed in subparagraph (1) of this paragraph, the flight characteristics provisions of section 4b.160 of part 4b of the Civil Air Regulations shall be complied with.

4T.113 ***Take-off; general*.**

(a) The take-off data in sections 4T.114 through 4T.117 shall be determined under the conditions of subparagraphs (1) and (2) of this paragraph.

(1) At all weights, altitudes, and ambient temperatures within the operational limits established by the applicant for the airplane.

(2) In the configuration for take-off (see sec. 4T.111).

(b) Take-off data shall be based on a smooth, dry, hard-surfaced runway and shall be determined in such a manner that reproduction of the performance does not require exceptional skill or alertness on the part of the pilot. In the case of seaplanes or float planes, the take-off surface shall be smooth water, while for skiplanes it shall be smooth dry snow. In addition, the take-off data shall be corrected in accordance with subparagraphs (1) and (2) of this paragraph for wind and for runway gradients within the operational limits established by the applicant for the airplane.

(1) Not more than 50 percent of nominal wind components along the take-off path opposite to the direction of take-off, and not less than 150 percent of nominal wind components along the take-off path in the direction of take-off.

(2) Effective runway gradients.

4T.114 ***Take-off speeds*****.**

(a) The critical-engine-failure speed V_1, in terms of calibrated air speed, shall be selected by the applicant, but shall not be less than the minimum speed at which controllability by primary aerodynamic controls alone is demonstrated during the take-off run to be adequate to permit proceeding safely with the take-off using average piloting skill, when the critical engine is suddenly made inoperative.

(b) The take-off safety speed V_2, in terms of calibrated air speed, shall be selected by the applicant so as to permit the gradient of climb required in section 4T.120 (a) and (b), but it shall not be less than:

(1) 1.2 V_S for two-engine propeller-driven airplanes and for airplanes without propellers which have no provisions for obtaining a significant reduction in the one-engine-inoperative power-on stalling speed;

(2) 1.15 V_S for propeller-driven airplanes having more than two engines and for airplanes without propellers which have provisions for obtaining a significant reduction in the one-engine-inoperative power-on stalling speed;

(3) 1.10 times the minimum control speed V_{MC}, established in accordance with section 4b.133 of part 4b of the Civil Air Regulations;

(4) The rotation speed V_R plus the increment in speed attained in compliance with section 4T.116(e).

(c) The minimum rotation speed V_R, in terms of calibrated air speed, shall be selected by the applicant, except that it shall not be less than:

(1) The speed V_1;

(2) A speed equal to 95 percent of the highest speed obtained in compliance with subparagraph (1) or (2), whichever is applicable, and with subparagraph (3) of paragraph (b) of this section;

(3) A speed which permits the attainment of the Speed V_2 prior to reaching a height of 35 feet above the take-off surface as determined in accordance with section 4T.116(e);

(4) A speed equal to 110 percent of the minimum speed above which the airplane, with all engines operating, can be made to lift off the ground and to continue the take-off without displaying any hazardous characteristics.

4T.115 ***Accelerate-stop distance*****.**

(a) The accelerate-stop distance shall be the sum of the following:

(1) The distance required to accelerate the airplane from a standing start to the speed V_1;

(2) Assuming the critical engine to fail at the speed V_1, the distance required to bring the airplane to a full stop from the point corresponding with the speed V_1.

(b) In addition to, or in lieu of, wheel brakes, the use of other braking means shall be acceptable in determining the accelerate-stop distance, provided that such braking means shall have been proven to be safe and reliable, that the manner of their employment is such that consistent results can be expected in service, and that exceptional skill is not required to control the airplane.

(c) The landing gear shall remain extended throughout the accelerate-stop distance.

4T.116 ***Take-off path*****.**

The take-off path shall be considered to extend from the standing start to a point in the take-off where a height of 1,500 feet above the take-off surface is reached or to a point in the take-off where the transition from the take-off to the en route configuration is completed and a speed is reached at which compliance with section 4T.120(c) is shown, whichever point is at a higher altitude. The conditions of paragraphs (a) through (i) of this section shall apply in determining the take-off path.

(a) The take-off path shall be based upon procedures prescribed in accordance with section 4T.111(c).

(b) The airplane shall be accelerated on the ground to the speed V_1 at which point the critical engine shall be made inoperative and shall remain inoperative during the remainder of the take-off. Subsequent to attaining speed V_1, the airplane shall be accelerated to speed V_2, during which time it shall be permissible to initiate raising the nose gear off the ground at a speed not less than the rotation speed V_R.

(c) Landing gear retraction shall not be initiated until the airplane becomes airborne.

(d) The slope of the airborne portion of the take-off path shall be positive at all points.

(e) The airplane shall attain the speed V_2 prior to reaching a height of 35 feet above the take-off surface and shall continue at a speed as close as practical to, but not less than, V_2 until a height of 400 feet above the take-off surface is reached.

(f) Except for gear retraction and propeller feathering, the airplane configuration shall not be changed before reaching a height of 400 feet above the take-off surface.

(g) At all points along the take-off path starting at the point where the airplane first reaches a height of 400 feet above the take-off surface, the available gradient of climb shall not be less than 1.2 percent for two-engine airplanes and 1.7 percent for four-engine airplanes.

(h) The take-off path shall be determined either by a continuous demonstrated take-off, or alternatively, by synthesizing from segments the complete take-off path.

(i) If the take-off path is determined by the segmental method, the provisions of subparagraphs (1) through (4) of this paragraph shall be specifically applicable.

(1) The segments of a segmental take-off path shall be clearly defined and shall be related to the distinct changes in the configuration of the airplane, in power and/or thrust, and in speed.

(2) The weight of the airplane, the configuration, and the power and/or thrust shall be constant throughout each segment and shall correspond with the most critical condition prevailing in the particular segment.

(3) The segmental flight path shall be based on the airplane's performance without ground effect.

(4) Segmental take-off path data shall be checked by continuous demonstrated takeoffs to insure that the segmental path is conservative relative to the continuous path.

4T.117 *Take-off distances and take-off run*.

(a) *Take-off distance.* The take-off distance shall be the greater of the distances established in accordance with subparagraphs (1) and (2) of this paragraph.

(1) The horizontal distance along the take-off path from the start of the take-off to the point where the airplane attains a height of 35 feet above the take-off surface, as determined in accordance with section 4T.116.

(2) A distance equal to 115 percent of the horizontal distance along the take-off path, with all engines operating, from the start of the take-off to the point where the airplane attains a height of 35 feet above the take-off surface, as determined by a procedure consistent with that established in accordance with section 4T.116.

(b) *Take-off run*. If the take-off distance is intended to include a clearway (see item 5 of this regulation), the take-off run shall be determined and shall be the greater of the distances established in accordance with subparagraphs (1) and (2) of this paragraph.

(1) The horizontal distance along the take-off path from the start of the take-off to a point equidistant between the point where the airplane first becomes airborne and the point where it attains a height of 35 feet above the take-off surface, as determined in accordance with section 4T.116.

(2) A distance equal to 115 percent of the horizontal distance along the take-off path, with all engines operating, from the start of the take-off to a point equidistant between the point where the airplane first becomes airborne and the point where it attains a height of 35 feet above the take-off surface, as determined by a procedure consistent with that established in accordance with section 4T.116.

4T.117a *Take-off flight path*.

(a) The take-off flight path shall be considered to begin at a height of 35 feet above the take-off surface at the end of the take-off distance as determined in accordance with section 4T.117(a).

(b) The net take-off flight path data shall be determined in such a manner that they represent the airplane's actual take-off flight paths, determined in accordance with paragraph (a) of this section, diminished by a gradient of climb equal to 1.0 percent.

4T.118 *Climb; general.* Compliance shall be shown with the climb requirements of sections 4T.119 and 4T.120 at all weights, altitudes, and ambient temperatures, within the operational limits established by the applicant for the airplane. The airplane's c.g. shall be in the most unfavorable position corresponding with the applicable configuration.

4T.119 *All engine-operating landing climb.* In the landing configuration the steady gradient of climb shall not be less than 3.2 percent, with:

(a) All engines operating at the power and/or thrust which is available 8 seconds after initiation of movement of the power and/or thrust controls from the minimum flight idle to the take-off position;

(b) A climb speed not in excess of 1.3 V_S.

4T.120 *One engine-inoperative climb.*

(a) *Take-off; landing gear extended*. In the take-off configuration existing at the point of the flight path where the airplane first becomes airborne, in accordance with section 4T.116 but without ground effect, the steady gradient of climb shall be positive for two-engine airplanes and shall not be less than 0.5 percent for four-engine airplanes, with:

(1) The critical engine inoperative, the remaining engine(s) operating at the available take-off power and/or thrust existing in accordance with section 4T.116 at the time

retraction of the airplane's landing gear is initiated, unless subsequently a more critical power operating condition exists along the flight path prior to the point where the landing gear is fully retracted;

(2) The weight equal to the airplane's weight existing in accordance with section 4T.116 at the time retraction of the airplane's landing gear is initiated;

(3) The speed equal to the speed V_2.

(b) *Take-off; landing gear retracted*. In the take-off configuration existing at the point of the flight path where the airplane's landing gear is fully retracted, in accordance with section 4T.116 but without ground effect, the steady gradient of climb shall not be less than 2.5 percent for two-engine airplanes and not less than 3.0 percent for four-engine airplanes, with:

(1) The critical engine inoperative, the remaining engine(s) operating at the available take-off power and/or thrust existing in accordance with section 4T.116 at the time the landing gear is fully retracted, unless subsequently a more critical power operating condition exists along the flight path prior to the point where a height of 400 feet above the take-off surface is reached;

(2) The weight equal to the airplane's weight existing in accordance with section 4T.116 at the time the airplane's landing gear is fully retracted.

(3) The speed equal to the speed V_2.

(c) *Final take-off*. In the en route configuration, the steady gradient of climb shall not be less than 1.2 percent for two-engine airplanes and not less than 1.7 percent for four-engine airplanes, at the end of the take-off path as determined by section 4T.116, with:

(1) The critical engine inoperative, the remaining engine(s) operating at the available maximum continuous power and/or thrust;

(2) The weight equal to the airplane's weight existing in accordance with section 4T.116 at the end of the take-off path;

(3) The speed equal to not less than 1.25 V_S.

(d) *Approach*. In the approach configuration such that the corresponding V_S for this configuration does not exceed 110 percent of the V_S, corresponding with the related landing configuration, the steady gradient of climb shall not be less than 2.2 percent for two-engine airplanes and not less than 2.7 percent for four-engine airplanes with:

(1) The critical engine inoperative, the remaining engine(s) operating at the available take-off power and/or thrust;

(2) The weight equal to the maximum landing weight;

(3) A climb speed established by the applicant in connection with normal landing procedures, except that it shall not exceed 1.5 V_S (see sec. 4T.111(c)).

4T.121 *En route flight paths.* With the airplane in the en route configuration, the flight paths prescribed in paragraphs (a) and (b) of this section shall be determined at all weights, altitudes, and ambient temperatures within the limits established by the applicant for the airplane.

(a) *One engine inoperative*. The one-engine-inoperative net flight path data shall be determined in such a manner that they represent the airplane's actual climb performance diminished by a gradient of climb equal to 1.1 percent for two-engine airplanes and 1.6 percent for four-engine airplanes. It shall be acceptable to include in these data the variation of the airplane's weight along the flight path to take into account the progressive consumption of fuel and oil by the operating engine(s).

(b) *Two engines inoperative*. For airplanes with four engines, the two-engine-inoperative net flight path data shall be determined in such a manner that they represent the airplane's actual climb performance diminished by a gradient of climb equal to 0.5 percent. It shall be acceptable to include in these data the variation of the airplane's weight along the flight path to take into account the progressive consumption of fuel and oil by the operating engines.

(c) *Conditions*. In determining the flight paths prescribed in paragraphs (a) and (b) of this section, the conditions of subparagraphs (1) through (4) of this paragraph shall apply.

(1) The airplane's c.g. shall be in the most unfavorable position.

(2) The critical engine(s) shall be inoperative, the remaining engine(s) operating at the available maximum continuous power and/or thrust.

(3) Means for controlling the engine cooling air supply shall be in the position which provides adequate cooling in the hot-day condition.

(4) The speed shall be selected by the applicant.

4T.122 *Landing distance.* The landing distance shall be the horizontal distance required to land and to come to a complete stop (to a speed of approximately 3 knots in the case of seaplanes or float planes) from a point at a height of 50 feet above the landing surface. Landing distances shall be determined for standard temperatures at all weights, altitudes, and winds within the operational limits established by the applicant for the airplane. The conditions of paragraphs (a) through (g) of this section shall apply.

(a) The airplane shall be in the landing configuration. During the landing, changes in the airplane's configuration, in power and/or thrust, and in speed shall be in accordance with procedures established by the applicant for the operation of the airplane in service. The procedures shall comply with the provisions of section 4T.111(c).

(b) The landing shall be preceded by a steady gliding approach down to the 50-foot height with a calibrated air speed of not less than 1.3 V_S.

(c) The landing distance shall be based on a smooth, dry, hard-surfaced runway, and shall be determined in such a manner that reproduction does not require exceptional skill or alertness on the part of the pilot. In the case of seaplanes or float planes, the landing surface shall be smooth water, while for skiplanes it shall be smooth dry snow. During landing, the airplane shall not exhibit excessive vertical acceleration, a tendency to bounce, nose over, ground loop, porpoise, or water loop.

(d) The landing distance shall be corrected for not more than 50 percent of nominal wind components along the landing path opposite to the direction of landing and not less than 150 percent of nominal wind components along the landing path in the direction of landing.

(e) During landing, the operating pressures on the wheel braking system shall not be in excess of those approved by the manufacturer of the brakes, and the wheel brakes shall not be used in such a manner as to produce excessive wear of brakes and tires.

(f) In addition to, or in lieu of, wheel brakes, the use of other braking means shall be acceptable in determining the landing distance, provided such braking means shall have been proven to be safe and reliable, that the manner of their employment is such that consistent results can be expected in service, and that exceptional skill is not required to control the airplane.

(g) If the characteristics of a device (e.g., the propellers) dependent upon the operation of any of the engines noticeably increase the landing distance when the landing is made with the engine inoperative, the landing distance shall be determined with the critical engine inoperative unless the Administrator finds that the use of compensating means will result in a landing distance not greater than that attained with all engines operating.

4T.123 *Limitations and information*.

(a) *Limitations*. The performance limitations on the operation of the airplane shall be established in accordance with subparagraphs (1) through (4) of this paragraph. (See also Sec. 4T.743.)

(1) *Take-off weights*. The maximum take-off weights shall be established at which compliance is shown with the generally applicable provisions of this regulation and with the take-off climb provisions prescribed in section 4T.120 (a), (b), and (c) for altitudes and ambient temperatures within the operational limits of the airplane (see subparagraph (4) of this paragraph).

(2) *Landing weights*. The maximum landing weights shall be established at which compliance is shown with the generally applicable provisions of this regulation and with the landing and take-off climb provisions prescribed in sections 4T.119 and 4T.120 for altitudes and ambient temperatures within the operational limits of the airplane (see subparagraph (4) of this paragraph).

