3 Conditions for 1 and 2:

Wing-flaps retracted.

Speedbrakes retracted and extended.

Landing gear retracted.

Trim. The aeroplane trimmed for straight flight at V_{MO}/M_{MO}. The trimming controls should not be moved during the manoeuvre.

Power:

(i) 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

(ii) if the effect of power is significant, with the throttles closed.

AMC 25.253(a)(5) High Speed Characteristics

ED Decision 2003/2/RM

Extension of Speedbrakes. The following guidance is provided to clarify the meaning of the words "the available range of movements of the pilot's control" in CS 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 CS 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.

CS 25.697(b) requires that lift and drag devices intended for ground operation only must 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 incorporating 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 aeroplane Flight Manual limitation or procedural means.

The effect of extension of speedbrakes may be evaluated during other high speed testing and during the development of emergency descent procedures. It may be possible to infer compliance with CS 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 load factor should be regarded as excessive if it exceeds 2.0. A nose-down pitching moment may be regarded as small if it necessitates an incremental control force of less than 89 N (20 lbf) to maintain 1g flight. These values may not be appropriate for all aeroplanes, and depend on the characteristics of the particular aeroplane design in high speed flight. Other means of compliance may be acceptable, provided that the Agency finds that compliance has been shown to the qualitative requirements specified in CS 25.253(a)(5).

CS 25.255 Out-of-trim characteristics

ED Decision 2003/2/RM

(See AMC 25.255)

(a) From an initial condition with the aeroplane trimmed at cruise speeds up to V_{MO}/M_{MO}, the aeroplane must have satisfactory manoeuvring stability and controllability with the degree of out-of-trim in both the aeroplane nose-up and nose-down directions, which results from the greater of –

(1) A three-second movement of the longitudinal trim system at its normal rate for the particular flight condition with no aerodynamic load (or an equivalent degree of trim for aeroplanes that do not have a power-operated trim system), except as limited by stops in the trim system, including those required by CS 25.655(b) for adjustable stabilisers; or

(2) The maximum mistrim that can be sustained by the autopilot while maintaining level flight in the high speed cruising condition.

(b) In the out-of-trim condition specified in sub-paragraph (a) of this paragraph, when the normal acceleration is varied from + 1 g to the positive and negative values specified in sub-paragraph (c) of this paragraph –

(1) The stick force vs. g curve must have a positive slope at any speed up to and including V_{FC}/M_{FC}; and

(2) At speeds between V_{FC}/M_{FC} and V_{DF}/M_{DF}, the direction of the primary longitudinal control force may not reverse.

(c) Except as provided in sub-paragraphs (d) and (e) of this paragraph compliance with the provisions of sub-paragraph (a) of this paragraph must be demonstrated in flight over the acceleration range –

(1) –1g to 2·5 g; or

(2) 0 g to 2·0 g, and extrapolating by an acceptable method to – 1 g and 2·5 g.

(d) If the procedure set forth in sub-paragraph (c)(2) of this paragraph is used to demonstrate compliance and marginal conditions exist during flight test with regard to reversal of primary longitudinal control force, flight tests must be accomplished from the normal acceleration at which a marginal condition is found to exist to the applicable limit specified in sub-paragraph (c)(1) of this paragraph.

(e) During flight tests required by subparagraph (a) of this paragraph the limit manoeuvring load factors prescribed in CS 25.333(b) and 25.337, and the manoeuvring load factors associated with probable inadvertent excursions beyond the boundaries of the buffet onset envelopes determined under CS 25.251(e), need not be exceeded. In addition, the entry speeds for flight test demonstrations at normal acceleration values less than 1 g must be limited to the extent necessary to accomplish a recovery without exceeding V_{DF}/M_{DF}.

(f) In the out-of-trim condition specified in sub-paragraph (a) of this paragraph, it must be possible from an overspeed condition at V_{DF}/M_{DF}, to produce at least 1·5 g for recovery by applying not more than 556 N (125 lbf) of longitudinal control force using either the primary longitudinal control alone or the primary longitudinal control and the longitudinal trim system. If the longitudinal trim is used to assist in producing the required load factor, it must be shown at V_{DF}/M_{DF} that the longitudinal trim can be actuated in the aeroplane nose-up direction with the primary surface loaded to correspond to the least of the following aeroplane nose-up control forces:

(1) The maximum control forces expected in service as specified in CS 25.301 and 25.397.

(2) The control force required to produce 1·5 g.

(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.

