



Designation: F3720/F3720M – 24

Standard Practice for General Guidance on Damage Tolerance Evaluation of Normal Category Aeroplane¹

This standard is issued under the fixed designation F3720/F3720M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice provides general guidance for damage tolerance evaluation of metallic structures. This information can be used in conjunction with Specification **F3115/F3115M** to demonstrate adequate structural durability. Damage tolerance evaluation is required for some aircraft levels and is available as an option for other levels; see Specification **F3115/F3115M** for those requirements. The material was developed through open consensus of international experts in general aviation. The content may be more broadly applicable; it is the responsibility of the applicant to substantiate broader applicability as a specific means of compliance.

1.2 An applicant intending to propose this information as Means of Compliance for a design approval must seek guidance from their respective oversight authority (for example, published guidance from applicable civil aviation authorities, or CAAs) concerning the acceptable use and application thereof. For information on which oversight authorities have accepted this standard (whole or in part) as an acceptable Means of Compliance to their regulatory requirements (hereinafter “the Rules”), refer to the ASTM Committee F44 web page (www.astm.org/COMMITTEE/F44.htm).

1.3 *Units*—This practice may present information in either SI units, English Engineering units, or both; the values stated in each system may not be exact equivalents. Each system shall be used independently of the other; combining values from the two systems may result in nonconformance with the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recom-*

mendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

2. Referenced Documents

2.1 ASTM Standards:²

F3114 Specification for Structures

F3115/F3115M Specification for Structural Durability for Small Aeroplanes

F3060 Terminology for Aircraft

F3066/F3066M Specification for Aircraft Powerplant Installation Hazard Mitigation

F3651/F3651M Practice for Determining Safe-Life, Inspection Threshold and Recurring Inspection Intervals

F3710 Guide for Structural Durability Component Selection

2.2 FAA Advisory Circular:³

AC 20-128A Design Considerations for Minimizing Hazards Caused by Uncontained Turbine Engine and Auxiliary Power Unit Rotor Failure

AC 23-13A Fatigue, Fail-Safe, and Damage Tolerance Evaluation of Metallic Structure for Normal, Utility, Acrobatic, and Commuter Category Airplanes

AC 25.571-1C Damage Tolerance and Fatigue Evaluation of Structure

AC 120-104 Establishing and Implementing Limit of Validity to Prevent Widespread Fatigue Damage

2.3 FAA Airworthiness Standards:³

14 CFR 23 Airworthiness Standards: Normal, Utility, Acrobatic, and Commuter Category Airplanes

14 CFR 23 Airworthiness Standards: Normal Category Airplanes

2.4 EASA Certification Specifications:⁴

CS-23 Certification Specifications for Normal-Category Aeroplanes

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at www.astm.org/contact. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

³ Available from Federal Aviation Administration (FAA), 800 Independence Ave., SW, Washington, DC 20591, <http://www.faa.gov>.

⁴ Available from European Union Aviation Safety Agency (EASA), Konrad-Adenauer-Ufer 3, D-50668 Cologne, Germany, <https://www.easa.europa.eu>.

¹ This practice is under the jurisdiction of ASTM Committee **F44** on General Aviation Aircraft and is the direct responsibility of Subcommittee **F44.30** on Structures.

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2.5 *EASA Certification Specifications and Acceptable Means of Compliance*.⁴

AMC 25.571 Damage Tolerance and Fatigue Evaluation of Structure

3. Terminology

3.1 See Terminology **F3060** and other listed reference documents for definitions and abbreviations.

4. Significance and Use

4.1 This practice provides general guidance for damage tolerance evaluation that can be used in conjunction with Specification **F3115/F3115M** to demonstrate adequate structural durability of metallic structures. Users of this practice must seek guidance from their CAAs for applicability and acceptance on guidance materials presented herein as one means of compliance.

4.1.1 Damage tolerance evaluation is required for Level 4 aeroplanes, and for pressurized aeroplanes with maximum operating altitude greater than 41 000 feet [12 497 meters].

4.1.2 For Levels 1, 2, or 3 aeroplanes when an applicant selects damage tolerance as certification basis, the scope of their damage tolerance evaluation, including assessment for widespread fatigue damage, can be defined in accordance with the guidance from their relevant CAA.

