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Federal Aviation Administration

Advisory Circular

Subject: Flight Test Guide for Certification of Transport Category Airplanes

Date: XX/XX/XX
Initiated By: AIR-621A

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Change: 2

1. PURPOSE. This advisory circular (AC) contains material changes that update guidance for the flight test evaluation, flight test methods, and procedures used to demonstrate compliance with Title 14, Code of Federal Regulations (14 CFR) part 25, subpart B for transport category airplanes.

2. PRINCIPAL CHANGES. This change incorporates new guidance for demonstrating that the airplane is free from excessive vibration and buffet. Specifically, revisions to Section 10.1 Vibration and Buffeting–25.251(b) include guidance for using analytical methods. It also corrects the list of related reading materials and hyperlinks within the document.

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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 transport category airplanes and, as such, represent current certification practice.

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

1.2 **Applicability.**

1.2.1 The guidance provided in this AC is for airplane manufacturers, modifiers, foreign regulatory authorities, Federal Aviation Administration (FAA) transport airplane type certification engineers, and FAA designees.

1.2.2 This is a guidance document. Its content is not legally binding in its own right and will not be relied upon by the Department as a separate basis for affirmative enforcement action or other administrative penalty. Conformity with the guidance document is voluntary only. Nonconformity will not affect rights and obligations under existing statutes and regulations.

1.2.3 The FAA will consider other means of demonstrating compliance that an applicant may elect to present. Terms such as “should,” “may,” and “must” are used only in the sense of ensuring applicability of this particular method of compliance when the acceptable method of compliance in this document is used. If the FAA becomes aware of circumstances in which following this AC would not result in compliance with the applicable regulations, the FAA may require additional substantiation or design changes as a basis for finding compliance.

1.2.4 The material contained in this AC does not change, or create any additional, regulatory requirement, nor does it authorize changes in, or permit deviations from existing regulatory requirements.

1.3 **Background.**

1.3.1 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.

1.3.2 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.

1.3.3 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.

1.3.4 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.

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

1.3.6 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 (NTSB).

1.3.7 AC 25-7D clarified paragraph 23.2.4, *Engine Restart Capability*—§ 25.903(e); added paragraph 34.4, *Circuit Protective Devices*—§ 25.1357; and revised appendix B, *Function and Reliability* (F&R) Tests, of this AC. The AC was re-formatted to use a new paragraph numbering system for improved usability.

1.3.8 Change 1 to AC 25-7D incorporates updates and adds or revises guidance for stall in ground effect and tailwind and crosswind capability, in response to several NTSB safety recommendations.

1.3.9 Change 2 to AC 25-7D incorporates new guidance for demonstrating that the airplane is free from excessive vibration and buffet by using analytical methods.

1.4 **Related Material.**

1.4.1 <u>FAA Orders</u>.

The following FAA orders are related to the guidance in this AC. The latest version of each order referenced in this document is available on the FAA website at FAA Orders and Notices and on the Dynamic Regulatory System.

- Order 8100.5E, *Aircraft Certification Service – Organizational Structure and Functions*, dated April 9, 2023.
- Order 8110.4C, with Change 7, *Type Certification*, dated October 20, 2023.

1.4.2 FAA Advisory Circulars.

The following ACs are related to the guidance in this AC. The latest version of each AC referenced in this document is available on the FAA website at FAA Advisory Circulars and on the Dynamic Regulatory System.

- 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, with Change 1, *Detecting and Reporting Suspected Unapproved Parts*, dated February 13, 2018.
- 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 25.1309-1B, *System Design and Analysis*, dated August 30, 2024.
- 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 43.13-2B, *Acceptable Methods, Techniques, and Practices—Aircraft Alterations*, dated March 03, 2008.
- 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 91-79B, *Mitigating the Risks of a Runway Overrun Upon Landing*, dated August 28, 2023.
- 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.

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 may cause structural damage or, if sustained over an extended period of time, could lead to structural fatigue; may cause pilot fatigue or annoyance that interferes with operation of the airplane or management of the airplane systems; or interferes with flight instrument readability.

10.1.1.3 When external modifications are made to an existing type design, compliance with § 25.251(b) must be addressed. If it can be shown by an acceptable method that the original compliance finding for this rule remains valid (i.e., no vibration/buffet issues exist due to the change), then additional flight testing above V_{MO}/M_{MO} is not required.

10.1.1.4 The FAA considers that the extent of the airplane modifications proposed by the applicant, particularly the size, shape, and location of those modifications with respect to the unmodified airplane, may cause significant changes in the aerodynamic flow field around the airplane at high speed, which may lead to excessive vibration/buffet. Potential vibration sources include unsteady flow conditions on the modification, fuselage, tail assembly, or control surfaces arising from shocks, flow separation or other unsteadiness in the flow. Because of these potential effects, the FAA has determined that the original demonstration of compliance for § 25.251(b) may not be valid for the modified airplanes. Therefore, unless it can be shown that the modification would not invalidate the original § 25.251(b) compliance demonstration, compliance must be re-demonstrated by flight testing at speeds up to V_{DF}/M_{DF}.