AMC 25.255 Out-of-trim characteristics

ED Decision 2003/2/RM

1 *Amount of Out-of-trim Required*

1.1 The equivalent degree of trim, specified in CS 25.255(a)(1) for aeroplanes which do not have a power-operated longitudinal trim system, has not been specified in quantitative terms, and the particular characteristics of each type of aeroplane must be considered. The intent of the requirement is that a reasonable amount of out-of-trim should be investigated, such as might occasionally be applied by a pilot.

1.2 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. Where the autopilot is equipped with an auto-trim function the amount of mistrim which can be sustained will generally be small or zero. If there is no auto-trim function, consideration should be given to the maximum amount of out-of-trim which can be sustained by the elevator servo without causing autopilot disconnect.

2 *Datum Trim Setting*

2.1 For showing compliance with CS 25.255(b)(1) for speeds up to V_{MO}/M_{MO}, the datum trim setting should be the trim setting required for trimmed flight at the particular speed at which the demonstration is to be made.

2.2 For showing compliance with CS 25.255(b)(1) for speeds from V_{MO}/M_{MO} to V_{FC}/M_{FC}, and for showing compliance with CS 25.255(b)(2) and (f), the datum trim setting should be the trim setting required for trimmed flight at V_{MO}/M_{MO}.

3 *Reversal of Primary Longitudinal Control Force at Speeds greater than V_{FC}/M_{FC}*

3.1 CS 25.255(b)(2) requires that the direction of the primary longitudinal control force may not reverse when the normal acceleration is varied, for +1 g to the positive and negative values specified, at speeds above V_{FC}/M_{FC}. The intent of the requirement is that it is permissible that there is a value of g for which the stick force is zero, provided that the stick force versus g curve has a positive slope at that point (see Figure 1).

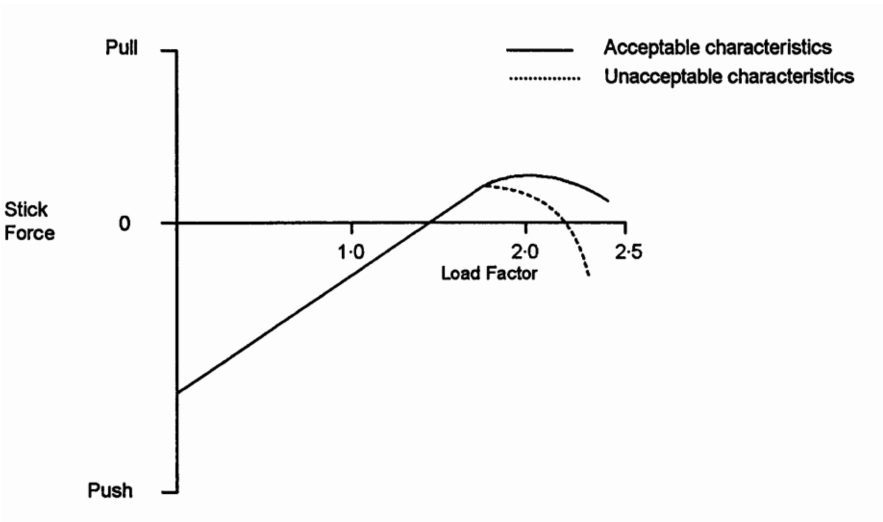

FIGURE 1

3.2 If stick force characteristics are marginally acceptable, it is desirable that there should be no reversal of normal control sensing, i.e. an aft movement of the control column should produce an aircraft motion in the nose-up direction and a change in aircraft load factor in the positive direction, and a forward movement of the control column should change the aircraft load factor in the negative direction.

3.3 It is further intended that reversals of direction of stick force with negative stick-force gradients should not be permitted in any mistrim condition within the specified range of mistrim. If test results indicate that the curves of stick force versus normal acceleration with the maximum required mistrim have a negative gradient of speeds above V_{FC}/M_{FC} then additional tests may be necessary. The additional tests should verify that the curves of stick force versus load factor with mistrim less than the maximum required do not unacceptably reverse, as illustrated in the upper curve of Figure 2. Control force characteristics as shown in Figure 3, may be considered acceptable, provided that the control sensing does not reverse (see paragraph 3.2)