(3) *Accelerate-stop distance, take-off distance, and take-off run*. The minimum distances required for take-off shall be established at which compliance is shown with the generally applicable provisions of this regulation and with sections 4T.115 and 4T.117(a), and with 4T.117(b) if the take-off distance is intended to include a clearway, for weights, altitudes,

temperatures, wind components, and runway gradients, within the operational limits of the airplane (see subparagraph (4) of this paragraph).

(4) *Operational limits*. The operational limits of the airplane shall be established by the applicant for all variable factors required in showing compliance with this regulation (weight, altitude, temperature, etc.). (See secs. 4T.113 (a)(1) and (b), 4T.118, 4T.121, and 4T.122.)

(b) *Information*. The performance information on the operation of the airplane shall be scheduled in compliance with the generally applicable provisions of this regulation and with sections 4T.117a(b), 4T.121, and 4T.122 for weights, altitudes, temperatures, wind components, and runway gradients, as these may be applicable, within the operational limits of the airplane (see subparagraph (a)(4) of this section). In addition, the performance information specified in subparagraphs (1) through (3) of this paragraph shall be determined by extrapolation and scheduled for the ranges of weights between the maximum landing and maximum take-off weights established in accordance with subparagraphs (a)(1) and (a)(2) of this section. (See also sec. 4T.743.)

(1) Climb in the landing configuration (see sec. 4T.119);

(2) Climb in the approach configuration (see sec. 4T.120(d));

(3) Landing distance (see sec. 4T.122).

Airplane Flight Manual

4T.743 *Performance limitations, information, and other data*.

(a) *Limitations*. The airplane's performance limitations shall be given in accordance with section 4T.123(a).

(b) *Information*. The performance information prescribed in section 4T.123(b) for the application of the operating rules of this regulation shall be given together with descriptions of the conditions, air speeds, etc., under which the data were determined.

(c) *Procedures*. Procedures established in accordance with section 4T.111(c) shall be given to the extent such procedures are related to the limitations and information set forth in accordance with paragraphs (a) and (b) of this section. Such procedures, in the form of guidance material, shall be included with the relevant limitations or information, as applicable.

(d) *Miscellaneous*. An explanation shall be given of significant or unusual flight or ground handling characteristics of the airplane.

3. In lieu of sections 40.70 through 40.78, 41.27 through 41.36(d), and 42.70 through 42.83, of Parts 40, 41, and 42 of the Civil Air Regulations, respectively, the following shall be applicable:

Operating Rules

40T.80 ***Transport category airplane operating limitations*.**

(a) In operating any passenger-carrying transport category airplane certificated in accordance with the performance requirements of this regulation, the provisions of sections 40T.80 through 40T.84 shall be complied with, unless deviations therefrom are specifically authorized by the Administrator on the ground that the special circumstances of a particular case make a literal observance of the requirements unnecessary for safety.

(b) The performance data in the AFM shall be applied in determining compliance with the provisions of sections 40T.81 through 40T.84. Where conditions differ from those for which specific tests were made, compliance shall be determined by approved interpolation or computation of the effects of changes in the specific variables if such interpolations or computations give results substantially equaling in accuracy the results of a direct test.

40T.81 ***Airplane's certificate limitations*.**

(a) No airplane shall be taken off at a weight which exceeds the take-off weight specified in the AFM for the elevation of the airport and for the ambient temperature existing at the time of the take-off. (See secs. 4T.123(a)(1) and 4T.743(a).)

(b) No airplane shall be taken off at a weight such that, allowing for normal consumption of fuel and oil in flight to the airport of destination and to the alternate airports, the weight on arrival will exceed the landing weight specified in the AFM for the elevation of each of the airports involved and for the ambient temperatures anticipated at the time of landing. (See secs. 4T.123(a)(2) and 4T.743(a).

(c) No airplane shall be taken off at a weight which exceeds the weight shown in the AFM to correspond with the minimum distances required for take-off. These distances shall correspond with the elevation of the airport, the runway to be used, the effective runway gradient, and the ambient temperature and wind component existing at the time of take-off. (See secs. 4T.123(a)(3) and 4T.743(a).) If the take-off distance includes a clearway as defined in Item 5 of this regulation, the take-off distance shall not include a clearway distance greater than one-half of the take-off run.

(d) No airplane shall be operated outside the operational limits specified in the AFM. (See secs. 4T.123(a)(4) and 42.743(a).)

40T.82 ***Take-off obstacle clearance limitations.*** No airplane shall be taken off at a weight in excess of that shown in the AFM to correspond with a net take-off flight path which clears all obstacles either by at least a height of 35 feet vertically or by at least 200 feet horizontally within the airport boundaries and by at least 300 feet horizontally after passing beyond the boundaries. In determining the allowable deviation of the flight path in order to avoid obstacles by at least the distances prescribed, it shall be assumed that the airplane is not banked before reaching a height of 50 feet as shown by the take-off path data in the AFM, and that a maximum bank thereafter does not exceed 15 degrees. The take-off path considered shall be for the elevation of the airport, the effective runway gradient, and for the ambient temperature and wind component existing at the time of take-off. (See secs. 4T.123(b) and 4T.743(b).)

40T.83 ***En route limitations*.**

(a) *One engine inoperative*. No airplane shall be taken off at a weight in excess of that which, according to the one-engine-inoperative en route net flight path data shown in the AFM, will permit compliance with either subparagraph (1) or subparagraph (2) of this paragraph at all points along the route. The net flight path used shall be for the ambient temperatures anticipated along the route. (See secs. 4T.123(b) and 4T.743(b).)

(1) The slope of the net flight path shall be positive at an altitude of at least 1,000 feet above all terrain and obstructions along the route within 5 miles on either side of the intended track.

(2) The net flight path shall be such as to permit the airplane to continue flight from the cruising altitude to an alternate airport where a landing can be made in accordance with the provisions of section 40T.84(b), the net flight path clearing vertically by at least 2,000 feet all terrain and obstructions along the route within 5 miles on either side of the intended track. The provisions of subdivisions (i) through (vii) of this subparagraph shall apply.

(i) The engine shall be assumed to fail at the most critical point along the route.

(ii) The airplane shall be assumed to pass over the critical obstruction following engine failure at a point no closer to the critical obstruction than the nearest approved radio navigational fix, except that the Administrator may authorize a procedure established on a different basis where adequate operational safeguards are found to exist.

(iii) The net flight path shall have a positive slope at 1,500 feet above the airport used as the alternate.

(iv) An approved method shall be used to account for winds which would otherwise adversely affect the flight path.

(v) Fuel jettisoning shall be permitted if the Administrator finds that the operator has an adequate training program, proper instructions are given to the flight crew, and all other precautions are taken to insure a safe procedure.

(vi) The alternate airport shall be specified in the dispatch release and shall meet the prescribed weather minima.

(vii) The consumption of fuel and oil after the engine becomes inoperative shall be that which is accounted for in the net flight path data shown in the AFM.

(b) *Two engines inoperative*. No airplane shall be flown along an intended route except in compliance with either subparagraph (1) or subparagraph (2) of this paragraph.

(1) No place along the intended track shall be more than 90 minutes away from an airport at which a landing can be made in accordance with the provisions of section 4OT.84(b), assuming all engines to be operating at cruising power.

(2) No airplane shall be taken off at a weight in excess of that which, according to the two-engine-inoperative en route net flight path data shown in the AFM, will permit the airplane to continue flight from the point where two engines are assumed to fail simultaneously to an airport where a landing can be made in accordance with the provisions of section 40T.84(b), the net flight path having a positive slope at an altitude of at least 1,000 feet above all terrain and obstructions along the route within 5 miles on either side of the intended track or at an altitude of 2,000 feet, whichever is higher. The net flight path considered shall be for the ambient temperatures anticipated along the route. The provisions of subdivisions (i) through (iii) of this subparagraph shall apply. (See secs. 4T.123(b) and 4T.743(b).)

(i) The two engines shall be assumed to fail at the most critical point along the route.

(ii) The airplane's weight at the point where the two engines are assumed to fail shall be considered to be not less than that which would include sufficient fuel to proceed to the airport and to arrive there at an altitude of at least 1,500 feet directly over the landing area and thereafter to fly for 15 minutes at cruise power and/or thrust.

(iii) The consumption of fuel and oil after the engines become inoperative shall be that which is accounted for in the net flight path data shown in the AFM.

40T.84 *Landing limitations*.

(a) *Airport of destination*. No airplane shall be taken off at a weight in excess of that which, in accordance with the landing distances shown in the AFM for the elevation of the airport of intended destination and for the wind conditions anticipated there at the time of landing, would permit the airplane to be brought to rest at the airport of intended destination within 60 percent of the effective length of the runway from a point 50 feet directly above the intersection of the obstruction clearance plane and the runway. The weight of the airplane shall be assumed to be reduced by the weight of the fuel and oil expected to be consumed in flight to the airport of intended destination. Compliance shall be shown with the conditions of subparagraphs (1) and (2) of this paragraph. (See secs. 4T.123(b) and 4T.743(b).)

(1) It shall be assumed that the airplane is landed on the most favorable runway and direction in still air.

(2) It shall be assumed that the airplane is landed on the most suitable runway considering the probable wind velocity and direction and taking due account of the ground handling characteristics of the airplane and of other conditions (i.e., landing aids, terrain, etc.). If full compliance with the provisions of this subparagraph is not shown, the airplane may be taken off if an alternate airport is designated which permits compliance with paragraph (b) of this section.

(b) *Alternate airport*. No airport shall be designated as an alternate airport in a dispatch release unless the airplane at the weight anticipated at the time of arrival at such airport can comply with the provisions of paragraph (a) of this section, provided that the airplane can be brought to rest within 70 percent of the effective length of the runway.

4. In lieu of section 43.11 of part 43 of the Civil Air Regulations, the following shall be applicable:

43T.11 ***Transport category airplane weight limitations.*** The performance data in the AFM shall be applied in determining compliance with the following provisions:

(a) No airplane shall be taken off at a weight which exceeds the take-off weight specified in the AFM for the elevation of the airport and for the ambient temperature existing at the time of the take-off. (See secs. 4T.123(a)(1) and 4T.743(a).)

(b) No airplane shall be taken off at a weight such that, allowing for normal consumption of fuel and oil in flight to the airport of destination and to the alternate airports, the weight on arrival will exceed the landing weight specified in the AFM for the elevation of each of the airports involved and for the ambient temperatures anticipated at the time of landing. (See secs. 4T.123(a)(2) and 4T.743(a).)

(c) No airplane shall be taken off at a weight which exceeds the weight shown in the AFM to correspond with the minimum distances required for take-off. These distances shall correspond with the elevation of the airport, the runway to be used, the effective runway gradient, and the ambient temperature and wind component existing at the time of take-off. (See secs. 4T.123(a)(3) and 4T.743(a).) If the take-off distance includes a clearway as defined in Item 5 of this regulation, the take-off distance shall not include a clearway distance greater than one-half of the take-off run.

(d) No airplane shall be operated outside the operational limits specified in the AFM. (See secs. 4T.123(a)(4) and 4T.743(a).)

5. The following definitions shall apply:

Clearway. A clearway is an area beyond the airport runway not less than 300 feet on either side of the extended center line of the runway, at an elevation no higher than the elevation at the end of the runway, clear of all fixed obstacles, and under the control of the airport authorities.

D.4 Special Civil Air Regulation No. SR-422B.

Effective: July 9, 1959
Issued: July 9, 1959

Turbine Powered Transport Category Airplane of Current Design

Special Civil Air Regulation No. SR-422, effective August 27, 1957, prescribes requirements applicable to the type certification and operation of turbine-powered transport category airplanes for which a type certificate is issued after August 27, 1957. Special Civil Air Regulation No. SR-422A, effective July 2, 1958, included substantive changes to SR-422 and was made applicable to all turbine-powered transport category airplanes for which a type certificate is issued after September 30, 1958.

This Special Civil Air Regulation makes further changes to the airworthiness rules for turbine-powered transport category airplanes to be applicable to all such airplanes for which a type certificate is issued after August 29, 1959. These changes were proposed in Draft Release No. 58-1 C (24 F.R. 128) by the Civil Aeronautics Board in connection with the 1958 Annual Airworthiness Review. The amendments herein have been adopted after careful consideration of all the discussion and comment received thereon.

Substantive and minor changes have been made to the provisions of SR-422A. For ease in identification they are listed as follows:

(a) Substantive changes: introductory paragraphs; 4T.114 (b), (c), (d), (e), and (f); 4T.115(d); 4T.117a(b); 4T.120(a)(3), (b), and (d); 40T.81(c); 43T.11(c); and item 5 (a) and (b).

(b) Minor changes; item 2; 4T.112 (title), (b)(1), (c), (d), and (e); 4T.113(b); 4T.116(i)(4); 4T.117(b) (1) and (2); 4T.120(a); 4T.121; 4T.122(d); 4T.123(a); 40T.82; and 40T.83.

Pertinent background information to this regulation is contained in the preambles to SR-422 and SR-422A. Following is a discussion of important issues relevant to the changed provisions contained herein.

One of the most important changes being introduced concerns the rotation speed V_R of the airplane during takeoff (4T.114). Experience gained in the certification of airplanes under the provisions of SR-422 and SR-422A indicates that relating V_R to the stall speed is not essential and might unduly penalize airplanes with superior flying qualities. It has been found that the primary limitations on V_R should be in terms of a margin between the actual lift-off speeds V_{LOF} and the minimum unstick speed V_{MU} at which the airplane can proceed safely with the takeoff. The provisions contained herein require that V_R speeds be established to be applicable to takeoffs with one engine inoperative as well as with all engines operating. The V_{MU} speeds can be established from free air data provided that the data are verified by ground takeoff tests. Certain safeguards are included in conjunction with the establishment of V_R speeds to ensure that takeoffs in service can be made with consistent safety.

A change is being introduced to the provision in 4T.117a(b) concerning the manner in which the net takeoff flight path is obtained. In accordance with this provision as contained in SR-422A, the net takeoff flight path would have a negative slope throughout the acceleration segment. Since this segment usually represents level flight easily controlled by reference to the normal flight instruments, a significant reduction in the flight path's gradient would not be expected. For these reasons, the provision is being changed to permit an equivalent reduction in acceleration in lieu of a reduction in gradient.

Section 4T.117a(b) is being amended additionally by changing the value of gradient margin in the net flight path for two-engine airplanes from 1.0 percent to 0.8 percent. The value for four engine airplanes remains 1.0 percent. Differentiation in gradient values in the net flight path between two and four-engine airplanes is consistent with the differentiation in the climb gradients for the takeoff, enroute, and approach stages of flight. Statistical analysis substantiates the specific reduction of the net flight path gradient to a value of 0.8 percent. Correlatively, a reevaluation of the climb gradients for twin-engine airplanes in the second segment takeoff and in the approach climb indicates that the respective values should be 2.4 percent and 2.1 percent and these changes are being made in 4T.120 (b) and (d).

A change is introduced in the conditions prescribed for meeting the climb gradient in the first segment takeoff climb (4T.120(a)), by changing the speed V_2 to the speed V_{LOF}. The intent of this requirement is to use the speed at which the airplane lifts off the ground. In SR-422 this speed was considered to be V_2; however, in SR-422A and in this regulation the speed V_2 is a higher speed which is reached at the end of the takeoff distance and no longer reflects the conditions pertinent to the first segment climb. In making this change consistent with relevant changes in SR-422A and in this regulation, no consideration has been given to the appropriateness of the minimum climb gradient values prescribed for the first segment climb. These are subject to alteration if results of further studies so indicate.