10.1.1.5 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.

10.1.1.6 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 using 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.

10.1.1.7 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.

10.1.1.8 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 shockwave 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.

10.1.1.9 Section 25.251(e) requires that "probable inadvertent excursions beyond the boundaries of buffet" may not result in "unsafe conditions." 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).**

10.1.2.2.1 New Type Designs.

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.

10.1.2.2.2 Modifications to Existing Type Designs.

For external modifications to an existing approved design, an evaluation must be performed to determine whether the modification could invalidate compliance with § 25.251(b). Previously, there were no valid analytical methods of substantiating that there is no excessive vibration at V_{DF}/M_{DF} other than flight testing to V_{DF}/M_{DF}. Analysis tools may now be used, however, in determining whether a given modification may invalidate the original § 25.251(b) compliance finding.

To evaluate whether the modification could invalidate the original compliance finding, the applicant may propose to use any suitable combination of the following:

1. Similarity to other approved designs. Consider the size, shape, and location of the respective modification, the airplanes they are installed on, the respective V_{DF}/M_{DF} speeds, and the method of compliance used for the approved designs.
2. Flow field analysis using acceptable Computational Fluid Dynamics (CFD). The applicant should show that the CFD is valid for its

intended use (see paragraph 10.1.2.2.2.1). The applicant should also address other known limitations and characteristics of the CFD to be used, such as:

- Grid sizes and spacing.
- Geometric fidelity of the airplane model and the effect of simplifications of the model (e.g., ignoring flap track fairings, vortex generators, small gaps, etc.; how the engines are modeled; aeroelastic effects; other differences between the actual airplane and the digital model used in the analysis).
- CFD modeling errors, particularly in turbulence modeling.
- Location of the trip point from laminar to turbulent flow.
- Boundary conditions (e.g., ensuring that far field conditions are applied sufficiently far away).

3. An analysis of the vibration due to buffeting, usually based on the results of the flow field analysis, as addressed in item 2.
4. Flight testing to speeds and altitudes from which the analyses described in this paragraph (10.1.2.2.2) can be used to extrapolate the findings to V_{DF}/M_{DF}. As a minimum, flight testing must include the critical flight conditions to cover the complete flight domain from low speed to a speed up to and including V_{MO}/M_{MO}, which may include high lift configurations, landing gear extended, or sideslips that could be experienced in service.

10.1.2.2.2.1 <u>CFD Validation</u>.

To use CFD in showing that the modification does not invalidate compliance with § 25.251(b), the applicant should show that it is valid for its intended use. The CFD needs to be capable of accurately assessing whether a shock is present, including its strength and location, and the area of separated flow. Generally, a full Navier-Stokes CFD with robust turbulence modeling is needed for such an analysis. Validation using flight test data is preferred, but suitable wind tunnel data may be acceptable. Validation includes:

- Showing that the CFD accurately models flow phenomena of interest (transonic shocks, shock induced flow separation, shock-boundary layer interaction and separated flows) that may result from the modification.
- Showing that the person/organization performing the analysis is experienced and qualified to properly run the CFD and interpret the results.

The modeling accuracy of the pertinent flow field phenomena should be demonstrated by comparing flow field characteristics (pressure distributions, shock strength/location, etc.) predicted by the model to flight test or wind tunnel data for a configuration (including shape, location, and airframe) similar to the modification being evaluated at airspeeds up to V_{DF}/M_{DF}. In addition, if there are no significant flow field phenomena of interest transonic shocks, shock-induced flow separation, shock-boundary layer interaction and separated flows) shown with the configuration being evaluated, a comparison should be made to another configuration that does exhibit such phenomena. Validation depends on the flow phenomena of interest being present to show that the CFD will accurately model such flow phenomena.

The test cases used to validate the CFD should be agreed to in advance by the FAA.

10.1.2.2.2.2 Aerodynamic Analysis.

An aerodynamic analysis using the validated CFD may be used to show that compliance with § 25.251(b) will remain valid for the modification, provided the FAA has accepted the CFD validation. The aerodynamic analysis need not cover all flight conditions. The critical flight conditions should be identified and those that need to be analyzed in detail selected. The applicant should document how these critical flight conditions have been identified. The applicant should analyze the effects of all simplifications or assumptions applied to the aerodynamic model (i.e., the analytical representation of the modified and unmodified airplanes) and show that these simplifications would not lead to an inappropriate conclusion.

After FAA acceptance of both the CFD validation and the results of the aerodynamic analysis, it may not be required to perform a flight test to V_{DF}/M_{DF} to show that the modification did not invalidate compliance with § 25.251(b). However, a flight test to V_{MO}/M_{MO} should be performed with a qualitative assessment that no buffeting condition exists up to that speed to show compliance with § 25.251(d).

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.