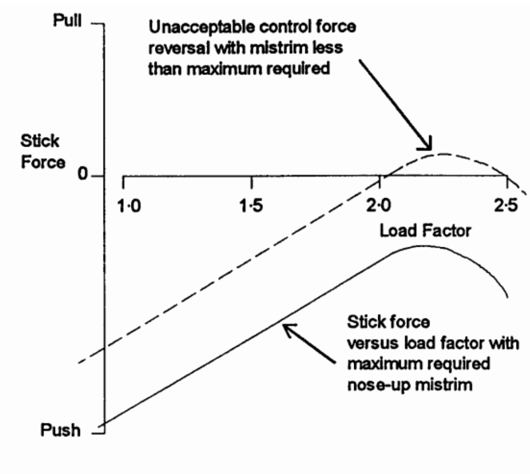

FIGURE 2

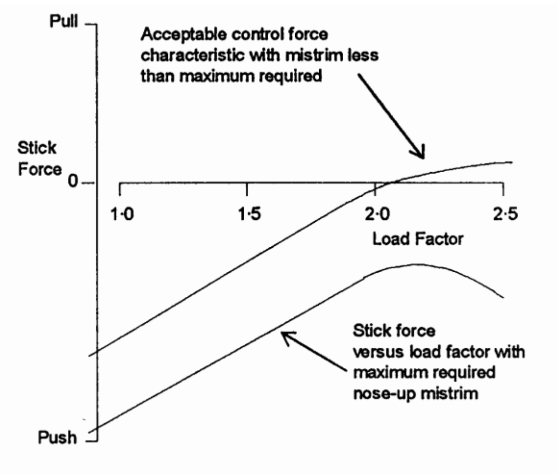

FIGURE 3

4 *Probable Inadvertent Excursions beyond the Boundaries of the Buffet Onset Envelopes.* CS 25.255(e) states that manoeuvring load factors associated with probable inadvertent excursions beyond the boundaries of the buffet onset envelopes determined under CS 25.251(e) need not be exceeded. It is intended that test flights need not be continued beyond a level of buffet which is sufficiently severe that a pilot would be reluctant to apply any further increase in load factor.

5 *Use of the Longitudinal Trim System to Assist Recovery*

5.1 CS 25.255(f) requires the ability to produce at least 1·5 g for recovery from an overspeed condition of V_{DF}/M_{DF}, using either the primary longitudinal control alone or the primary longitudinal control and the longitudinal trim system. Although the longitudinal trim system may be used to assist in producing the required normal acceleration, it is not acceptable for recovery to be completely dependent upon the use of this system. It should be possible to produce 1·2 g by applying not more than 556 N (125 lbf) of longitudinal control force using the primary longitudinal control alone.

5.2 Recovery capability is generally critical at altitudes where airspeed (V_{DF}) is limiting. If at higher altitudes (on the M_{DF} boundary) the manoeuvre capability is limited by buffeting of such an intensity that it is a strong deterrent to further increase in normal acceleration, some reduction of manoeuvre capability will be acceptable, provided that it does not reduce to below 1·3 g. The entry speed for flight test demonstrations of compliance with this requirement should be limited to the extent necessary to accomplish a recovery without exceeding V_{DF}/M_{DF}, and the normal acceleration should be measured as near to V_{DF}/M_{DF} as is practical.

SUBPART C – STRUCTURE

GENERAL

CS 25.301 Loads

ED Decision 2016/010/R

(See AMC 25.301)

(a) Strength requirements are specified in terms of limit loads (the maximum loads to be expected in service) and ultimate loads (limit loads multiplied by prescribed factors of safety). Unless otherwise provided, prescribed loads are limit loads.

(b) Unless otherwise provided the specified air, ground, and water loads must be placed in equilibrium with inertia forces, considering each item of mass in the aeroplane. These loads must be distributed to conservatively approximate or closely represent actual conditions. (See AMC No. 1 to CS 25.301(b).) Methods used to determine load intensities and distribution must be validated by flight load measurement unless the methods used for determining those loading conditions are shown to be reliable. (See AMC No. 2 to CS 25.301(b).)

(c) If deflections under load would significantly change the distribution of external or internal loads, this redistribution must be taken into account.

[Amdt 25/1]
[Amdt 25/18]

AMC No. 1 to 25.301(b) Loads

ED Decision 2005/006/R

The engine and its mounting structure are to be stressed to the loading cases for the aeroplane as a whole.

[Amdt 25/1]

AMC No. 2 to 25.301(b) Flight Load Validation

ED Decision 2005/006/R

1. PURPOSE

This AMC sets forth an acceptable means, but not the only means, of demonstrating compliance with the provisions of CS-25 related to the validation, by flight load measurements, of the methods used for determination of flight load intensities and distributions, for large aeroplanes.