5. Damage-Tolerance Evaluation

5.1 The damage tolerance evaluation of structure is intended to ensure that should fatigue, corrosion, or accidental damage occur within the operational life (OL) of the aeroplane, the remaining structure can withstand required loading conditions without failure or excessive structural deformation until the damage is detected. The operational life (OL) is a period of time, in flight cycles, flight hours, or both, up to which it has been demonstrated by test evidence, analysis and, if available, service experience and teardown inspection results of high-time aeroplanes, that structural failures due to foreseeable causes of strength degradation will not occur. Foreseeable causes of strength degradation can include (but are not limited to) fatigue, environmental deterioration, accidental damage, widespread fatigue damage (that is, MSD, MED), etc.; refer to Specification **F3115/F3115M**.

5.2 In certain instances, however, damage-tolerant design might be more realistically assessed by a probabilistic evaluation employing methods such as risk analysis with acceptance by the relevant CAA. Risk analyses are routinely employed in fail-safe evaluation of aeroplane systems but have occasionally been used where structure and systems are interrelated. These methods can be of particular value for structure consisting of discrete isolated elements where damage tolerance depends on the ability of the structure to sustain redistributed loads after failures of discrete elements resulting from fatigue, corrosion, or accidental damage. Where considered appropriate on multiple load path structure, a probabilistic analysis may be used if it can be shown that loss of the aeroplane is extremely improbable, and the statistical data employed in the analysis is based on tests or operational experience, or both, of similar structure. Note that risk analysis is outside the scope of this practice.

5.3 Damage tolerance design is required in accordance with §23.2240(b) & (c)(2), unless it entails such complications that an effective damage-tolerant structure cannot be achieved within the limitations of geometry, inspectability, or good design practice. Under these circumstances, a design that complies with fatigue evaluation (safe-life) requirements is used. A typical example of structure that might not be conducive to damage tolerance design is the landing gear and its attachments.

5.4 Experience with the application of methods of fatigue evaluation indicates that a test background should exist in order to achieve the design objective. Even under the damage tolerance method discussed herein, it is the general practice within the industry to conduct damage tolerance tests for design information and validate assumptions. Damage location, growth, and detection data should also be considered in establishing a recommended inspection program.

5.5 The damage tolerance evaluation should encompass establishing the components that are to be designed as damage-tolerant, defining the loading conditions and extent of damage, conducting structural tests or analysis, or both, to substantiate that the design objective has been achieved, and establishing data for inspection programs to ensure detection of damage.

5.6 *Damage-tolerant Design*—Although this evaluation applies to either single or multiple load path structure, the use of multiple load path structure should be given priority in achieving damage-tolerant design.

5.6.1 Design features that should be considered in attaining a damage-tolerant structure include the following:

5.6.1.1 Multiple load path construction and the use of crack stoppers to control the rate of crack growth and to provide adequate residual static strength;

5.6.1.2 Materials and stress levels that, after initiation of cracks, provide a predictable rate of crack propagation combined with high residual strength;

5.6.1.3 Arrangement of design details to ensure a sufficiently high probability that a failure in any critical structural element will be detected before the strength has been reduced below the level necessary to withstand the loading conditions specified in Specification **F3115/F3115M**, so as to allow replacement or repair of the failed elements; and

5.6.1.4 Provisions to preclude the possibility of widespread fatigue damage (WFD), that is, multiple site damage (MSD) or multiple element damage (MED), or both, within the operational life of the aeroplane. These provisions include both the structural design aspects and the in-service maintenance aspects. Refer to Appendix 5 of AC 120-104 for examples of structure susceptible to widespread fatigue damage. Examples of concerns are:

(a) A number of small cracks that might coalesce to form a critical single long crack;

(b) Loss of residual strength for a lead crack (or accidental damage) due to very small MSD along its growth trajectory;

(c) Failures, or partial failures, in adjacent areas due to the redistribution of loading following a failure of a single element; and

(d) Simultaneous failure, or partial failure, of multiple load path discrete elements, working at similar stress levels.

