UNITED STATES OF AMERICA
FEDERAL AVIATION AGENCY
WASHINGTON, D.C.

Civil Air Regulations Amendment 4b-16
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[Reg. Docket No. 1797; Amdt. 4b-16]

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_C.

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

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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.

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 if 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 altered 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_{MO} rather than V_{FC} since V_{MO} is compatible with the fail-safe criteria of § 4b.270(b), and that test demonstration of good damping at V_{MO} should be an adequate procedure for insuring a safe airplane. The Agency does not agree since the V_{MO}, 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 provability 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.

A comment indicated that in the last sentence of the introductory paragraph of proposed § 4b.308(d) it is not logical to require conservative static strength margins in addition to substantiating the fatigue strength. The intent is that adequate static or fatigue strength may be used to substantiate a particular element, and the final rule is clarified in this respect.

A comment suggested that proposed § 4b.308(d) (2) be deleted as being unreasonable and incapable of compliance by the airplane manufacturer, since he has no control over the engine design. This suggestion is not accepted since the airplane manufacturer must provide a complete airplane type design that meets the requirements of the applicable airworthiness regulations, including the engine installation. Furthermore, the proposed requirement has been a special design condition applicable to airplane type certification since the subject came to light in the engineering studies during investigation of the aforementioned accidents. It presented no difficulties to the airplane manufacturers.

In further regard to proposed § 4b.308 (d) (2), a second comment suggested that it be reworded to include only those structural failures of the engine that can affect the support stiffness of the engine-propeller combination. The Agency agrees that the suggested clarification is consistent with the intent of the proposal and that some limitation can be placed on the extent of consideration of a failed engine. The final rule is clarified by limiting the failures to those which would reduce the yaw or pitch rigidity of the propeller rotational axis.

A number of comments were received concerning the effect of feathered propellers in proposed § 4b.308(d) (3). Some comments requested clarification of the intent, and others pertained to the number of feathered propellers to be considered. Regarding clarification of intent, the rule is to insure that, with elimination of the propeller aerodynamic forces from one propeller, the basic aircraft structure is free from flutter. The aerodynamic forces from the propeller whirl mode can be shown to stabilize a wing flutter mode. Hence, in the normal condition, with all propellers rotating, it can be assumed that there are resultant propeller aerodynamic forces present which influence the wing flutter mode.

As a fail-safe condition, therefore, the airplane must remain free from flutter up to V_D with these aerodynamic forces removed from one feathered propeller. The final rule is clarified in this respect. Regarding the number of feathered propellers to be considered, comments from the Aerospace Industries Association of America (AIA), which represents the aircraft manufacturing industry, indicated that normal rotating propellers have a tendency to introduce stabilizing forces which may alleviate a flutter condition. In the past, airplanes were design conservatively without full consideration being given to this alleviating factor. The AIA considers that consideration of only one feathered propeller may not be sufficiently conservative. The agency agrees that the proposal was technically insufficient in this respect. The rule, therefore, as adopted provides that, for four or more engine airplanes, an additional investigation must be made for the critical combination of two propellers feathered.

A related comment stated that some clarification is necessary in the application of § 4b.308(d) (4), as proposed, relative to the pairing of the feathered propeller condition with other failure cases, and suggested that proposed § 4b.308(d) (4) and (5) be combined with § 4b.308(d) (3) and paired with other single failures related to direct loss in propeller support stiffness. The intent of proposed § 4b.308(d) (4) was to insure that flutter stability does not rely on the stabilizing effects of propeller aerodynamic forces in the propeller whirl mode. The airplane should be free from flutter to at least V_D with propellers rotating or stopped, and this should apply to both the basic airplane and to the failure cases where reliance upon fully available propeller aerodynamic forces otherwise might be made to establish flutter stability. The notice proposed pairing the feathered condition with § 4b.308(d) (1) and (2), since these contain failure areas whose flutter stability most likely could be augmented by propeller aerodynamic forces under conditions where propeller feathering could be expected. The agency agrees that some clarification should be made and the final rule is amended to combine proposed § 4b.308(d) (3) and (4) as suggested. On the other hand, the additional inclusion of § 4b.308(d) (5) in the subparagraph would combine the case of an overspeeding propeller with other failures, which not only is unnecessary as a minimum standard but also is a substantive change from the proposal and would require issuance of another notice.