2. RELATED CERTIFICATIONS SPECIFICATIONS

CS 25.301(b) "Loads"

CS 25.459 "Special Devices"

3. BACKGROUND

(a) CS-25 stipulates a number of load conditions, such as flight loads, ground loads, pressurisation loads, inertia loads and engine/APU loads. CS 25.301 requires methods used to determine load intensities and distributions to be validated by flight load measurements unless the methods used for determining those loading conditions are shown to be reliable. Although this applies to all load conditions of CS-25, the scope of this AMC is limited to flight loads.

(b) The sizing of the structure of the aircraft generally involves a number of steps and requires detailed knowledge of air loads, mass, stiffness, damping, flight control system characteristics, etc. Each of these steps and items may involve its own validation. The scope of this AMC however is limited to validation of methods used for determination of loads intensities and distributions by flight load measurements.

(c) By reference to validation of "methods", CS 25.301(b) and this AMC are intended to convey a validation of the complete package of elements involved in the accurate representation of loads, including input data and analytical process. The aim is to demonstrate that the complete package delivers reliable or conservative calculated loads for scenarios relevant to CS-25 flight loads requirements.

(d) Some measurements may complement (or sometimes even replace) the results from theoretical methods and models. Some flight loads development methods such as those used to develop buffeting loads have very little theoretical foundation, or are methods based directly on flight loads measurements extrapolated to represent limit conditions.

4. NEED FOR AND EXTENT OF FLIGHT LOAD MEASUREMENTS

4.1. General

(a) The need for and extent of the flight load measurements has to be discussed and agreed between the Agency and Applicant on a case by case basis. Such an assessment should be based on:

(i) a comparison of the design features of the aeroplane under investigation with previously developed (by the Applicant) and approved aeroplanes. New or significantly different design features should be identified and assessed.

(ii) the Applicant's previous experience in validating load intensities and distributions derived from analytical methods and/or wind tunnel tests. This experience should have been accumulated on previously developed (by the Applicant) and approved types and models of aeroplanes. The validation should have been by a flight load measurement program that was conducted by the Applicant and found acceptable to the Agency for showing compliance.

(iii) the sensitivity to parametric variation and continued applicability of the analytical methods and/or wind tunnel test data.

(b) Products requiring a new type certificate will in general require flight-test validation of flight loads methods unless the Applicant can demonstrate to the Agency that this is unnecessary.

If the configuration under investigation is a similar configuration and size as a previously developed and approved design, the use of analytical methods, such as computational fluid dynamics validated on wind tunnel test results and supported by previous load validation flight test experience, may be sufficient to determine flight loads without further flight test validation.

(c) Applicants who are making a change to a Type Certificated airplane, but who do not have access to the Type certification flight loads substantiation for that airplane, will be required to develop flight loads analyses, as necessary, to substantiate the change.

In general, the loads analyses will require validation and may require flight test loads measurements, as specified in this AMC.

(d) The Applicant is encouraged to submit supporting data or test plans for demonstrating the reliability of the flight loads methods early in the certification planning process.

4.2. New or significantly different design features.

Examples of new or significantly different design features include, but are not limited to:

— Wing mounted versus fuselage mounted engines;

— Two versus three or more engines;

— Low versus high wing;

— Conventional versus T-tail empennage;

— First use of significant sweep;

— Significant expansion of flight envelope;

— Addition of winglets;

— Significant modification of control surface configuration;

— Significant differences in airfoil shape, size (span, area);

— Significant changes in high lift configurations;

— Significant changes in power plant installation/configuration;

— Large change in the size of the aeroplane.

4.3. Other considerations

(a) Notwithstanding the similarity of the aeroplane or previous load validation flight test experience of the Applicant, the local loads on the following elements are typically unreliably predicted and may require a measurement during flight tests:

— Loads on high lift devices;

— Hinge moments on control surfaces;

— Loads on the empennage due to buffeting;

— Loads on any unusual device.

(b) For non-deterministic loading conditions, such as stall buffet, the applicant should compile a sufficient number of applicable flight loads measurements to develop a reliable method to predict the appropriate design load.

5. <u>FLIGHT LOAD MEASUREMENTS</u>

5.1. Measurements.

Flight load measurements (for example, through application of strain gauges, pressure belts, accelerometers) may include:

— Pressures / air loads /net shear, bending and torque on primary aerodynamic surfaces;

— Flight mechanics parameters necessary to correlate the analytical model with flight test results;

— High lift devices loads and positions;

— Primary control surface hinge moments and positions;

— Unsymmetric loads on the empennage (due to roll/yaw manoeuvres and buffeting);

— Local strains or response measurements in cases where load calculations or measurements are indeterminate or unreliable.

