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FEDERAL AVIATION AGENCY
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Civil Air Regulations Amendment 4b-16
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PART 4b—AIRPLANE AIRWORTHINESS; TRANSPORT CATEGORIES

Flutter, Deformation, and Vibration Requirements

This amendment increases the scope of the flutter, deformation, and vibration requirements by providing that the dynamic evaluation of the airplane take into account elastic, inertia, and aerodynamic forces associated with rotations and displacements of the plane of the propeller; and that the airplane, under specified conditions, remain free from hazardous flutter, vibration, and divergence after any reasonably probable single structural failure or equipment malfunction. The details of the amendment were published by the Federal Aviation Agency as a notice of proposed rule making (28 F.R. 6358), circulated to the industry as Notice 63-21 dated June 13, 1963.

Regulations dealing specifically with flutter, deformation, and vibration on transport category airplanes were first introduced when Part 04 (later designated as Part 4b) became effective on November 9, 1945. These regulations evolved into currently effective § 4b.308 with the adoption of two substantive revisions, as follows: (1) Effective March 5, 1952, the requirement that freedom from flutter and divergence be demonstrated at all speeds up to 1.2 V_D was amended to permit this demonstration at speeds up to a value less than 1.2 V_D if the characteristics of the airplane are such that it would be unlikely to attain a speed of 1.2 V_D and if it is shown that a proper margin of damping exists at speed V_D; and (2) effective October 1, 1959, a provision was added requiring that, if control surface flutter dampers are used for flutter prevention, the flutter damper system be of such design that a single failure will not preclude continued safe flight of the airplane at any speed up to V_D.

During the period between 1945 and 1955, § 4b.308 and predecessor regulations generally were effective in insuring freedom from flutter and divergence in transport category airplanes, despite the absence of a provision requiring an investigation of the influence of a single structural failure on flutter stability. A reasonable margin of safety evidently was provided by the required demonstration that the airplane be free from flutter and divergence at speeds up to 1.2 V_D, over the critical ranges of the pertinent parameters.

Subsequently, several reported instances of tab flutter on a transport category airplane led to adoption of the current requirement that tab control systems be free from hazardous flutter after disconnection or failure of any element at speeds up to V_D.

In general, applicants have resorted to analyses in showing compliance with the regulations, supplemented in some cases by flight flutter tests. In the past, such analyses have taken into account, for propeller-driven airplanes, the mass of the engine-propeller combination and the natural frequency of vibration of its suspension, but not the elastic, inertia, and aerodynamic forces associated with the rotations and displacements of the propeller plane. These forces had no significant effect on wing flutter stability.

Two fatal accidents, both involving a four-engine turboprop airplane, focused attention on the hazards associated with aeroelastic instabilities in transport category airplanes. An investigation into the cause of these accidents, and associated engineering studies by both industry and Government, indicated that the various forces associated with the rotations and displacements of the plane of the propeller must be considered in evaluating the flutter and divergence stability of transport category airplanes. The oscillatory motion of the plane of the propeller may itself become unstable, or diverge, or may contribute to instability of the wing. For these reasons, § 4b.308 (a) is amended by adding a requirement that the dynamic evaluation of the airplane include consideration of the effect of significant elastic, inertia, and aerodynamic forces associated with rotations and displacements of the plane of the propeller.

The provisions of present § 4b.308(a) are limited in scope in that they prescribe freedom from flutter and divergence for wing and tail units only, whereas it is well known that the higher speeds of modern transport category airplanes may introduce flutter or divergence in other portions of the airplane. To insure that tests or analyses take this possibility into account, § 4b.308(a) is amended to prescribe freedom from flutter and divergence for all portions of the airplane.

(As published in the Federal Register [29 F.R. 12609] on September 5, 1964)

In past application of the term "proper margin of damping" in present § 4b.308 (a), the Agency has indicated that the margin is acceptable if a satisfactory damping coefficient exists for all potential flutter modes at all speeds up to V_D, and ... no large and rapid reduction in damping with increased speed is indicated upon approaching V_D. In this regard, § 4b.308(a) is amended to state clearly what is meant by the term "proper margin of damping."

The previously mentioned Government-industry studies also disclosed that severe degradation of the aeroelastic properties of the wing could result from failure of a structural member (including those which form part of the engine itself in the case of turboprop engines) which supports the engine-propeller combination, or from failure of the propeller control system such that overspeeding of the propeller occurs.

In view of these findings, and in view of past findings indicating that failures in tab and damper control elements may result in flutter, the Agency finds there is a need for a comprehensive set of requirements dealing with the effect of probable failures on flutter stability. The Agency has noted, for example, that hazardous flutter may be induced by any failure reducing the rigidity of irreversible main control systems which are fitted with power boost; by a failure in the power boost itself; by a failure or malfunction of an automatic flight control system; or by failure or partial failure of single principal structural elements. Therefore, a new paragraph (d) is added to § 4b.308 to require that the airplane be free of flutter, after specified failures or malfunctions, at all speeds up to V_D.

In general, the comments received on Notice 63-21 either were favorable or offered no objection to the main objectives of the proposal, although a number of detailed revisions were suggested. Among these was an objection to the notice of proposed rule making, which opposed increasing the scope and detail of the regulations. The comment also indicated that airframe manufacturers will comply voluntarily with the basic requirements in the proposal. The Agency does not consider this objection valid since the purpose of the rule change is to establish and record in the Civil Air Regulations the minimum standards which should apply to this area of flight safety.