With regard to § 4b.308(d)(5) (proposed subparagraph (6)), one comment indicated that clarification is needed since it appears to negate the alternate provisions for safe life compliance for failures under § 4b.308(d) (1) and (2). A second comment questioned why only § 4b.270(b) is quoted but not the safe life alternative of § 4b.270(a). Evidently, there is some misunderstanding regarding engine failures since current fatigue requirements in § 4b.270 and associated CAM 4b.270-1 make no reference to the engine. Furthermore, proposed § 4b.308(d) (6) referred only to failures for which compliance with § 4b.270(b) is required. This would not require consideration of a failure if fatigue substantiation was by the safe life method under § 4b.270(a). Notwithstanding this, the final rule is amended to clarify the applicability of § 4b.308(d) (5) to only those parts for which compliance with the alternative provisions of § 4b.270(b) is selected.

Several comments expressed concern that § 4b.308(d) (5), as amended, an excessive amount of costly detailed analysis and testing to show literal compliance for each particular failure case, and recommended that provision be made for suitable alternate courses. One comment went on to suggest that allowance be made to permit assuming a given percentage loss in stiffness accompanied by a percentage adverse movement of the flexural axis in either one or two areas to bracket the effect of many different discrete assumed failures. The comments obviously are concerned that “failure of each principal structural element * * *” will literally require separate analyses or tests for each discrete failure case. This would excessively burden an analysis problem already in itself extensively complicated. It appears both reasonable and appropriate, however, that overall stiffness and nodal displacement investigations could be applied in evaluating the effects of discrete failures. Nevertheless, the comments express concern that the proposed wording may not allow this approach and confirm a need for a specific procedure within the rule. Therefore, the final rule is revised to include this acceptable procedure.

An objection was made to applying proposed § 4b.308(d) (7) (amended subparagraph (6)) to investigations of autopilot oscillatory signals and control system package chatter, and stated that more experience needs to be gained with this matter before attempting to cover it in the regulations. The comment continued that when and if a rule ultimately is adopted it should contain at least enough detail to identify and define properly the intended design condition. The wording is written clearly through inclusion of the reference “(See also § 4b.612(d) (4).)” to indicate that failures, malfunctions, and adverse conditions involving the autopilot should not result in flutter, divergence, or vibrations which could preclude safe flight. The amendment is general and objective in nature as are the special conditions on this subject which have been applied to recently type certificated jet transport airplanes. The service records of oscillatory c.g. loadings, such as appear in NASA TN-1390, and more recent accident or near-accident investigations, have drawn increased attention to a need for analyzing the effects of automatic control system malfunctioning for oscillatory as well as hardover effects. In reviewing the special conditions on this subject which have been applied in the past, it is noted that the oscillatory force effects of failures and malfunctions in the automatic control system have been investigated over the operating range of the airplanes and not to V_D. A distinction is made between the highest speed at which the more destructive phenomena of flutter and divergence are substantiated and the speed at which forced vibrations result from a malfunctioning automatic control system. Therefore, the final rule includes the proposed § 4b.308(d) (7), but amended § 4b.308(d) (6) is revised to permit limiting the airspeed to V_C.

Some comments were received concerning areas which are not the subject of regulation changes proposed in the notice and they are not considered in the final rule.

Interested persons have been afforded an opportunity to participate in the making of this amendment and due consideration has been given to all relevant matter presented.

These amendments are made under the authority of sections 313(a), 601, and 603 of the Federal Aviation Act of 1958 (49 U.S.C. 1354, 1421, 1423).

In consideration of the foregoing, Part 4b of the Civil Air Regulations (14 CFR Part 4b, as amended) is hereby amended as follows, effective October 5, 1964:

By amending § 4b.308(a) and adding a new paragraph (d) to read as follows:

§ 4b.308 Flutter, deformation, and vibration.