5.2. Variation of parameters.

The test points for the flight loads measurements should consider the variation of the main parameters affecting the loads under validation. Examples of these parameters include: load factor, speeds, altitude, aircraft c.g., weight and inertia, power settings (thrust, for wing mounted engines), fuel loading, speed brake settings, flap settings and gear conditions (up/down) within the design limits of the aeroplane. The range of variation of these parameters must be sufficient to allow the extrapolation to the design loads conditions. In general, the flight test conditions need not exceed approximately 80% of limit load.

5.3. Conditions.

In the conduct of flight load measurements, conditions used to obtain flight loads may include:

— Pitch manoeuvres including wind-up turns, pull-ups and push-downs (e.g. for wing and horizontal stabiliser manoeuvring loads);

— Stall entry or buffet onset boundary conditions (e.g. for horizontal stabiliser buffet loads);

— Yaw manoeuvres including rudder inputs and steady sideslips;

— Roll manoeuvres.

Some flight load conditions are difficult to validate by flight load measurements, simply because the required input (e.g. gust velocity) cannot be accurately controlled or generated. Therefore, these type of conditions need not be flight tested. Also, in general, failures, malfunctions or adverse conditions are not subject to flight tests for the purpose of flight loads validation.

5.4. Load alleviation.

When credit has been taken for an active load alleviation function by a particular control system, the effectiveness of this function should be demonstrated as far as practicable by an appropriate flight test program.

6. RESULTS OF FLIGHT LOAD MEASUREMENTS

6.1. Comparison / Correlation.

Flight loads are not directly measured, but are determined through correlation with measured strains, pressures or accelerations. The load intensities and distributions derived from flight testing should be compared with those obtained from analytical methods. The uncertainties in both the flight testing measurements and subsequent correlation should be carefully considered and compared with the inherent assumptions and capabilities of the process used in analytic derivation of flight loads. Since in most cases the flight test points are not the limit design load conditions, new analytical load cases need to be generated to match the actual flight test data points.

6.2. Quality of measurements.

Factors which can affect the uncertainty of flight loads resulting from calibrated strain gauges include the effects of temperature, structural non-linearities, establishment of flight/ground zero reference, and large local loads, such as those resulting from the propulsion system installation, landing gear, flap tracks or actuators. The static or dynamic nature of the loading can also affect both strain gauge and pressure measurements.

6.3. Quality of correlation.

A given correlation can provide a more or less reliable estimate of the actual loading condition depending on the "static" or "flexible dynamic" character of the loading action, or on the presence and level of large local loads. The quality of the achieved correlation depends also on the skills and experience of the Applicant in the choice of strain gauge locations and conduct of the calibration test programme.

Useful guidance on the calibration and selection of strain gauge installations in aircraft structures for flight loads measurements can be found, but not exclusively, in the following references:

1. Skopinski, T.H., William S. Aiken, Jr., and Wilbur B. Huston,

"Calibration of Strain-Gage Installations in Aircraft Structures for Measurement of Flight Loads", NACA Report 1178, 1954.

2. Sigurd A. Nelson II, "Strain Gage Selection in Loads Equations Using a Genetic Algorithm", NASA Contractor Report 4597 (NASA-13445), October 1994.

6.4. Outcome of comparison / correlation.

Whatever the degree of correlation obtained, the Applicant is expected to be able to justify the elements of the correlation process, including the effects of extrapolation of the actual test conditions to the design load conditions.

If the correlation is poor, and especially if the analysis underpredicts the loads, then the Applicant should review and assess all of the components of the analysis, rather than applying blanket correction factors.

For example:

(a) If the level of discrepancy varies with the Mach number of the condition, then the Mach corrections need to be evaluated and amended.

(b) If conditions with speed brakes extended show poorer correlation than clean wing, then the speed brake aerodynamic derivatives and/or spanwise distribution need to be evaluated and amended.

[Amdt 25/1]

CS 25.302 Interaction of systems and structures

ED Decision 2005/006/R

For aeroplanes equipped with systems that affect structural performance, either directly or as a result of a failure or malfunction, the influence of these systems and their failure conditions must be taken into account when showing compliance with the requirements of Subparts C and D. Appendix K of CS-25 must be used to evaluate the structural performance of aeroplanes equipped with these systems.

[Amdt 25/1]