There is being introduced in this regulation the concept of "stopways," the definition of which is contained in item 5(b). Stopways have been used outside the United States in meeting the accelerate-stop distances in case of aborted takeoffs. They are considered to result in more practical operations. In order to ensure that they can be used without detrimental effects on safety, a provision is being included in 4T.115(d) requiring taking into account the surface characteristics of the stopways to be used in scheduling the accelerate-stop distances in the AFM.

In conjunction with the introduction of stopways, there are changes being made in the definition of a "clearway" (item 5(a)). One of the changes is to specify that a clearway begins at the end of the runway whether or not a stopway is being used. Of the other changes, the most significant one expresses the clearway in terms of a clearway plane and permits this plane to have an upward slope of 1.25 percent. In effect, this change will allow, in some cases, use of clearways which would not be allowed under the definition in SR-422A because of relatively small obstacles or slightly sloping terrain. (See also 40T.81(c) and 43T.11(c).)

There are also included in this regulation a number of minor, editorial, or clarifying changes.

Draft Release No. 58-1C included a proposal for expanding lateral obstacle clearances in the takeoff flight path. Studies indicate that some expanding lateral clearances are necessary for safety in operations with all turbine-powered airplanes. It appears, therefore, that an appropriate rule should be made applicable not only to airplanes certificated in accordance with this regulation, but also to those certificated in accordance with SR-422 and SR-422A. Accordingly, no change is being made in this regulation to the lateral obstacle clearance provisions, instead, a Notice of Proposed Rule Making is now being prepared to amend SR-422, SR-422A, and this regulation, to require expanding lateral obstacle clearances for all airplanes certificated thereunder.

This Special Civil Air Regulation is not intended to compromise the authority of the Administrator under section 4b.10 to impose such special conditions as are found necessary in any particular case to avoid unsafe design features and otherwise to ensure equivalent safety.

Interested persons have been afforded an opportunity to participate in the making of this regulation (24 F.R. 128), and due consideration has been given to all relevant matter presented.

This regulation does not require compliance until after August 29, 1959; however, since applicants for a type certificate for turbine-powered transport category airplanes may elect to show compliance with this regulation before that date, it is being made effective immediately.

In consideration of the foregoing, the following Special Civil Air Regulation is hereby promulgated to become effective immediately:

Contrary provisions of the Civil Air Regulations notwithstanding, all turbine-powered transport category airplanes for which a type certificate is issued after August 29, 1959, shall comply with the following requirements. Applicants for a type certificate for a turbine-powered transport category airplane may elect and are authorized to meet the requirements of this Special Civil Air Regulation prior to August 29, 1959, in which case however, all of the following provisions must be complied with.

1 The provisions of part 4b of the Civil Air Regulations, effective on the date of application for type certificate; and such of the provisions of all subsequent amendments to part 4b, in effect prior to August 27, 1957, as the Administrator finds necessary to ensure that the level of safety of turbine-powered airplanes is equivalent to that generally intended by part 4b.

2 In lieu of sections 4b.110 through 4b.125, 4b.183, and 4b.743 of part 4b of the Civil Air Regulations, the following shall be applicable:

Performance

4T.110 *General*.

(a) The performance of the airplane shall be determined and scheduled in accordance with, and shall meet the minima prescribed by, the provision of sections 4T.110 through 4T.123. The performance limitations, information, and other data shall be given in accordance with section 4T.743.

(b) Unless otherwise specifically prescribed, the performance shall correspond with ambient atmospheric conditions and still air. Humidity shall be accounted for as specified in paragraph (c) of this section.

(c) The performance as affected by engine power and, or thrust shall be based on a relative humidity of 80 percent at and below standard temperatures and on 34 percent at and above standard temperatures plus 50° F. Between these two temperatures the relative humidity shall vary linearly.

(d) The performance shall correspond with the propulsive thrust available under the particular ambient atmospheric conditions, the particular flight condition, and the relative humidity specified in paragraph (c) of this section. The available propulsive thrust shall correspond with engine power and/or thrust not exceeding the approved power and/or thrust less the installational losses and less the power and or equivalent thrust absorbed by the accessories and services appropriate to the particular ambient atmospheric conditions and the particular flight condition.

4T.111 ***Airplane configuration, speed, power, and/or thrust; general*.**

(a) The airplane configuration (setting of wing and cowl flaps, air brakes, landing gear, propeller, etc.), denoted respectively as the takeoff, en route, approach, and landing configurations, shall be selected by the applicant except as otherwise prescribed.

(b) It shall be acceptable to make the airplane configurations variable with weight, altitude, and temperature to an extent found by the Administrator to be compatible with operating procedures required in accordance with paragraph (c) of this section.

(c) In determining the accelerate-stop distances, takeoff flight paths, takeoff distances, and landing distances, changes in the airplane's configuration and speed, and in the power and thrust shall be in accordance with procedures established by the applicant for the operation of the airplane in service, except as otherwise prescribed. In addition, procedures shall be established for the execution of balked landings and missed approaches associated with the conditions prescribed in sections 4T.119 and 4T.120(d), respectively. All procedures shall comply with the provisions of subparagraphs (1) through (3) of this paragraph.

(1) The Administrator shall find that the procedures can be consistently executed in service by crews of average skill.

(2) The procedures shall not involve methods or the use of devices which have not been proven to be safe and reliable.

(3) Allowance shall be made for such time delays in the execution of the procedures as may be reasonably expected to occur during service.

4T.112 ***Stalling and minimum control speed*.**

(a) The speed V_S shall denote the calibrated stilling speed or the minimum steady flight speed at which the airplane is controllable, in knots, with:

(1) Zero thrust at the stalling speed or engines idling and throttles closed if it is shown that the resultant thrust has no appreciable effect on the stalling speed;

(2) If applicable, propeller pitch controls in the position necessary for compliance with subparagraph (1) of this paragraph; the airplane in all other respects (flaps, landing gear, etc.) in the particular configuration corresponding with that in connection with which V_S is being used;

(3) The weight of the airplane equal to the weight in connection with which V_S is being used to determine compliance with a particular requirement;

(4) The c.g. in the most unfavorable position within the allowable range.

(b) The stall speed defined in this section shall be the minimum speed obtained in flight tests conducted in accordance with the procedure of subparagraphs (1) and (2) of this paragraph.

(1) With the airplane trimmed for straight flight at a speed chosen by the applicant, but not less than 1.2 V_S nor greater than 1.4 V_S, and from a speed sufficiently above the stalling speed to ensure steady conditions, the elevator control shall be applied at a rate such that the airplane speed reduction does not exceed 1 knot per second.

(2) During the test prescribed in subparagraph (1) of this paragraph, the flight characteristics provisions of section 4b.160 of part 4b of the Civil Air Regulations shall be complied with.

(c) The minimum control speed V_{MC}, in terms of calibrated air speed, shall be determined under the conditions specified in this paragraph so that, when the critical engine is suddenly made inoperative at that speed, it is possible to recover control of the airplane with the engine still inoperative and to maintain it in straight flight at that speed, either with zero yaw or, at the option of the applicant, with an angle of bank not in excess of 5 degrees. V_{MC} shall not exceed 1.2 V_S with:

(1) Engines operating at the maximum available takeoff thrust and/or power;

(2) Maximum sea level takeoff weight or such lesser weight as might be necessary to demonstrate V_{MC}.

(3) The airplane in the most critical takeoff configuration existing along the flight path after the airplane becomes airborne, except that the landing gear is retracted;

(4) The airplane trimmed for takeoff;

(5) The airplane airborne and the ground effect negligible;

(6) The c.g. in the most unfavorable position;

(d) In demonstrating the minimum speed specified in paragraph (c) of this section, the rudder force required to maintain control shall not exceed 180 pounds and it shall not be necessary to reduce the power and/or thrust of the operative engine(s).

(e) During recovery from the maneuver specified in paragraph (c) of this section, the airplane shall not assume any dangerous attitude, nor shall it require exceptional skill, strength, or alertness on the part of the pilot to prevent a change of heading in excess of 20 degrees before recovery is complete.

4T.113 *Takeoff; general*.

(a) The takeoff data in sections 4T.114 through 4T.117 shall be determined under the conditions of subparagraphs (1) and (2) of this paragraph.

(1) At all weights, altitudes, and ambient temperatures, within the operational limits established by the applicant for the airplane.

(2) In the configuration for takeoff (see sec. 4T.111).

(b) Takeoff data shall be based on a smooth, dry, hard-surfaced runway and shall be determined in such a manner that reproduction of the performance does not require exceptional skill or alertness on the part of the pilot. In the case of seaplanes or floatplanes, the takeoff surface shall be smooth water, while for skiplanes it shall be smooth, dry snow. In addition, the takeoff data shall include operational correction factors in accordance with subparagraphs (1) and (2) of this paragraph for wind and for runway gradients, within the operational limits established by the applicant for the airplane.

(1) Not more than 50 percent of nominal wind components along the takeoff path opposite to the direction of takeoff, and not less than 150 percent of nominal wind components along the takeoff path in the direction of takeoff.

(2) Effective runway gradients.

4T.114 *Takeoff speeds*.

(a) The critical-engine-failure speed V_1 in terms of calibrated air speed, shall be selected by the applicant, but shall not be less than the minimum speed at which controllability by primary aerodynamic controls alone is demonstrated during the takeoff run to be adequate to permit proceeding safely with the takeoff using average piloting skill, when the critical engine is suddenly made inoperative.

(b) The minimum takeoff safety speed V_{2min}, in terms of calibrated air speed, shall not be less than:

(1) 1.2 V_S for two-engine propeller-driven airplanes and for airplanes without propellers which have no provisions for obtaining a significant reduction in the one-engine-inoperative power-on stalling speed;

(2) 1.15 V_S for propeller-driven airplanes having more than two engines and for airplanes without propellers which have provisions for obtaining a significant reduction in the one-engine-inoperative power-on stalling speed;

(3) 1.10 times the minimum control speed V_{MC}.

(c) The takeoff safety speed V_2, in terms of calibrated air speed, shall be selected by the applicant so as to permit the gradient of climb required in section 4T.120(b), but it shall not be less than:

(1) The speed V_{2min},

(2) The rotation speed V_R (see paragraph (e) of this section) plus the increment in speed attained prior to reaching a height of 35 feet above the takeoff surface in compliance with section 4T.116(e).

(d) The minimum unstick speed V_{MU}, in terms of calibrated air speed, shall be the speed at and above which the airplane can be made to lift off the ground and to continue the takeoff without displaying any hazardous characteristics. V_{MU} speeds shall be selected by the applicant for the all-engines-operating and the one-engine-inoperative conditions. It shall be acceptable to establish the V_{MU} speeds from free air data: *Provided*, that these data are verified by ground takeoff tests.

NOTE: In certain cases, ground takeoff tests might involve some takeoffs at the V_{MU} speeds.

(e) The rotation speed V_R, in terms of calibrated air speed, shall be selected by the applicant in compliance with the conditions of subparagraphs (1) through (4) of this paragraph.

(1) The V_R, speed shall not be less than:

(i) The speed V_1;

(ii) A speed equal to 105 percent of V_{MC};

(iii) A speed which permits the attainment of the speed V2 prior to reaching a height of 35 feet above the takeoff surface as determined in accordance with section 4T.116(e);

(iv) A speed which, if the airplane is rotated at its maximum practicable rate, will result in a lift-off speed V_{LOF} (see paragraph (f) of this section) not less than 110 percent of V_{MU} in the all-engines-operating condition nor less than 105 percent of V_{MU} in the one-engine-inoperative condition.

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

(3) It shall be shown that the one-engine-inoperative takeoff distance determined with a rotation speed 5 knots less than the V_R speed established in accordance with subparagraphs (1) and (2) of this paragraph does not exceed the corresponding one-engine-inoperative takeoff distance determined with the established V_R speed. The determination of the takeoff distances shall be in accordance with section 4T.117(a) (1).

(4) It shall be demonstrated that reasonably expected variations in service from the takeoff procedures established by the applicant for the operation of the airplane (See sec. 4T.111(c)) (e.g., over-rotation of the airplane, out of trim conditions) will not result in unsafe flight characteristics nor in marked increases in the scheduled takeoff distances established in accordance with section 4T.117(a).

(f) The lift-off speed V_{LOF}, in terms of calibrated air speed, shall be the speed at which the airplane first becomes airborne.

4T.115 ***Accelerate-stop distance*.**

(a) The accelerate-stop distance shall be the sum of the following:

(1) The distance required to accelerate the airplane from a standing start to the speed V_1;

(2) Assuming the critical engine to fail at the speed V_1, the distance required to bring the airplane to a full stop from the point corresponding with the speed V_1.

(b) In addition to, or in lieu of, wheel brakes, the use of other braking means shall be acceptable in determining the accelerate-stop distance, provided that such braking means shall have been proven to be safe and reliable, that the manner of their employment is such that consistent results can be expected in service and that exceptional skill is not required to control the airplane.

(c) The landing gear shall remain extended throughout the accelerate-stop distance.

(d) If the accelerate-stop distance is intended to include a stop-way with surface characteristics substantially different from those of a smooth hard-surfaced runway, the takeoff data shall include operational correction factors for the accelerate-stop distance to account for the particular surface characteristics of the stopway and the variations in such characteristics with seasonal weather conditions (i.e., temperature, rain, snow, ice, etc.), within the operational limits established by the applicant.

4T.116 ***Takeoff path.*** The takeoff path shall be considered to extend from the standing start to a point in the takeoff where a height of 1,500 feet above the takeoff surface is reached or to a point in the takeoff where the transition from the takeoff to the en route configuration is completed and a speed is reached at which compliance with section 4T.120(c) is shown, whichever point is at a higher altitude. The conditions of paragraphs (a) through (i) of this section shall apply in determining the takeoff path.

(a) The takeoff path shall be based upon procedures prescribed in accordance with section 4T.111(c).

(b) The airplane shall be accelerated on the ground to the speed V_1 at which point the critical engine shall be made inoperative and shall remain inoperative during the remainder of the takeoff. Subsequent to attaining speed V_1, the airplane shall be accelerated to speed V_2 during which time it shall be permissible to initiate raising the nose gear off the ground at a speed not less than the rotating speed V_R.

(c) Landing gear retraction shall not be initiated until the airplane becomes airborne.

(d) The slope of the airborne portion of the takeoff path shall be positive at all points.

(e) The airplane shall attain the speed V_2 prior to reaching a height of 35 feet above the takeoff surface and shall continue at a speed as close as practical to, but not less than, V_2 until a height of 400 feet above the takeoff surface is reached.

(f) Except for gear retraction and propeller feathering, the airplane configuration shall not be changed before reaching a height of 400 feet above the takeoff surface.

(g) At all points along the takeoff path starting at the point where the airplane first reaches a height of 400 feet above the takeoff surface, the available gradient of climb shall not be less than 1.2 percent for two-engine airplanes, and 1.7 percent for four-engine airplanes.

(h) The takeoff path shall be determined either by a continuous demonstrated takeoff, or alternatively, by synthesizing from segments the complete takeoff path.

(i) If the takeoff path is determined by the segmental method the provisions of subparagraphs (1) through (4) of this paragraph shall be specifically applicable.