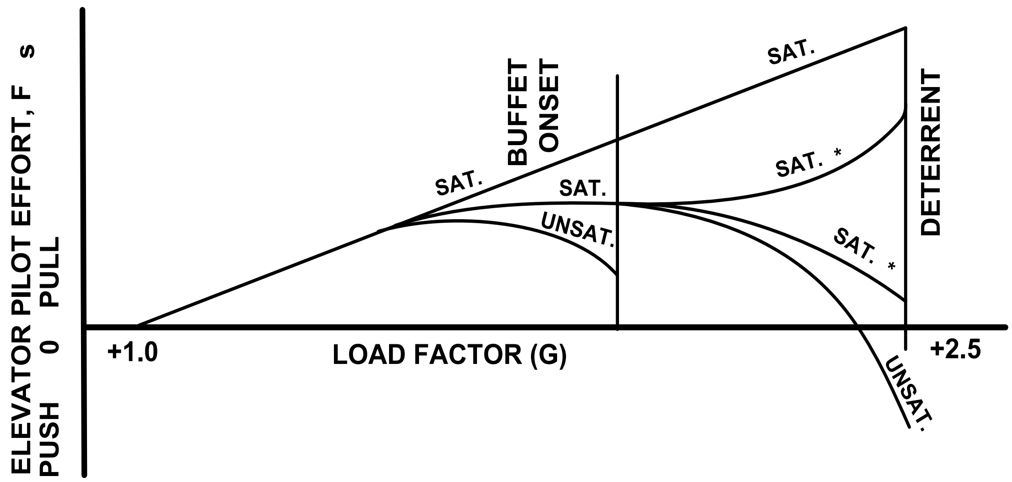
10.1.2.5.1 The determination of compliance with § 25.251(e), using flight test data from maneuvers conducted well into buffet, is extremely difficult due to the dynamics of this type of maneuver and the establishment of the F_S/g relationship from such data. The pilot flying the airplane needs to evaluate the airplane characteristics under such conditions. Figure 10-1 provides guidance on stick force per g (F_S/g) characteristics that would be considered acceptable or unacceptable.

10.1.2.5.2 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:

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) vs. g curve should have a positive slope at any speed up to V_{MO}/M_{MO} 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 item #1 above and item #2 below.

Figure 10-1. Maneuvering Characteristics at Speeds up to V_{MO}/M_{MO}



Under the airplane weight/altitude combinations of item #1 above but at load factors beyond buffet onset, the following F_S characteristics apply (see figure 10-1):

a. 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.

b. Any pitching tendency (uncommanded changes in load factor) should be mild and readily controllable.

c. 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.

d. The airplane's pitch response to primary longitudinal control should be predictable to the pilot.

10.1.2.5.3 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:

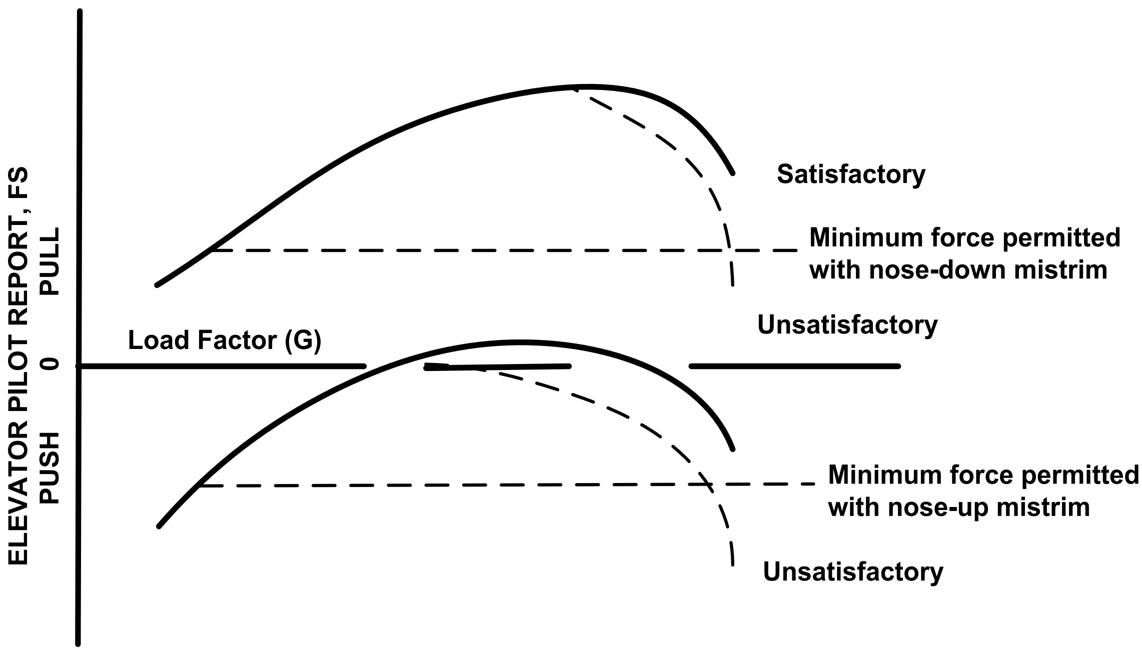
- For speeds up to V_{MO}/M_{MO}, the particular speed at which the demonstration is being made; and
- For speeds higher than V_{MO}/M_{MO}, V_{MO}/M_{MO}.

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.

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