A recommendation was made to revise the first sentence of § 4b.308(a) to apply to the airframe instead of the airplane since the latter could be interpreted to include all minor protruding items. The Agency does not agree since the airframe is not sufficiently inclusive to account for the engine-propeller combination which is of prime importance in this amendment. The intent of the proposal is to prevent a single failure from causing flutter in any structural component that could result in destruction of the airplane. It is not intended that minor protruding items be treated any differently under the proposal than under the currently effective requirements which limit the scope of the flutter investigation to the wing, tail, and control surfaces.

In discussing § 4b.308(a), a comment indicated that a damping coefficient is superfluous since no quantitative value for the required damping is included. The Agency does not agree. Although a minimum value of damping coefficient cannot be established as a standard for all cases, the damping coefficient still remains a necessary measure of flutter stability in individual cases whether analytical or experimental results are quoted.

Another comment suggested that maximum weight and mass distribution be considered in flutter criteria, and that § 4b.308(a) require flight test demonstration either of the absence of flutter or that sufficient margins exist with fuel and other movable mass distributed to give the lowest natural frequencies of the aircraft. The requirements have general application with respect to gross weight and mass distribution. Furthermore, the lowest natural frequencies of the airplane do not necessarily represent the most unstable flutter configuration. Therefore, the suggestion is not accepted.

Fail-safe criteria being added to § 4b.308 by new paragraph (d), which prompted the suggestion that this paragraph be subdivided into two new paragraphs, Fail-Safe Criteria and Alternatives to Fail-Safe Criteria. The Agency does not concur since alternative provisions (negligible probability of failure) are not applicable to all failures listed.

A comment objected to § 4b.308(d) (1) and (2) because data has not been presented to justify applying the failure concept to engine structure and engine supporting structure. As previously mentioned, this regulatory action stemmed from the results of the investigation of two fatal accidents involving turboprop airplanes. These results alerted the aircraft industry to the possibility that the propeller whirl mode could alter significantly the wing aeroelastic stability. Section 4b.270 presently requires that consideration beyond the basic strength requirements and fatigue substantiation must be given to those areas where partial structural failure would have catastrophic effect. Wing flutter is a catastrophic in most cases. Therefore, since failure of a turboprop engine or its supporting structure, via the resulting loss in propeller support rigidity, could result in wing flutter, the Agency finds that the amendment is justified.

New § 4b.308(d) includes the phrases "reasonably probable single failure" and "probability of their occurrence is negligible" which were objected to because they are difficult to interpret consistently and would result in differences of opinion between Agency regions as to verification requirements. The comment assumed that compliance with Part 4b basic structural requirements provides a negligible probability of failure. The comment further states that a more specific definition of the phrase "conservative static strength margin" is needed if the implication is that margins greater than Part 4b requirements are required. The purpose of this amendment is to prevent the possibility that a single structural failure could lead to flutter and subsequent destruction of the airplane. The fail-safe provisions recognize a finite probability of the failure of individual elements and provide for demonstrating that structural elements are so conservatively designed that the effects of their failure need not be considered. The particular phrases quoted are to provide for such demonstrations. The final rule retains these phrases since they properly indicate the intent. The assumption of the relation between Part 4b compliance and probability of failure is not correct. Section 4b.270(b) already provides for protection against failures in primary structure areas such as wing, fuselage, etc., without regard to static margin of safety. The proposal concerning a conservative static strength margin is part of the provision for not having to evaluate individual failures, but minimum values of static margin cannot be established to apply to all cases. It will depend on the particular installation, type of airplane, previous experience, and the relative significance of fatigue loads to static loads.

Another comment stated that the maximum speed for flight test substantiation in § 4b.308(d) should be V_{HO} rather than V_{FC} since V_{HO} is compatible with the fail-safe criteria of § 4b.270(b), and that test demonstration of good damping at V_{HO} should be an adequate procedure for insuring a safe airplane. The Agency does not agree since the V_{HO}, particularly for turbine-powered airplanes, may be expected in service during a high percentage of flights. Flutter is usually expected to be approached most closely at the highest flight speed. The strength provisions of § 4b.270(b) provide margins against failure by requiring design to accelerated flight conditions, but flutter can occur in level unaccelerated flight. Hence, the only safety margin against flutter is a margin in speed, and the value of V_{FC} is adopted to provide this margin. It is noted that the speed used for flight flutter test verification of freedom from flutter is V_D, but a lesser speed, V_{FC}, is required for failure cases.

Several comments suggested that the second sentence of proposed § 4b.308(d) be revised to begin "The structural failures described in subparagraphs (1), (2), and (7) * * *" to permit the alternative provisions (negligible probability of failure) of safe life compliance for control systems under subparagraph (7). Part 4b currently requires consideration of a failed or disconnected tab control system and flutter damper system. The need for these fail-safe provisions was established on the basis of service experience, and the suggested reduction in the degree of compliance has not been justified. Subparagraph (6) of § 4b.308(d) (proposed subparagraph (7)) is amended to extend this same fail-safe provision to the main control system, based on hazards introduced by the increased complexities of main control systems, use of hydraulic and electric powered controls, and use of a wider scope of automatic control functioning. Therefore, the suggestion is not accepted.