(1) The segments of a segmental takeoff path shall be clearly defined and shall be related to the distinct changes in the configuration of the airplane in power and/or thrust and in speed.

(2) The weight of the airplane, the configuration, and the power and/or thrust shall be constant throughout each segment and shall correspond with the most critical condition prevailing in the particular segment.

(3) The segmental flight path shall be based on the airplane's performance without ground effect.

(4) Segmental takeoff path data shall be checked by continuous demonstrated takeoffs up to the point where the airplane's performance is out of ground effect and the airplane's speed is stabilized, to ensure that the segmental path is conservative relative to the continuous path.

NOTE: The airplane usually is considered out of ground effect when it reaches a height above the ground equal to the airplane's wing span.

4T.117 ***Takeoff distance and takeoff run*.**

(a) *Takeoff distance*. The takeoff distance shall be the greater of the distances established in accordance with subparagraphs (1) and (2) of this paragraph.

(1) The horizontal distance along the takeoff path from the start of the takeoff to the point where the airplane attains a height of 35 feet above the takeoff surface, as determined in accordance with section 4T.116.

(2) A distance equal to 115 percent of the horizontal distance along the takeoff path, with all engines operating, from the start of the takeoff to the point where the airplane attains a height of 35 feet above the takeoff surface, as determined by a procedure consistent with that established in accordance with section 4T.116.

(b) *Takeoff run*. If the takeoff distance is intended to include a clearway (see item 5 of this regulation), the takeoff run shall be determined and shall be the greater of the distances established in accordance with subparagraphs (1) and (2) of this paragraph.

(1) The horizontal distance along the takeoff path from the start of the takeoff to a point equidistant between the point where the speed V_{LOF} is reached and the point where the airplane attains a height of 35 feet above the takeoff surface, as determined in accordance with section 4T.116.

(2) A distance equal to 115 percent of the horizontal distance along the takeoff path, with all engines operating, from the start of the takeoff to a point equidistant between the point where the speed V_{LOF} is reached and the point where the airplane attains a height of 35 feet above the takeoff surface, as determined by a procedure consistent with that established in accordance with section 4T.116.

4T.117a ***Takeoff flight path*.**

(a) The takeoff flight path shall be considered to begin at a height of 35 feet above the takeoff surface at the end of the takeoff distance as determined in accordance with section 4T.117(a).

(b) The net takeoff flight path data shall be determined in such a manner that they represent the airplane's actual takeoff flight paths, determined in accordance with section 4T.116 and with paragraph (a) of this section, reduced at each point by a gradient or climb equal to 0.8 percent for two-engine airplanes and equal to 1.0 percent for four-engine airplanes. It shall be acceptable to apply the prescribed reduction in climb gradient as an equivalent reduction in the airplane's acceleration along that portion of the actual takeoff flight path where the airplane is accelerated in level flight.

4T.118 ***Climb; general.*** Compliance shall be shown with the climb requirements of sections 4T.119 and 4T.120 at all weights; altitudes, and ambient temperatures, within the operational limits established by the applicant for the airplane. The airplane's c.g. shall be in the most unfavorable position corresponding with the applicable configuration.

4T.119 *All-engine-operating landing climb.* In the landing configuration the steady gradient of climb shall not be less than 3.2 percent, with:

(a) All engines operating at the power and/or thrust which are available 8 seconds after initiation of movement of the power and/or thrust controls from the minimum flight idle to the takeoff position;

(b) A climb speed not in excess of 1.3 V_S.

4T.120 *One-engine-inoperative climb*.

(a) *Takeoff; landing gear extended*. In the critical takeoff configuration existing along the flight path between the points where the airplane reaches the speed V_{LOF} and where the landing gear is fully retracted, in accordance with section 4T.116 but without ground effect, the steady gradient of climb shall be positive for two-engine airplanes and shall not be less than 0.5 percent for four-engine airplanes, with:

(1) The critical engine inoperative, the remaining engine(s) operating at the available takeoff power and/or thrust existing in accordance with section 4T.116 at the time retraction of the airplane's landing gear is initiated, unless subsequently a more critical power operating condition exists along the flight path prior to the point where the landing gear is fully retracted;

(2) The weight equal to the airplane's weight existing in accordance with section 4T.116 at the time retraction of the airplane's landing gear is initiated;

(3) The speed equal to the speed V_{LOF}.

(b) *Takeoff; landing gear retracted*. In the takeoff configuration existing at the point of the flight path where the airplane's landing gear is fully retracted, in accordance with section 4T.116 but without ground effect, the steady gradient of climb shall not be less than 2.4 percent for two-engine airplanes and not less than 3.0 percent for four-engine airplanes, with:

(1) The critical engine inoperative, the remaining engine(s) operating at the available takeoff power and/or thrust existing in accordance with section 4T.116 at the time the landing gear is fully retracted, unless subsequently a more critical power operating condition exists along the flight path prior to the point where a height of 400 feet above the takeoff surface is reached;

(2) The weight equal to the airplane's weight existing in accordance with section 4T.116 at the time the airplane's landing gear is fully retracted;

(3) The speed equal to the speed V_2.

(c) *Final takeoff*. In the en route configuration, the steady gradient of climb shall not be less than 1.2 percent for two-engine airplanes and not less than 1.7 percent for four-engine airplanes, at the end of the takeoff path as determined by section 4T.116, with:

(1) The critical engine inoperative, the remaining engine(s) operating at the available maximum continuous power and/or thrust;

(2) The weight equal to the airplane's weight existing in accordance with section 4T.116 at the end of the takeoff path;

(3) The speed equal to not less than 1.25 V_S.

(d) *Approach*. In the approach configuration corresponding with the normal all-engines-operating procedure such that V_S related to this configuration does not exceed 110 percent of the V_S corresponding with the related landing configuration, the steady gradient of climb shall not be less than 2.1 percent for two-engine airplanes and not less than 2.7 percent for four-engine airplanes with:

(1) The critical engine inoperative, the remaining engine(s) operating at the available takeoff power and/or thrust;

(2) The weight equal to the maximum landing weight;

(3) A climb speed established by the applicant in connection with normal landing procedures, except that it shall not exceed 1.5 V_S. (see sec. 4T.111(c)).

4T.121 *En route flight paths*.

With the airplane in the en route configuration, the flight paths prescribed in paragraphs (a) and (b) of this section shall be determined at all weights, altitudes, and ambient temperatures, within the operational limits established by the applicant for the airplane.

(a) One engine inoperative. The one-engine-inoperative net flight path data shall be determined in such a manner that they represent the airplane's actual climb performance diminished by a gradient of climb equal to 1.1 percent for two-engine airplanes and 1.6 percent for four-engine airplanes. It shall be acceptable to include in these data the variation of the airplane's weight along the flight path to take into account the progressive consumption of fuel and oil by the operating engine(s).

(b) *Two engines inoperative*. For airplanes with four engines, the two-engine-inoperative net flight path data shall be determined in such a manner that they represent the airplane's actual climb performance diminished by a gradient of climb equal to 0.5 percent. It shall be acceptable to include in these data the variation of the airplane's weight along the flight path to take into account the progressive consumption of fuel and oil by the operating engines.

(c) *Conditions*. In determining the flight paths prescribed in paragraphs (a) and (b) of this section, the conditions of subparagraphs (1) through (4) of this paragraph shall apply.

(1) The airplane's c.g. shall be in the most unfavorable position.

(2) The critical engine(s) shall be inoperative, the remaining engine(s) operating at the available maximum continuous power and/or thrust.

(3) Means for controlling the engine cooling air supply shall be in the position which provides adequate cooling in the hot-day condition.

(4) The speed shall be selected by the applicant.

4T.122 *Landing distance*.

The landing distance shall be the horizontal distance required to land and to come to a complete stop (to a speed of approximately 3 knots in the case of seaplanes or float planes) from a point at a height of 50 feet above the landing surface. Landing distances shall be determined for standard temperatures at all weights, altitudes, and winds, within the operational limits established by the applicant for the airplane. The conditions of paragraphs (a) through (g) of this section shall apply.

(a) The airplane shall be in the landing configuration. During the landing, changes in the airplane's configuration, in power and/or thrust, and in speed shall be in accordance with procedures established by the applicant for the operation of the airplane in service. The procedures shall comply with the provisions of section 4T.111(c).

(b) The landing shall be preceded by a steady gliding approach down to the 50-foot height with a calibrated air speed of not less than 1.3 V_S.

(c) The landing distance shall be based on a smooth, dry, hard-surfaced runway, and shall be determined in such a manner that reproduction does not require exceptional skill or alertness on the part of the pilot. In the case of seaplanes or floatplanes, the landing surface shall be smooth water, while for skiplanes it shall be smooth, dry snow. During landing, the airplane shall not exhibit excessive vertical acceleration, a tendency to bounce, nose over, ground loop, porpoise, or water loop.

(d) The landing distance data shall include operational correction factors for not more than 50 percent of nominal wind components along the landing path opposite to the direction of landing and not less than 150 percent of nominal wind components along the landing path in the direction of landing.

(e) During landing, the operating pressures on the wheel braking system shall not be in excess of those approved by the manufacturer of the brakes, and the wheel brakes shall not be used in such a manner as to produce excessive wear of brakes and tires.

(f) In addition to, or in lieu of, wheel brakes, the use of other braking means shall be acceptable in determining the landing distance, provided such braking means shall have been proven to be safe and reliable, that the manner of their employment is such that consistent results can be expected in service, and that exceptional skill is not required to control the airplane.

(g) If the characteristics of a device (e.g., the propellers) dependent upon the operation of any of the engines noticeably increase the landing distance when the landing is made with the engine inoperative, the landing distance shall be determined with the critical engine inoperative unless the Administrator finds that the use of compensating means will result in a landing distance not greater than that attained with all engines operating.

4T.123 *Limitations and information*.

(a) *Limitations*. The performance limitations on the operation of the airplane shall be established in accordance with subparagraph (1) through (4) of this paragraph. (See also sec. 4T.743.)

(1) *Takeoff weights*. The maximum takeoff weights shall be established at which compliance is shown with the generally applicable provisions of this regulation and with the takeoff climb provisions prescribed in section 4T.120 (a), (b), and (c) for altitudes and ambient temperatures, within the operational limits of the airplane (see subparagraph (4) of this paragraph).

(2) *Landing weights*. The maximum landing weights shall be established at which compliance is shown with the generally applicable provisions of this regulation and with the landing and takeoff climb provisions prescribed in sections 4T.119 and 4T.120 for altitudes and ambient temperatures, within the operational limits of the airplane (see subparagraph (4) of this paragraph).

(3) *Accelerate-stop distance, takeoff distance, and takeoff run*. The minimum distances required for takeoff shall be established at which compliance is shown with the generally applicable provisions of this regulation and with sections 4T.115 and 4T.117(a) and with 4T.117(b) if the takeoff distance is intended to include a clearway, for weights, altitudes, temperatures, wind components, and runway gradients, within the operational limits of the airplane (see subparagraph (4) of this paragraph).

(4) *Operational limits*. The operational limits of the airplane shall be established by the applicant for all variable factors required in showing compliance with this regulation (weight, altitude, temperature, etc.). (See secs. 4T.113 (a)(1) and (b), 4T.115(d), 4T.118, 4T.121, and 4T.122.)

(b) *Information*. The performance information on the operation of the airplane shall be scheduled in compliance with the generally applicable provisions of this regulation and with sections 4T.117a(b), 4T.121, and 4T.122 for weights, altitudes, temperatures, wind components and runway gradients, as these may be applicable, within the operational limits of the airplane (see subparagraph (a)(4) of this section). In addition, the performance information specified in subparagraphs (1) through (3) of this paragraph shall be determined by extrapolation and scheduled for the ranges of weights between the maximum landing and maximum takeoff weights established in accordance with subparagraphs (a)(1) and (a) (2) of this section. (See also sec. 4T.743.)

(1) Climb in the landing configuration (see sec. 4T.119);

(2) Climb in the approach configuration (see sec. 4T.120(d));

(3) Landing distance (see sec. 4T.122).

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4T.743 ***Performance limitations, information, and other data*.**

(a) *Limitations*. The airplane's performance limitations shall be given in accordance with section 4T.123(a).

(b) *Information*. The performance information prescribed in section 4T.123(b) for the application of the operating rules of this regulation shall be given together with descriptions of the conditions, air speeds, etc., under which the data were determined.

(c) *Procedures*. Procedures established in accordance with section 4T.111(c) shall be given to the extent such procedures are related to the limitations and information set forth in accordance with paragraphs (a) and (b) of this section. Such procedures, in the form of guidance material, shall be included with the relevant limitations or information, as applicable.

(d) *Miscellaneous*. An explanation shall be given of significant or unusual flight or ground handling characteristics of the airplane.

3. In lieu of sections 40.70 through 40.78, 41.27 through 41.36(d), and 42.70 through 42.83, of Parts 40, 41, and 42, respectively, of the Civil Air Regulations, the following shall be applicable:

Operating Rules

40T.80 ***Transport category airplane operating limitations*.**

(a) In operating any passenger-carrying transport category airplane certificated in accordance with the performance requirements of this regulation, the provisions of sections 40T.80 through 40T.84 shall be complied with, unless deviations therefrom are specifically authorized by the Administrator on the ground that the special circumstances of a particular case make a literal observance of the requirements unnecessary for safety.

(b) The performance data in the AFM shall be applied in determining compliance with the provisions of sections 40T.81 through 40T.84. Where conditions differ from those for which specific tests were made, compliance shall be determined by approved interpolation or computation of the effects of changes in the specific variables if such interpolations or computations give results substantially equaling in accuracy the results of a direct test.

40T.81 ***Airplane's certificate limitations*.**

(a) No airplane shall be taken off at a weight which exceeds the takeoff weight specified in the AFM for the elevation of the airport and for the ambient temperature existing at the time of the takeoff. (See secs. 4T.123(a)(1) and 4T.743(a).)

(b) No airplane shall be taken off at a weight such that, allowing for normal consumption of fuel and oil in flight to the airport of destination and to the alternate airports, the weight on arrival will exceed the landing weight specified in the AFM for the elevation of each of the airports involved and for the ambient temperatures anticipated at the time of landing. (See secs. 4T.123(a)(2) and 4T.743(a).)

(c) No airplane shall be taken off at a weight which exceeds the weight at which, in accordance with the minimum distances for takeoff scheduled in the AFM, compliance with subparagraphs (1) through (3) of this paragraph is shown. These distances shall correspond with the elevation of the airport, the runway to be used, the effective runway gradient, and the ambient temperature and wind component existing at the time of takeoff. (See secs. 4T.123(a)(3) and 4T.743(a).)

(1) The accelerate-stop distance shall not be greater than the length or the runway plus the length or the stopway if present.

(2) The takeoff distance shall not be greater than the length of the runway plus the length of the clearway if present, except that the length of the clearway shall not be greater than one-half of the length of the runway.

(3) The takeoff run shall not be greater than the length of the runway.

(d) No airplane shall be operated outside the operational limits specified in the Airplane Flight Manua1 (See secs. 4T.123(a)(4) and 4T.743(a).)