* * * * *

(a) *Flutter and divergence prevention.* The airplane shall be designed to be free from flutter and divergence (i.e., unstable structural distortion due to aerodynamic loading) at all speeds up to 1.2 V_D. A smaller margin above V_D shall be acceptable if the characteristics of the airplane (including the effects of compressibility) render a speed of 1.2 V_D unlikely to be achieved, and if it is shown that a satisfactory damping coefficient exists at all speeds up to V_D and that there is no large and rapid reduction in damping as V_D is approached. In the absence of more accurate data, the terminal velocity in a dive of 30 degrees to the horizontal shall be acceptable as the maximum speed likely to be achieved. If concentrated balance weights are used on control surfaces, their effectiveness and strength, including supporting structure, shall be substantiated. The dynamic evaluation of the airplane shall include an investigation of the significant elastic, inertia, and aerodynamic forces associated with the rotations and displacements of the plane of the propeller.

* * * * *

(d) *Fail-safe criteria.* It shall be shown, by analyses or tests, that the airplane will remain free from such flutter, divergence, or vibrations as would preclude safe flight, at all speeds up to V_D, after each of the failures, malfunctions, and adverse conditions stated in subparagraphs (1) through (6) of this paragraph, and after any other reasonably probable single failure, malfunctions, or adverse condition affecting flutter, divergence, or vibration; except that, if the failure, malfunction, or adverse condition is simulated during flight tests to show compliance with this paragraph, the maximum speed investigated need not exceed V_{FC} when it is shown, by correlation of the flight test data with other test data or analyses, that hazardous flutter, divergence, or vibration will not occur at all speeds up to V_D. The structural failures described in subparagraphs (1) and (2) of this paragraph need not be considered in showing compliance with this paragraph if engineering data verify that the probability of their occurrence is negligible. Such engineering data shall substantiate, by test or analysis, that the structural element is designed with conservative static strength margins for all ground and flight loading conditions specified in this part or with fatigue strength sufficient for the loading spectrum expected in service.

(1) Failure of any single element of the structure supporting any engine, independently mounted propeller shaft, large auxiliary power unit, or large externally mounted aerodynamic body such as an external fuel tank.

(2) Any single failure of the engine structure on turbo-propeller airplanes which would reduce the yaw or pitch rigidity of the propeller rotational axis.

(3) Absence of propeller aerodynamic forces resulting from the feathering of any single propeller, and also for airplanes with four or more engines, the feathering of the critical combination of two propellers. In addition, any single propeller feathered shall be paired with the failures specified in subparagraph (1) of this paragraph involving failure of any single element of the structure supporting any engine or independently mounted propeller shaft and the failures covered in subparagraph (2) of this paragraph.

(4) Any single propeller rotating at the highest likely overspeed.

(5) Failure of each principal structural element for which compliance with the alternative provisions of § 4b.270(b) is selected. Safety following a failure may be substantiated by showing that possible losses

in rigidity or changes in frequency, modal form, or damping, resulting from the failure, are within the general parameter variations covered in the flutter and divergence investigations.

(6) Failure, malfunction, or disconnection of any single element in the main flight control system (including automatic flight control systems, if installed), in any tab control system, or in any flutter damper connected to a control surface or tab. (See also § 4b.612 (d) (4).) Investigation of the forced structural vibrations, other than flutter resulting from failures, malfunctions, or adverse conditions in the automatic flight control system, may be limited to airspeeds up to V_C.

Issued in Washington, D.C., on August 31, 1964.

By the Civil Aeronautics Board:

/s/ N. E. Halaby

N. E. Halaby

Administrator

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(SEAL)

Deletion of

Items 1 and 2 of SR-422

Items 1, 2, and 5 of SR-422A

Items 1, 2, and 5 of SR-422B

CAR Parts 4a and 4b

[See new FAR Part 25]

Deletion of

§§ 1.50, 1.50-1, 1.55-2(b) and (d), and 1.100-1.110 of CAR Part 1

§§ 3.791 and 3.792 of CAR Part 3

§§ 4b.750 and 4b.751 of CAR Part 4b

§§ 6.750 and 6.751 of CAR Part 6

§§ 7.750 and 7.751 of CAR Part 7

§ 10.30 of CAR Part 10

§ 13.20 of CAR Part 13

§ 14.20 of CAR Part 14

Last sentence of sixth paragraph of SR-425C

[See new FAR Part 45]