40T.82 ***Takeoff obstacle clearance limitations.*** No airplane shall be taken off at a weight in excess of that shown in the AFM to correspond with a net takeoff flight path which clears all obstacles either by at least a height of 35 feet vertically or by at least 200 feet horizontally within the airport boundaries and by at least 300 feet horizontally after passing beyond the boundaries. In determining the allowable deviation of the net takeoff flight path in order to avoid obstacles by at least the distances prescribed, it shall be assumed that the airplane is not banked before reaching a height of 50 feet as shown by the net takeoff flight path data in the AFM, and that a maximum bank thereafter does not exceed 15 degrees. The net takeoff flight path considered shall be for the elevation of the airport, the effective runway gradient, and for the ambient temperature and wind component existing at the time of takeoff. (See secs. 4T.123(b) and 4T.743(b).)

40T.83 ***En route limitations.*** All airplanes shall be operated in compliance with paragraph (a) of this section. In addition, no airplane shall be flown along an intended route if any place along the route is more than 90 minutes away from an airport at which a landing can be made in accordance with section 40T.84(b), assuming all engines to be operating at cruising power, unless compliance is shown with paragraph (b) of this section.

(a) *One engine inoperative*. No airplane shall be taken off at a weight in excess of that which, according to the one-engine-inoperative en route net flight path data shown in the AFM, will permit compliance with either subparagraphs (1) or (2) of this paragraph at all points along the route. The net flight path shall have a positive slope at 1,500 feet above the airport where the landing is assumed to be made after the engine fails. The net flight path used shall be for the ambient temperatures anticipated along the route. (See secs. 4T.123(b) and 4T.743(b).)

(1) The slope of the net flight path shall be positive at an altitude of at least 1,000 feet above all terrain and obstructions along the route within 5 statute miles (4.34 nautical miles) on either side of the intended track.

(2) The net flight path shall be such as to permit the airplane to continue flight from the cruising altitude to an airport where a landing can be made in accordance with the provisions of section 40T.84(b), the net flight path clearing vertically by at least 2,000 feet all terrain and obstructions along the route within 5 statute miles (4.34 nautical miles) on either side of the intended track. The provisions of subdivisions (i) through (vi) of this subparagraph shall apply.

(i) The engine shall be assumed to fail at the most critical point along the route.

(ii) The airplane shall be assumed to pass over the critical obstruction following engine failure at a point no closer to the critical obstruction than the nearest approved radio navigational fix, except that the Administrator may authorize a procedure established on a different basis where adequate operational safeguards are found to exist.

(iii) An approved method shall be used to account for winds which would otherwise adversely affect the flight path.

(iv) Fuel jettisoning shall be permitted if the Administrator finds that the operator has an adequate training program, proper instructions are given to the flight crew, and all other precautions are taken to ensure a safe procedure.

(v) The alternate airport shall be specified in the dispatch release and shall meet the prescribed weather minima.

(vi) The consumption of fuel and oil after the engine is assumed to fail shall be that which is accounted for in the net flight path data shown in the AFM.

(b) *Two engines inoperative*. No airplane shall be taken off at a weight in excess of that which, according to the two-engine-inoperative en route net flight path data shown in the AFM, will permit the airplane to continue flight from the point where two engines are assumed to fail simultaneously to an airport where a landing can be made in accordance with the provisions of section 40T.84(b), the net flight path clearing vertically by at least 2,000 feet all terrain and obstructions along the route within 5 statute miles (4.34 nautical miles) on either side of the intended track. The net flight path considered shall be for the ambient temperatures anticipated along the route. The provisions of subparagraphs (1) through (5) of this paragraph shall apply. (See secs. 4T.123(b) and 4T.734(b).)

(1) The two engines shall be assumed to fail at the most critical point along the route.

(2) The net flight path shall have a positive slope at 1,500 feet above the airport where the landing is assumed to be made after failure of two engines.

(3) Fuel jettisoning shall be permitted if the Administrator finds that the operator has an adequate training program, proper instructions are given to the flight crew, and all other precautions are taken to ensure a safe procedure.

(4) The airplane's weight at the point where the two engines are assumed to fail shall be considered to be not less than that which would include sufficient fuel to proceed to the airport and to arrive there at an altitude of at least 1,500 feet directly over the landing area and thereafter to fly for 15 minutes at cruise power and/or thrust.

(5) The consumption of fuel and oil after the engines are assumed to fail shall be that which is accounted for in the net flight path data shown in the AFM.

40T.84 ***Landing limitations*.**

(a) *Airport of destination*. No airplane shall be taken off at a weight in excess of that which, in accordance with the landing distances shown in the AFM for the elevation of the airport of intended destination and for the wind conditions anticipated there at the time of landing, would permit the airplane to be brought to rest at the airport of intended destination within 60 percent of the effective length of the runway from a point 50 feet directly above the intersection of the obstruction clearance plane and the runway. The weight of the airplane shall be assumed to be reduced by the weight of the fuel and oil expected to be consumed in flight to the airport of intended destination. Compliance shall be shown with the conditions of subparagraphs (1) and (2) of this paragraph. (See secs. 4T.123(b) and 4T.743(b).)

(1) It shall be assumed that the airplane is landed on the most favorable runway and direction in still air.

(2) It shall be assumed that the airplane is landed on the most suitable runway considering the probable wind velocity and direction and taking due account of the ground handling characteristics of the airplane and of other conditions (i.e., landing aids, terrain, etc.). If full compliance with the provisions of this subparagraph is not shown, the airplane may be taken off if an alternate airport is designated which permits compliance with paragraph (b) of this section.

(b) *Alternate airport*. No airport shall be designated as an alternate airport in a dispatch release unless the airplane at the weight anticipated at the time of arrival at such airport can comply with the provisions of paragraph (a) of this section, provided that the airplane can be brought to rest within 70 percent of the effective length of the runway.

4. In lieu of section 43.11 of part 43 of the Civil Air Regulations the following shall be applicable.

43T.11 ***Transport category airplane weight limitations.*** The performance data in the AFM shall be applied in determining compliance with the following provisions:

(a) No airplane shall be taken off at a weight which exceeds the takeoff weight specified in the AFM for the elevation of the airport and for the ambient temperature existing at the time of the takeoff. (See secs. 4T.123(a)(1) and 4T.743(a).)

(b) No airplane shall be taken off at a weight such that, allowing for normal consumption of fuel and oil in flight to the airport of destination and to the alternate airports, the weight on arrival will exceed the landing weight specified in the AFM for the elevation of each of the airports involved and for the ambient temperatures anticipated at the time of landing. (See secs. 4T.123(a) (2) and 4T.743(a).)

(c) No airplane shall be taken off at a weight which exceeds the weight at which, in accordance with the minimum distances for takeoff scheduled in the AFM, compliance with subparagraphs (1) through (3) of this paragraph is shown. These distances shall correspond with the elevation of the airport, the runway to be used, the effective runway gradient, and the ambient temperature and wind component existing at the time of takeoff. (See secs. 4T.123(a)(3) and 4T.734(a).)

(1) The accelerate-stop distance shall not be greater than the length of the runway plus the length of the stopway if present.

(2) The takeoff distance shall not be greater than the length of the runway plus the length of the clearway if present, except that the length of the clearway shall not be greater than one-half of the length of the runway.

(3) The takeoff run shall not be greater than the length of the runway.

(d) No airplane shall be operated outside the operational limits specified in the AFM. (See secs. 4T.123(a)(4) and 4T.743(a).)

5. The following definitions shall apply:

(a) *Clearway*. A clearway is an area beyond the runway, not less than 500 feet wide, centrally located about the extended centerline of the runway, and under the control of the airport authorities. The clearway is expressed in terms of a clearway plane, extending from the end of the runway with an upward slope not exceeding 1.25 percent, above which no object nor any portion of the terrain protrudes, except that threshold lights may protrude above the plane if their height above the end of the runway is not greater than 26 inches and if they are located to each side of the runway.

NOTE: For the purpose of establishing takeoff distances and takeoff runs, in accordance with section 4T.117 of this regulation, the clearway plane is considered to be the takeoff surface.

(b) *Stopway*. A stopway is an area beyond the runway, not less in width than the width of the runway, centrally located about the extended centerline of the runway, and designated by the airport authorities for use in decelerating the airplane during an aborted takeoff: To be considered as such, a stopway must be capable of supporting the airplane during an aborted takeoff without inducing structural damage to the airplane. (See also sec. 4T.115(d) of this regulation.)

APPENDIX E. FAA HANDLING QUALITIES RATING METHOD

E.1 Explanation.

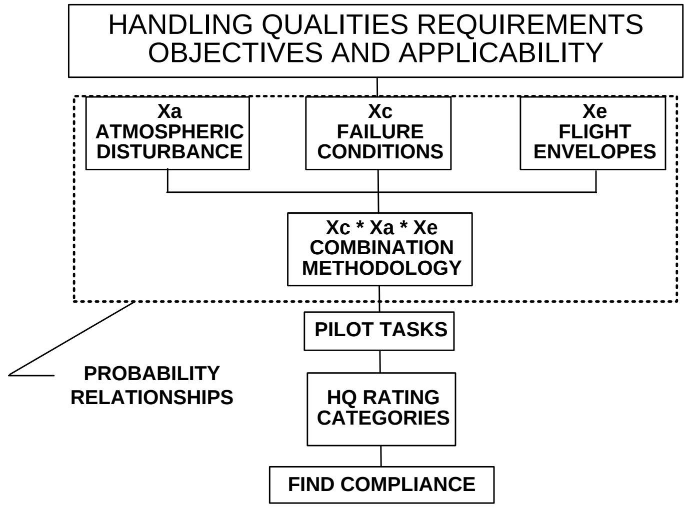
Many of the stability and control requirements of part 25 are inadequate or unsuitable safety standards for airplanes with electronic flight control systems (EFCS) because these systems use control laws to define or augment the airplane's natural handling qualities. As a result, the handling qualities rating method (HQRM) was developed to provide a systematic way to determine appropriate minimum handling qualities requirements that take into account the features, characteristics, and limitations of an EFCS. The HQRM defines the minimum acceptable handling characteristics as a function of the atmospheric conditions, flight envelope conditions, piloting task, and probability of the particular failure condition being evaluated. The pilot rating levels used in this HQRM may also be useful in evaluating flying qualities for showing compliance with existing part 25 requirements where the airplane must be shown to be capable of continued safe flight and landing. Unless otherwise specified in a special condition, the HQRM does not replace or override any of the systems and equipment requirements of §§ 25.1301 and 25.1309 or the control system requirements of §§ 25.671 and 25.672.

E.2 Procedures.

E.2.1 The HQRM is a pilot task-oriented approach for evaluating airplane handling qualities.

E.2.2 The HQRM uses a probability of occurrence versus safety effect philosophy in relating the minimum acceptable handling qualities to the probability of being in a particular portion of the airplane's flight envelope (referred to as Xe), the probability of encountering certain atmospheric disturbance levels (referred to as Xa), and the probability of a specific flight control failure state (referred to as Xc). The overall process used for the HQRM is shown in figure E-1.

Figure E-1. Overall HQRM Process



E.2.3 Handling qualities to perform a specified pilot task for a particular flight condition are expressed in terms of one of three levels: Satisfactory (SAT), Adequate (ADQ), and Controllable (CON). A description of these handling qualities ratings is presented in table E-1 below, along with the equivalent Cooper-Harper and Military Standard ratings for comparison. The handling qualities rating will be used to determine if the handling qualities of a specific test condition are acceptable, considering the probabilities of the failure state being evaluated (Xc), being in a particular portion of the flight envelope (Xe), and the atmospheric disturbance level (Xa).

Table E-1. Comparison of Handling Qualities Ratings

FAA Handling Qualities (HQ)		**Cooper-Harper Rating**	**Military Standard**	
HQ Rating	**Definition**		**Level**	**Quality**
Satisfactory (SAT)	Full performance criteria met with routine pilot effort and attention.	1-3	1	SAT
Adequate (ADQ)	Adequate for continued safe flight and landing. Full or specified reduced performance met, but with heightened pilot effort and attention.	4-6	2	ACCEPT
Controllable (CON)	Inadequate for continued safe flight and landing, but controllable for return to a safe flight condition, a safe flight envelope, and/or allows a reconfiguration that provides HQ that are at least ADEQUATE.	7-8	3	CON

E.2.4 The HQRM should be used to evaluate airplane handling qualities while performing typical static and dynamic maneuvers. A sample list of such tasks is presented in figure E-2. Task performance criteria should be defined for each identified task. From a test execution perspective, test tasks with criteria are defined (which may include a failure state, region of the flight envelope, and/or atmospheric condition), the tasks are flown and ratings are determined (from the HQRM rating scale shown in table E-1) for each task as flown. If desired, the Cooper Harper Handling Qualities Rating Scale can be used along with table E-1 to determine HQRM ratings for a given task.

Figure E-2. Sample Tasks for Evaluating Airplane Handling Qualities

A. Trim and Unattended Operation

Characteristics of the airplane to stay at or depart from an initial trim or unaccelerated condition.

- Dynamic and steady-state flight path response to pulse input (all 3 axes).
- Dynamic and steady-state flight path response to atmospheric disturbance.
- Spiral stability (e.g., release controls at 40° bank).

B. Large Amplitude Maneuvering

Generally, these are open-loop maneuvers in which the pilot attempts a significant change in airplane path, speed, or attitude in order to evaluate safe airplane capability that are beyond those expected in normal operational service. Maneuvers may be initiated outside the Normal Flight Envelope and transition flight envelopes. Most of these maneuvers are representative of airworthiness stability and control tests.

<u>Pitch/Longitudinal</u>

- Wind-up turn or symmetric pull-up/push-over.
- Slow-down turn at fixed g or on AOA or g-limiter.
- Stall or AOA-limiter approach.
- Push-pull off trim speed.

<u>Roll</u>

- Rapid bank-to-bank roll.

<u>Yaw</u>

- Sudden heading change.
- Constant heading sideslip.

<u>Operational</u>

- Pitch/roll upset recover.
- Emergency descent.
- Climbing/diving turn.
- Takeoff/land windshear escape maneuver.
- Takeoff/land windshear escape maneuver—Go around/power or thrust application from low speed.
- Arrest of high sink rate, at touchdown or level-off altitude.
- Collision avoidance roll/pull.
- Takeoff and landing flare with underspeed or high crosswind.

C. Closed-Loop Precision Regulation of Flight Path

Generally, these are tightly-bounded, pilot closed-loop tasks expected to be performed in routine commercial flight. These controlling tasks are almost exclusively within the Normal Flight Envelope, or not far outside the NFE boundary.

- ILS and precision touchdown, various atmospheric disturbance and initial offset.
- Formation flying (as simulator for maneuver tracking).

SPD/ALT/HDG tracking, in various atmospheric disturbance and cockpit display status, for:

- Takeoff.
- Cruise.
- Hold.
- Configuration changes/power or thrust changes.
- Transition between the aforementioned.
- Climb.
- Descent.

E.2.5 Figure E-3 provides guidance for determining the probability of occurrence associated with being in a particular portion of the flight envelope (Xe), in a particular atmospheric disturbance level (Xa), and with a particular flight control failure state (Xc). It also describes how the flight envelope probability (Xe) should be modified for interrelationships with the atmospheric condition.

Figure E-3. Probability of Occurrence Guidelines

A. Flight Envelope (Xe)		
		Probability of occurrence (at flight envelope boundary)
Normal Flight Envelope	Generally associated with routine operational and/or prescribed conditions, either all engines operating or one engine inoperative.	10^{0}
Operational Flight Envelope	Generally associated with warning onset; outside the normal flight envelope.	10^{-3}
Limit Flight Envelope	Generally associated with airplane design limits or EFCS protection limits.	10^{-5}
Refer to this figure and figures E-4 and E-5 for more detail on determining which flight envelope is applicable. It may be necessary to consider several of the pertinent flight parameters together to determine which flight envelope a given flight condition is in. For the more influential flight parameters, such as angle-of-attack (AOA), speed, and load factor normal to the flight path (Nz), the choice of which flight envelope a condition is in may be determined by as few as one of the parameter values. Since the flight envelopes cover ranges of parameters (e.g., for Flaps UP, Nz in the LFE can be from 1.6 to 2.5), the above target probabilities for OFE and LFE might vary slightly depending on the expected airplane behavior and the assigned task.		

Figure E-3. Probability of Occurrence Guidelines (continued)

B. Atmospheric Disturbance Level

		Probability of occurrence (at flight envelope boundary)
Light:	Turbulence that momentarily causes slight, erratic changes in altitude and/ or attitude (pitch, roll, yaw). Crosswinds up to 10 knots.	10^{0}
Moderate:	Turbulence that is similar to light turbulence, but of greater intensity. Changes in altitude and/or attitude occur. Usually causes variations in indicated airspeed. Crosswinds up to 25 knots.	10^{-3}
Severe:	Turbulence that causes large, abrupt deviations in altitude and/or attitude. Usually causes large variations in indicated airspeeds. Crosswinds substantially in excess of the minimum required crosswind to be demonstrated safe for takeoff and landing.	10^{-5}

C. Flight Control System Failure State

	Probability of occurrence (at flight envelope boundary)
Normal Operation:	10^{0}
Probable Failures:	10^{0} - 10^{-5}
Improbable Failures:	10^{-5} - 10^{-9}

D. Modifying the Flight Envelope Probability for Interrelationships with Atmospheric Conditions

The above probability of occurrence values apply when considered separately. When obvious interrelationships exist due to the design or the intended or expected operation of the airplane, the way to address this within HQRM is to modify the flight envelope probability value. For example, a severe windshear event may result in a flight envelope probability of 100, not 10^{-3} or 10^{-5} as shown above for the OFE or LFE, since the operational procedure for escape would be to pull toward the AOA limit in windshear. Similarly, an airplane may experience overspeed, from V_{MO} cruise, into the OFE due to a gust, in which case the modified flight envelope probability would be 100, not 10^{-3}. This probability adjustment concept would also apply to EFCS failure cases where, for example, loss of warnings or exposure to reduced airplane stability might contribute to excursions outside the normal flight envelope (NFE) or OFE, in which case the flight envelope probability should be appropriately increased.

E.2.6 Three different flight envelopes (or portions of the airplane's flight envelope), called the normal, operational, and limit flight envelopes have been defined as a function of various flight parameters. These flight envelopes are shown for flaps up and flaps down configurations in figures E-4 and E-5, respectively.

Figure E-4. Flaps UP Flight Envelopes

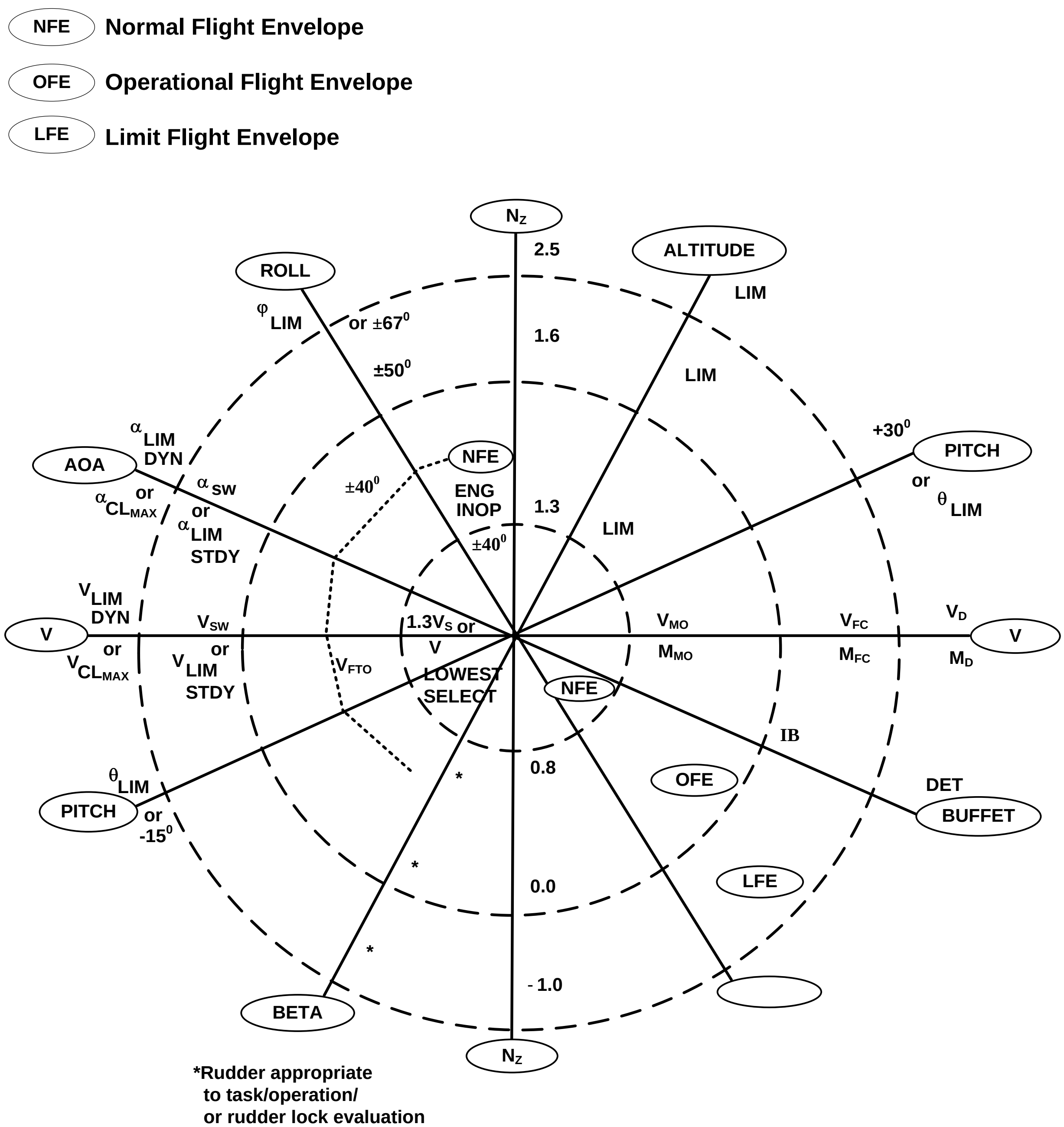
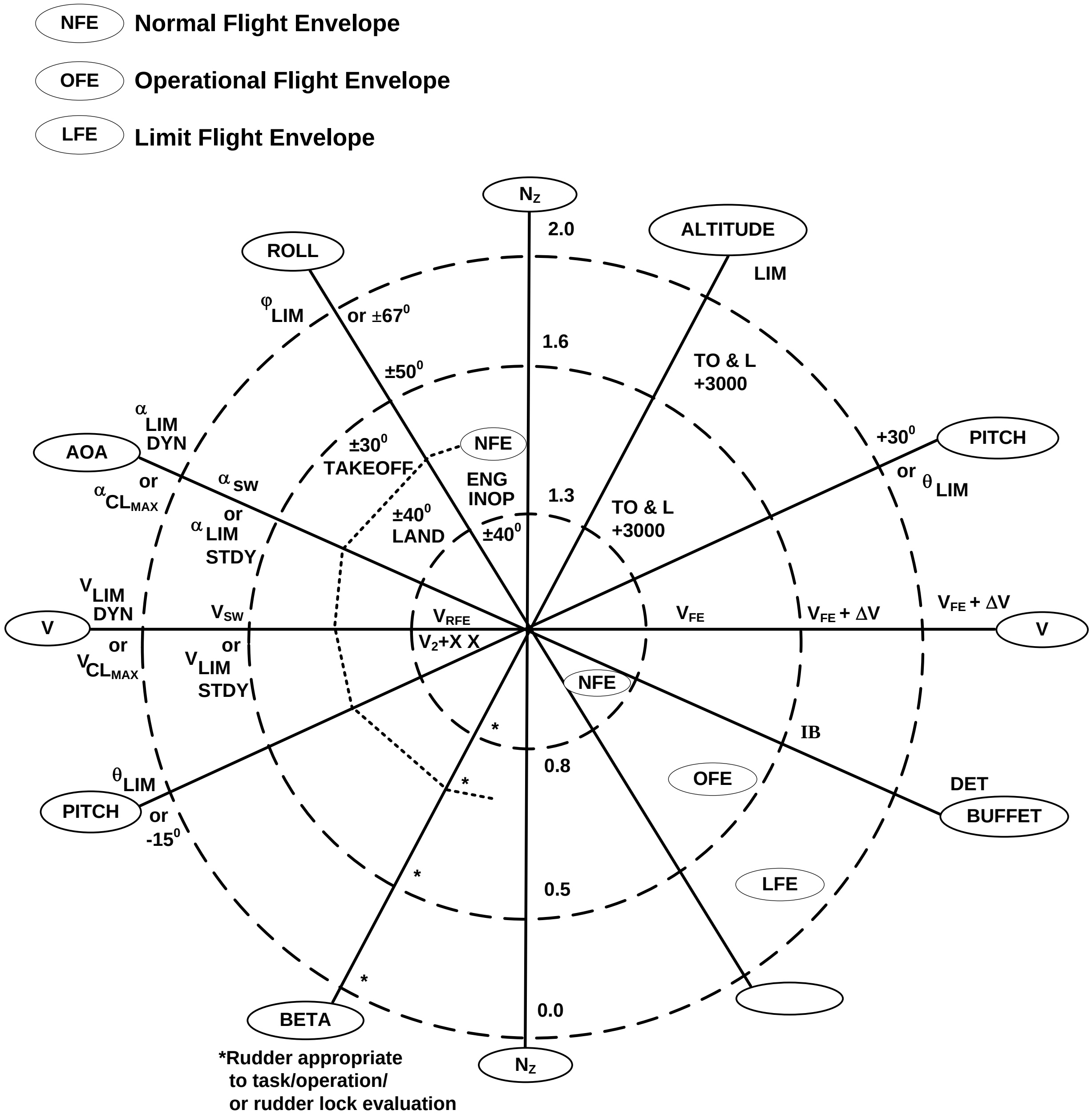


Figure E-5. Flaps DOWN Flight Envelopes



E.2.7 Figure E-6 presents the method for combining the various flight condition parameter probabilities to determine the minimum acceptable handling qualities rating for each combination of these parameters. This method is shown graphically in Figure E-7.

Figure E-6. Combining Values

A. Analyze Failures/Determine Flight Control System Failure Probability (Xc).

- Predicted failure rates/check failure co-dependence
- Equipment Inoperative Dispatch under MEL
- Service Difficulty Records (continuing airworthiness)

B. Determine Flight Envelope Probabilities (Xe) and Atmospheric Probabilities (Xa) for the Flight Condition.

C. Modify the Flight Envelope Probability if Inter-related with the Atmospheric Condition.

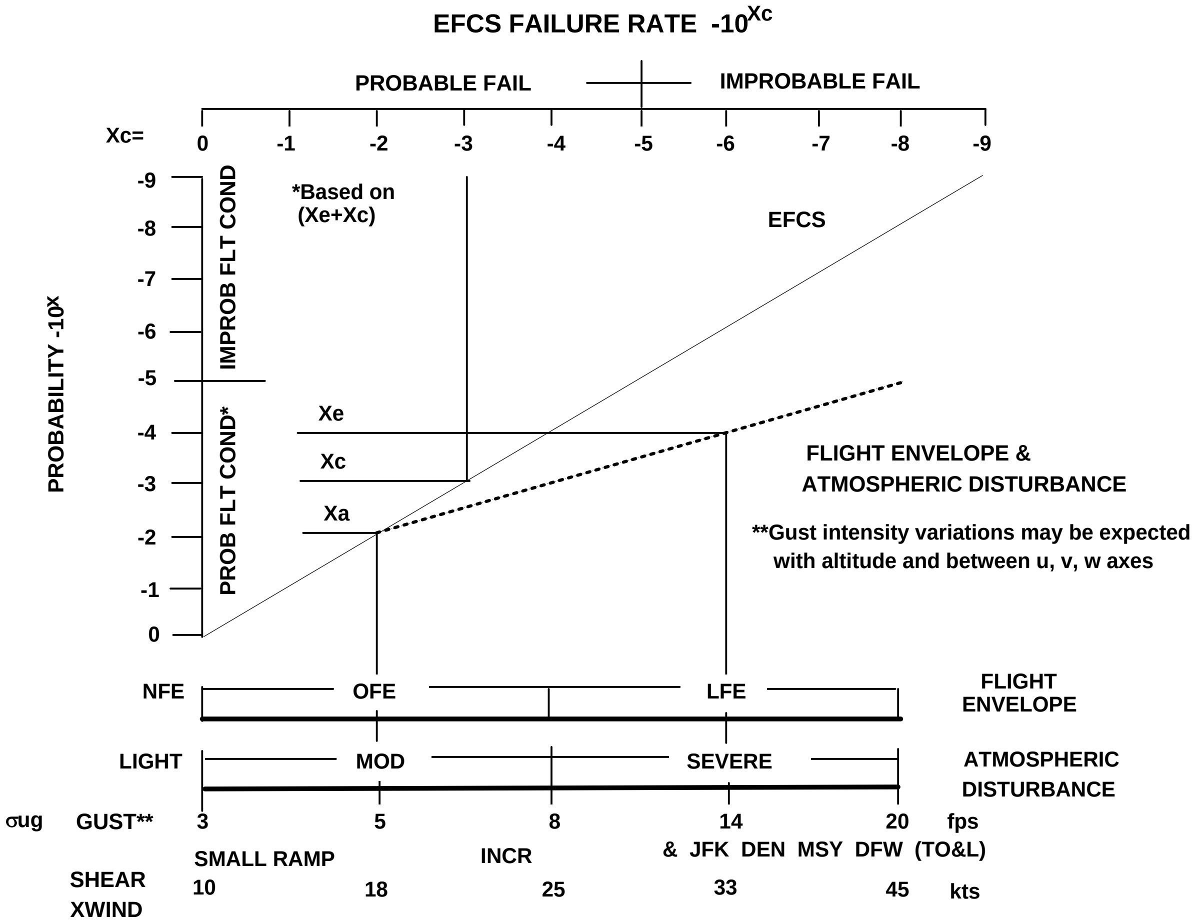
(See Figure E-3, Section D.)

D. Repeat Process to Identify All Cases Where Xc * Xa * Xe $\Rightarrow \geq 10^{-9}$

E. Determine: "Flight Condition" (Xc * Xe)

- Probable Flight Condition: $10^{-5} \leq (Xc * Xe) < 0$
- Improbable Flight Condition: $10^{-9} \leq (Xc * Xe) < 10^{-5}$

Figure E-7. Probability Guidelines to Determine HQ Requirements



E.2.8 Table E-2 shows the minimum acceptable FAA handling qualities rating for a given flight condition, defined as a combination of the flight envelope conditions and the level of atmospheric disturbance, relative to the probability of the failure condition being evaluated. Table E-2 is not meant to imply that every atmospheric disturbance level and every flight envelope combination must be tested. It simply shows the minimum acceptable handling qualities rating for a handling qualities task conducted in a specific environmental state (i.e., atmospheric disturbance level), in a specific segment of the flight envelope, and in a specific system failure state.

Table E-2. Minimum HQ Requirements

Flight Condition (Xc*Xe)	**Atmospheric Disturbance (Xa)**								
	Light			Moderate			Severe		
	Flight Envelope (Xe)								
	NFE	OFE	LFE	NFE	OFE	LFE	NFE	OFE	LFE
Probable Condition	S	S	A	A	C	C	C	C	C
Improbable Condition	A	A	C	C	C		C		

NFE = Normal Flight Envelope

OFE = Operational Flight Envelope

LFE = Limit Flight Envelope

S = Satisfactory

A = Adequate

C = Controllable

APPENDIX F. CORRECTION OF AIR MINIMUM CONTROL SPEED TO STANDARD CONDITIONS

F.1 Overview.

The following analysis presents three methods of correcting a flight test derived value of air minimum control speed to standard conditions. These methods are applicable only to rudder deflection limited V_{MCA}, for either jet or propeller driven airplanes. The effect of banking into the operating engine is accounted for, and the method will work with either fixed pitch or constant speed propellers, including the effects of windmilling drag. For rudder pedal force limited V_{MCA}, see appendix G of this AC.

F.2 Theoretical Basis.

Given the static lateral/directional equations of motion for straight line, unaccelerated flight:

$$\sum F_y = 0 \qquad C_{y_\beta} \cdot \beta + C_{y_{\delta a}} \cdot \delta_a + C_{y_{\delta r}} \cdot \delta_r = C_L \sin \emptyset \qquad (1)$$

$$\sum M_x = 0 \qquad C_{l_\beta} \cdot \beta + C_{l_{\delta a}} \cdot \delta_a + C_{l_{\delta r}} \cdot \delta_r = 0 \qquad (2)$$

$$\sum M_z = 0 \qquad C_{n_\beta} \cdot \beta + C_{n_{\delta a}} \cdot \delta_a + C_{n_{\delta r}} \cdot \delta_r = C_{na} \qquad (3)$$

Where:

$$C_L = \frac{295 \cdot W}{V_e^2 \cdot S}$$

$$C_{na} = \frac{295 \cdot F_{na} \cdot l_e}{V_e^2 \cdot S \cdot b}$$

W = Weight (lbs)

V_e = Equivalent airspeed (kts)

S = Wing area (ft^2)

F_{na} = Asymmetric net thrust (lbs)

$F_{na} = (F_n + D_w)$ for engine inoperative

$F_{na} = (F_n + F_i)$ for engine at idle

F_n = Net thrust of the operating engine (lbs)

F_i = Idle engine net thrust (lbs)

D_w = Windmill drag (lbs)

l_e = Distance from aircraft center line to engine thrust line (ft)

b = Wingspan (ft)

F.3 Constant C_n Method.

F.3.1 For the case where full rudder deflection is achieved, δ_r is a constant, and the system of equations can be resolved to an identity that shows that C_{na} is a linear function of $C_L \sin Ø$.

$$C_{na} = A \cdot C_L \sin \emptyset + B \tag{4}$$

F.3.2 If it is assumed that test and standard day V_{MCA} occur at the same angle-of-attack and bank angle, the asymmetric yawing moment coefficient will be constant, and V_{MCA} can be corrected to standard conditions by the relationship:

$$V_{MCA_s} = V_{MCA_t} \cdot \sqrt{\frac{F_{na_s}}{F_{na_t}}} \text{ for turbojets}$$

$$V_{MCA_s} = V_{MCA_t} \cdot \left[\frac{THP_S\sqrt{\sigma_S}}{THP_t\sqrt{\sigma_t}}\right]^{\frac{1}{3}} \cdot \sqrt{\frac{F_{na_S}}{F_{na_t}}} \text{ for propeller driven}$$

Where:

THP_s = Maximum AFM scheduled brake/shaft horsepower multiplied by standard day propeller efficiency.

THP_t = Test day brake/shaft horsepower where V_{MCA} was achieved multiplied by test day propeller efficiency.

$\sqrt{\sigma_s}$ = *Atmospheric density ratio at standard conditions.*

$\sqrt{\sigma_t}$ = *Atmospheric density ratio at test conditions.*

F.3.3 Windmilling shaft horsepower is not considered because the current part 25 takeoff requirements for propeller driven airplanes result in such large performance penalties with a windmilling propeller that all part 25 turboprops to date have had autofeather installed.

F.3.4 Since both net thrust and shaft horsepower vary with speed, use of these equations will require an iterative solution. Because this constant C_n method does not consider the effect on V_{MCA} due to variations in bank angle, weight, sideslip angle, or adverse yaw, its use is limited to corrections of 5 percent or less in asymmetric net thrust or power.

F.3.5 For corrections beyond 5 percent, the relationship shown in equation (4) should be used, and enough flight test data should be obtained to define the correlation between C_{na} and $C_L \sin Ø$.

F.4 Graphical Method.

F.4.1 In theory this data could be obtained by varying any combination of asymmetric power or thrust, airspeed, weight, and bank angle that would provide a representative variable set. However, since V_{MCA} and stall speed are nearly coincident for most airplanes, there are some severe constraints on most of the variables. Typically, any reduction in maximum asymmetric power or thrust will cause V_{MCA} to decrease below stall speed, and any increase in weight will cause stall speed to increase above V_{MCA}. Therefore, the only parameter that can reasonably be varied is bank angle.

F.4.2 To maximize the spread between stall and minimum control speed, V_{MCA} tests are normally done at the lightest possible weight, at the maximum allowable asymmetric power or thrust (even with a short duration overboost, if the engine manufacturer will agree). At typical test altitudes (2000 to 3000 feet) and prototype gross weights, it will usually still not be possible to define V_{MCA} with the full 5° bank, because of stall buffet.

F.4.3 To obtain the data necessary for extrapolation to the 5° bank limit, and to maximum asymmetric power or thrust, testing at three bank angles is required for the definition of the C_{na} versus $C_L \sin Ø$ relationship. This data should be obtained by shutting down the critical engine (normally the left), setting maximum allowable power or thrust on the operative engine, and slowing down while maintaining constant heading until full rudder deflection is achieved. The first point, a wings level condition, is easy to set up, and results in a speed well above stall buffet. A second point, at zero sideslip, will be achieved at approximately 2° to 3° bank (flown with a yaw string, or instrumented sideslip vane) and will provide an intermediate speed, still above buffet. The third data point is flown with as much bank angle that can be used without excessive buffeting (no more than would be accepted as the minimum level of stall warning). If necessary, an additional point can be obtained by banking 2° to 3° into the inoperative engine.

F.4.4 To use this method, instrumentation is necessary for the determination of net thrust/shaft horsepower, and an accurate calibrated airspeed system is required, as well as engine/propeller charts for windmill drag, charts for propeller efficiency, and the ability to measure bank angle to at least a tenth of a degree.

F.4.5 Data obtained using this method with a typical business jet and a large jet transport are shown in figures F-1 and F-2, respectively:

Figure F-1. Two-Engine Business Jet

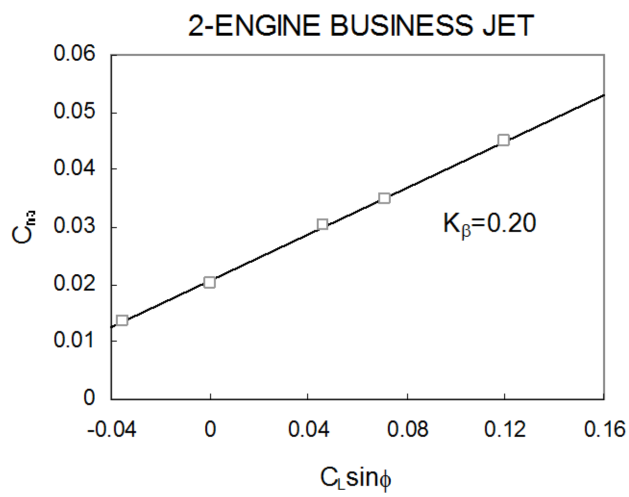
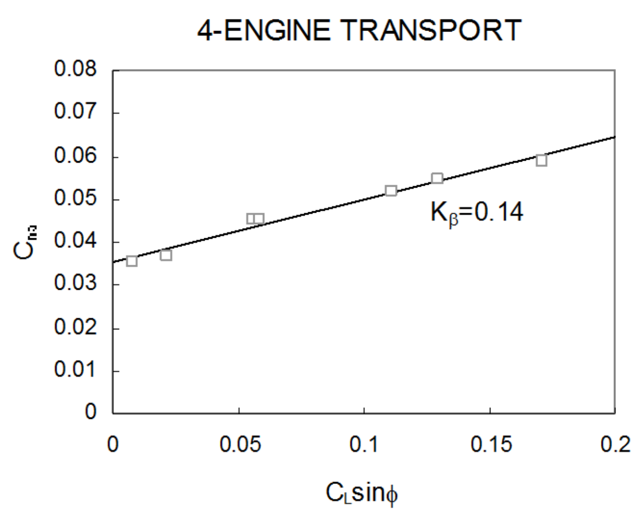


Figure F-2. Four-Engine Transport



F.4.6 These plots represent the capability of the airframe to produce yawing moment by a combination of rudder deflection (full, in this case), and the sideslip which results from the bank angle. In order to determine the limiting condition for V_{MCA}, it is necessary to know what the applied yawing moment is (due to the engine-out moments), and to plot the applied moments on the same plot, in a similar form. It is possible to do this by choosing a gross weight to be used to calculate C_L, and since standard bank angle will be 5°, the only remaining variable in C_L sin Ø is V_e. By choosing the appropriate values of F_n available versus V_e, a plot of C_{na} versus $C_L \sin Ø$ can be made which represents the applied yawing moments. If the weight chosen represents some standard minimum weight, and the available net power or thrust values represent the maximum allowable power or thrust scheduled in the AFM, the intersection point of the airframe curve and the engine curve will be the desired standard day values, which can be used to calculate V_{MCA}.

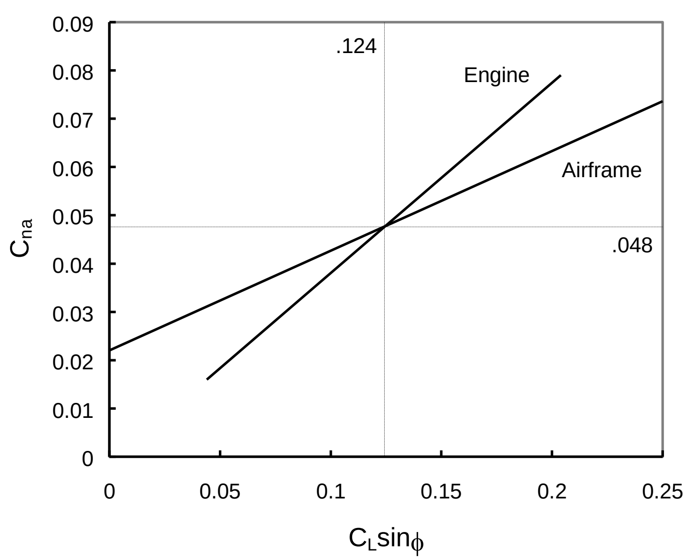
F.4.7 As an example, the following values of net thrust plus windmill drag have been extracted from a typical corporate jet engine spec. The data represent a maximum thrust engine, and have been corrected for ram drag and minimum accessory bleed and electrical load. The $C_L \sin Ø$ values are based on a gross weight of 9000 lbs.

Table F-1. Example Data for Typical Business Jet Engine

V_e	F_{na}	C_{na}	$C_L \sin\phi$
70	2,846	0.079	0.204
90	2,798	0.047	0.123
110	2,764	0.031	0.082
130	2,737	0.022	0.059
150	2,710	0.016	0.044

F.4.8 Plotting both the airframe and engine yawing moment curves on the same graph looks like:

Figure F-3. Yawing Moment—Engine and Airframe



F.4.9 The intersection of the airframe and the engine curve shows values of:

$$C_{na} = 0.048 \qquad C_L \sin\emptyset = 0.124$$

F.4.10 Since the engine C_n curve was based on W = 9000 lbs, the standard day value of V_{MCA} can be determined from:

$$C_L \sin\emptyset = 0.124 = \frac{295 \cdot W}{V_e^2 \cdot S}$$

$$V_e^2 = \frac{0.1108 \cdot 9000}{0.124}$$

$$V_{MCA} = 89.7\ KEAS$$

F.4.11 If the airframe data is obtained from flight test, there are no assumptions or simplifications, and the value of V_{MCA} derived from this method includes all the effects of bank angle, sideslip, adverse yaw, angle-of-attack, etc. Also, since the standard day value of C_{na} will always be less than the test value, no extrapolation is required, and there is no restriction on the value of standard day power or thrust that may be used.

F.5 Equation Method

F.5.1 A single test day value of V_{MCA} can also be corrected to standard conditions (using all the appropriate variables) without using this graphical method, provided either the slope of the C_{na} versus C_L sin Ø relationship is known (from wind tunnel, or analytical estimates), or one is willing to use a default (conservative) value. Power or thrust extrapolation using slope values not based on flight test is limited to 10 percent of the test day power or thrust. The following analysis shows the derivation of this single-point correction equation:

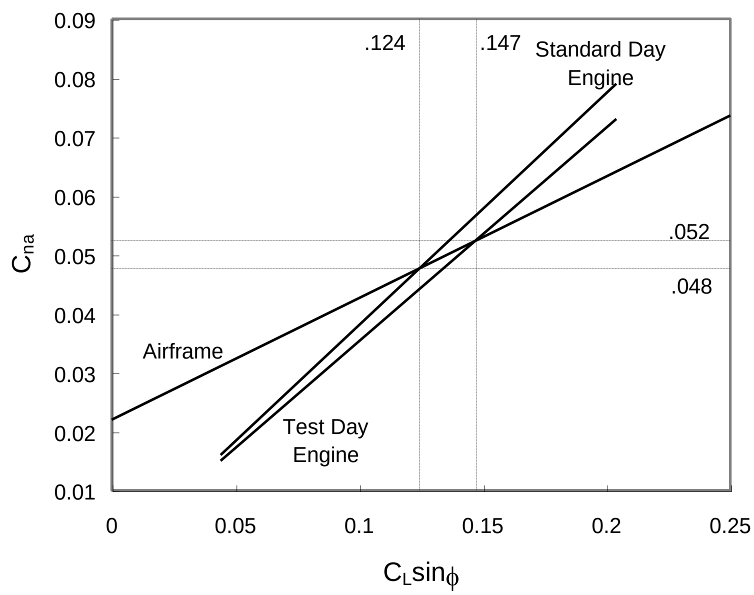
F.5.2 If the test day engine C_{na} curve was added to the previous plot, it would be possible to see how far, and in what direction, the correction from test to standard day was made. Assuming that a single value of V_{MCA} was determined at 3000 feet at a weight of 9000 lbs, a test day engine C_{na} curve could be plotted using the same technique used for the standard day curve, except substituting the 3000-foot thrust values from the engine specification:

Table F-2. Example Data for Typical Business Jet Engine at Altitude of 3,000 Feet

V_e	F_{na}	C_{na}	$C_L \sin\phi$
70	2,634	0.073	0.204
90	2,589	0.043	0.123
110	2,554	0.029	0.082
130	2,528	0.02	0.059
150	2,510	0.015	0.044

F.5.3 The following C_{na} versus C_L sin Ø plot shows the airframe curve, the standard day engine curve, and the test day curve:

Figure F-4. Yawing Moment—Engine and Airframe at Altitude of 3,000 Feet (Test Day)



F.5.4 From the airframe/engine curve intersections:

$$C_{nt} = 0.052 \qquad C_{ns} = 0.048$$

$$C_L \sin \emptyset_t = 0.147 \; C_L \sin \emptyset_s = 0.124$$

$$V_{MCA_t} = 82.4\ KEAS \qquad V_{MCA_s} = 89.7\ KEAS$$

F.5.5 This is a thrust correction of approximately 8 percent. If the constant C_n method had been used, the test value of .052 would have applied, and the corresponding V_{MCA_t}

would have been 85.7 KEAS, an error of 4 knots (5 percent) in the non-conservative direction.

F.5.6 Noting that the correction from test day to standard day is along the C_n versus C_L sin Ø curve, which is a straight line, and denoting the slope of the airframe curve as K_β, the intersection of the standard day thrust line with the airframe curve as C_{ns} and C_L sin Ø, and the intersection of the test day thrust line with the airframe curve as C_{nt} and C_L sin Ø, the following equation can be derived:

Given the point slope form of a straight line,

$$Y_2 - Y_1 = m(X_2 - X_1)$$

Correspondingly,

$$C_{ns} - C_{nt} = K_\beta(C_L\, sin\, \emptyset_s - C_L sin\, \emptyset_t)$$

$$C_{ns} - K_\beta \cdot C_L\, sin\, \emptyset_s = C_{nt} - K_\beta \cdot C_L sin\, \emptyset_t$$

$$\frac{F_{na_s} \cdot l_e}{q_s \cdot S \cdot b} - K_\beta \cdot \frac{W_s\, sin\, \emptyset_s}{q_s \cdot S} = \frac{F_{na_t} \cdot l_e}{q_t \cdot S \cdot b} - K_\beta \cdot \frac{W_t\, sin\, \emptyset_t}{q_t \cdot S}$$

Substituting

$$q = \frac{V_e^2}{295}$$

And then multiplying through by

$$\frac{V_{e_s}^2 \cdot S}{295}$$

$$F_{na_s} \cdot \frac{l_e}{b} - K_\beta W_s\, sin\, \emptyset_s = \frac{V_{e_s}^2}{V_{e_t}^2} \cdot \left[F_{na_t} \cdot \frac{l_e}{b} - K_\beta W_t sin\, \emptyset_t\right]$$

And finally,

$$V_{MCA_s} = V_{MCA_t}\left[\frac{F_{na_s} \cdot \left(\frac{l_e}{b}\right) - K_\beta W_s\, sin\, \emptyset_s}{F_{na_t} \cdot \left(\frac{l_e}{b}\right) - K_\beta W_t\, sin\, \emptyset_t}\right]^{\frac{1}{2}} for\ turbojets$$

And

$$V_{MCA_s} = V_{MCA_t}\left[\frac{326 \cdot \frac{SHP_s \times \eta_s\sqrt{\sigma_s}}{V_{MCA_s}} \cdot \left(\frac{l_e}{b}\right) - K_\beta W_s\, sin\, \emptyset_s}{326 \cdot \frac{SHP_t \times \eta_t\sqrt{\sigma_t}}{V_{MCA_t}} \cdot \left(\frac{l_e}{b}\right) - K_\beta W_t\, sin\, \emptyset_t}\right]^{\frac{1}{2}} for\ turboprops$$

F.5.7 In the simplified form of the lateral directional equations, K_β is C_{n_β}/C_{y_β}, which is the directional static margin. The value of K_β typically varies from approximately 0.14 to 0.19, depending on the lateral/directional characteristics of the airplane being tested. As with the graphical method, if K_β is determined by flight test, power or thrust corrections to V_{MCA} are based on an interpolation of flight test defined airframe capability, and there is no limit on the amount of the power or thrust correction to V_{MCA}. A somewhat conservative default value of 0.20 for K_β may be used if flight test data is not available; however, in this case, any power or thrust extrapolation is limited to 10 percent of the test day power or thrust. To assure that corrections for bank angle and weight do not result in standard day V_{MCA} values at or below stall speed, the corrections made by either the graphical or equation method should not result in a V_{MCA}, which is based on a $C_L \sin Ø$ that is greater than $C_{L_{MAX}} \sin 5°$.

APPENDIX G. RUDDER PEDAL FORCE-LIMITED AIR MINIMUM CONTROL SPEED

G.1 **One Acceptable Method.**

The following analysis presents one method of addressing rudder pedal force limited air minimum control speed. This method is applicable to either jet or propeller driven airplanes. The effect of banking into the operating engine is accounted for, and the method will work with either fixed pitch or constant speed propellers, including the effects of windmilling drag. For rudder deflection limited V_{MCA}, see appendix F of this AC.

G.1.1 Given the static lateral/directional equations of motion for straight line, unaccelerated flight:

$$\sum F_y = 0 \qquad C_{y_\beta} \cdot \beta + C_{y_{\delta a}} \cdot \delta_a + C_{y_{\delta r}} \cdot \delta_r = C_L \sin \emptyset \qquad (1)$$

$$\sum M_x = 0 \qquad C_{l_\beta} \cdot \beta + C_{l_{\delta a}} \cdot \delta_a + C_{l_{\delta r}} \cdot \delta_r = 0 \qquad (2)$$

$$\sum M_z = 0 \qquad C_{n_\beta} \cdot \beta + C_{n_{\delta a}} \cdot \delta_a + C_{n_{\delta r}} \cdot \delta_r = C_{na} \qquad (3)$$

G.1.2 For a reversible control system, rudder force versus deflection is:

$$F_R = G_R \cdot q \cdot S_R \cdot C_R \cdot C_{h_{\delta R}} \cdot \delta_R$$

and $\delta_R = \mathrm{k_R} \cdot \frac{\mathrm{F_R}}{\mathrm{V_e^2}}$

G.1.3 Substituting for F_R in equations (1) through (3), and solving, results in an identity of the form:

$$F_R = A \cdot F_{na} - B \cdot W \sin \emptyset$$

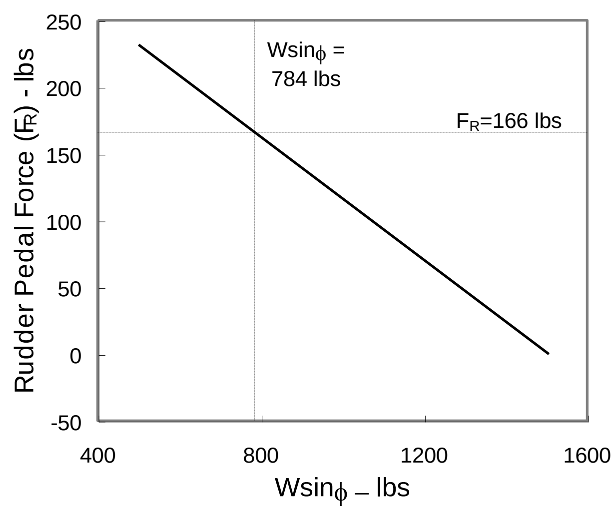
G.1.4 All the airspeed terms cancel, indicating that the engine-out rudder force required for straight flight is not a function of airspeed, but only of asymmetric power or thrust, weight, and bank angle. If asymmetric power or thrust did not vary with airspeed, it would be possible to stabilize at any airspeed with the same rudder force. At higher speeds, less rudder deflection would be required (varies inversely with V_e^2), but the same force would be required (varies directly with V_e^2). When a force limited V_{MCA} is determined during flight test, the variation in rudder force with airspeed results solely from the change in net power or thrust with speed, and if an airspeed (i.e., power or thrust level) is reached at which the rudder force is 150 lbs, there is no way to correct this force limited V_{MCA} to any other power or thrust level. Therefore, if V_{MCA} is rudder pedal force limited, takeoff power or thrust at all flight conditions should be limited to the test value of asymmetric power or thrust.

G.1.5 In some cases, it is possible to achieve full rudder deflection at the test altitude without reaching a pedal force limit, but with the higher power or thrust at standard conditions, a force limit would exist. To preclude missing this crossover effect, the following analysis should be performed whenever test day rudder pedal forces are greater than 90 percent of the part 25 limit (i.e., 135 lbs after amendment 25-42; 162 lbs prior to amendment 25-42).

G.1.5.1 At any convenient airspeed (typically 1.13 V_{SR} with minimum takeoff flaps), shut down the critical engine, and leave it windmilling (propeller feathered if autofeather is required), apply maximum available power/thrust to the operating engine, and while maintaining constant heading, vary the bank angle from 10° to less than 5° in approximately 2°-3° increments, noting the rudder force at each stabilized bank angle.

G.1.5.2 Plot the rudder force versus Wsin Ø for each of the test points. See figure G-1.)

Figure G-1. Rudder Force Versus WsinΦ



G.1.5.3 Calculate W_S sin 5° where W_S is either the average test weight, or the lightest weight scheduled in the AFM, and define standard day rudder force (F_{R_S}) as the intersection of this value of W_S sin 5° and the curve from step (2). For example:

$F_{na_t} = 2600\ lbs$ $\quad V = 1.13\ V_{SR}$ $\quad W_s = 9000\ lbs$

G.1.5.4 Determine the maximum allowable asymmetric thrust from the relationship:

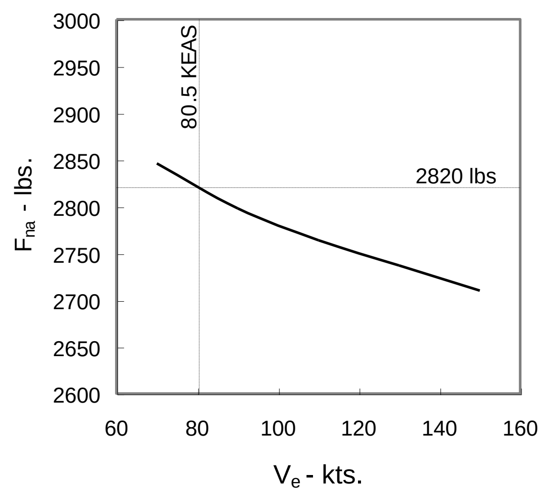
$$F_{na_{max}} = F_{na_t} \cdot \left(\frac{150}{F_{R_S}}\right)^{1}$$

Assuming a 180 lb force limit:

$$F_{na_{max}} = 2600 \cdot \left(\frac{180}{166}\right) = 2820\ lbs$$

G.1.5.5 Plot the maximum scheduled AFM thrust versus airspeed (see figure G-2), and determine V_{MCA} at the intersection of this curve and $F_{na_{max}}$:

Figure G-2. Plot to Determine V_{MCA}



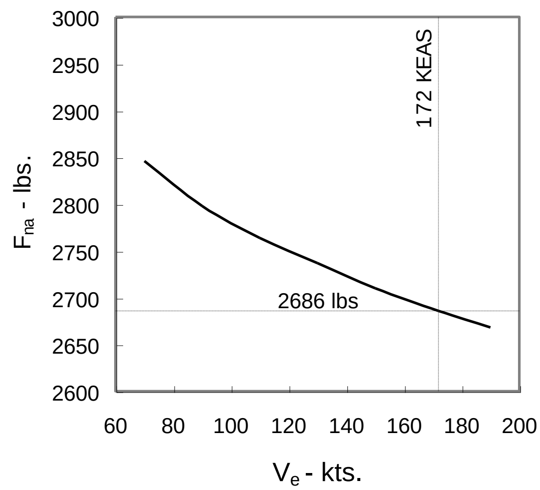
G.1.6 If the force limited V_{MCA} value is high enough to adversely impact the takeoff speed schedule, it can be reduced to an acceptable value by derating takeoff power or thrust. For example, if the standard day rudder force (F_{R_S}) was 140 lbs on an amendment 25-42 airplane, the maximum allowable asymmetric takeoff thrust would be:

$$F_{na_{max}} = 2600 \cdot \frac{150}{140} = 2686\ lbs$$

[1] $\left(\frac{180}{F_{R_S}}\right)$ prior to amendment 25-42.

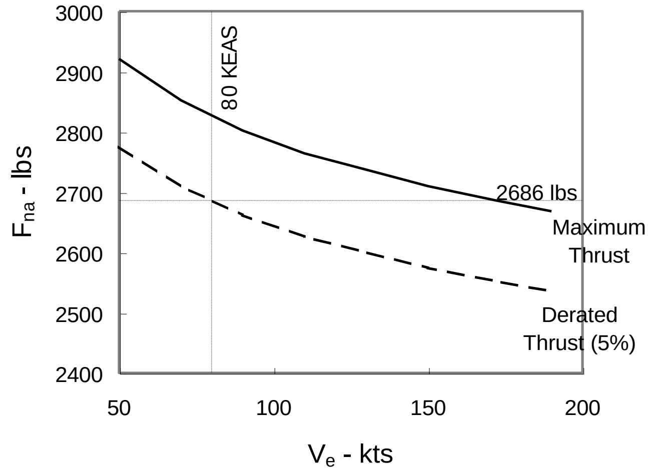
G.1.7 Using the same maximum asymmetric thrust available versus airspeed as before:

Figure G-3. Plot to Determine V_{MCA} for an Amendment 25-42 Airplane



G.1.8 Because of the shallow thrust lapse rate with airspeed, the force limited V_{MCA} for these conditions would be 172 knots, which is obviously unacceptable. To reduce this value back to 80 knots (or any other speed), takeoff thrust should be derated to a level that provides a maximum asymmetric thrust value of $F_{na_{max}}$ at the desired V_{MCA} (80 knots in this example). The amount of derate required can be determined from the following plot:

Figure G-4. Plot to Determine V_{MCA} for Derate Thrust



G.1.9 For a given weight and bank angle, rudder pedal force is determined solely by asymmetric thrust; consequently, takeoff thrust should be limited to a value that results in a pedal force no greater than 150 lbs (180 lbs prior to amendment 25-42).

APPENDIX H. ADVISORY CIRCULAR FEEDBACK

If you find an error in this AC, have recommendations for improving it, or have suggestions for new items/subjects to be added, you may let us know by (1) emailing this form to 9-AWA-AVS-AIR-DMO@faa.gov or (2) faxing it to (202) 267-1813.

Subject: AC 25-7D

Date: Click here to enter text.

Please check all appropriate line items:

☐ An error (procedural or typographical) has been noted in paragraph Click here to enter text. on page Click here to enter text..

☐ Recommend paragraph Click here to enter text. on page Click here to enter text. be changed as follows:

Click here to enter text.

☐ In a future change to this AC, please cover the following subject:
(Briefly describe what you want added.)

Click here to enter text.

☐ Other comments:

Click here to enter text.

☐ I would like to discuss the above. Please contact me.

Submitted by: ________________________________

Date: _________________________