5.7 Identification of Principal Structural Elements (PSE)—A PSE is an element of structure that contributes significantly to the carrying of flight, ground, or pressurized loads, and whose integrity is essential in maintaining the overall structural integrity of the aeroplane. Reference Guide **F3710** for identifying PSEs. Examples of typical PSEs are presented as follows; additional elements can be identified as PSE based on the guidance from the relevant CAA.

5.7.1 Wing, Horizontal Stabilizer, Vertical Fin, Canard, Forward Wing, Winglets/Tip Fins:

5.7.1.1 Fixed surfaces, stabilator, or trimmable stabilizer attachment fittings;

5.7.1.2 Integrally stiffened plates;

5.7.1.3 Primary fittings;

5.7.1.4 Principal splices;

5.7.1.5 Skin or reinforcement around cutouts or discontinuities;

5.7.1.6 Skin-stringer combinations;

5.7.1.7 Spar caps; and

5.7.1.8 Spar webs.

5.7.2 Pressurized cabin:

5.7.2.1 Circumferential frames and adjacent skin;

5.7.2.2 Pressure bulkheads;

5.7.2.3 Cockpit window posts;

5.7.2.4 Skin and any single frame or stiffener element around a cutout;

5.7.2.5 Skin or skin splices, or both, under circumferential loads;

5.7.2.6 Skin or skin splices, or both, under fore and aft loads;

5.7.2.7 Skin around a cutout;

5.7.2.8 Skin and stiffener combinations under fore and aft loads;

5.7.2.9 Door frames, skins, and latches; and

5.7.2.10 Window frames.

5.8 In assessing the possibility of fatigue failures, the design should be examined to determine probable points of failure in service. In this examination, consideration should be given, as necessary, to the results of stress analysis, static tests, fatigue tests, strain gauge surveys, tests of similar structural configurations, and service experience. Service experience has shown that special attention should be focused on the design details of important discontinuities, main attach fittings, tension joints, splices, and cutouts such as windows, doors and other openings. Locations prone to accidental damage (such as that due to impact with ground servicing equipment near aeroplane doors) or to corrosion should also be considered.

5.9 Identification of Locations to be Evaluated—The locations of damage to structure for damage tolerance evaluation should be identified as follows:

5.9.1 Determination of general damage locations. The location and modes of damage can be determined by analysis or by fatigue tests on complete structures or subcomponents. However, tests may be necessary when the basis for analytical prediction is not reliable, such as for complex components. If less than the complete structure is tested, care should be taken to ensure that the internal loads and boundary conditions are valid.

5.9.1.1 If a determination is made by analysis, factors such as the following should be taken into account:

(a) Strain data on undamaged structure to establish point of high stress concentrations, as well as the magnitude of the concentration;

(b) Locations where permanent deformation occurs in the static tests;

(c) Locations of potential fatigue damage identified by fatigue analysis; and

(d) Design details that service experience of similarly designed components indicates are prone to fatigue or other damage.

5.9.1.2 In addition, the areas of probable damage from other sources, such as severe corrosion and accidental damage, should be determined from a review of the design and past service experience.

5.9.2 Selection of Critical Damage Areas—The process of actually locating where damage should be simulated in principal structural elements should take into account factors such as the following:

5.9.2.1 Review analysis to locate areas of maximum stress and low margin of safety;

5.9.2.2 Select locations in an element where the stresses in adjacent elements would be the maximum with the damage present;

5.9.2.3 Select partially fracture locations in an element where high stress concentrations are present in the residual structure; and

5.9.2.4 Select location where detection would be difficult.

5.10 Extent of Damage—Each particular design should be assessed to establish appropriate damage criteria in relation to inspectability and damage extension characteristics.

5.10.1 In any damage determination, including those involving multiple cracks, it is possible to establish the extent of damage in terms of detectability with the inspection techniques to be used, the associated initially detectable crack size, the residual strength capabilities of the structure, and the likely damage-extension rate, considered the expected stress redistribution under the repeated loads expected in service and with the expected inspection frequency.

5.10.2 An obvious partial failure could be considered to be the extent of the damage for residual strength assessment, provided a positive determination is made that the fatigue cracks will be detectable by the available inspection techniques at a sufficiently early stage of the crack development.

5.10.3 In the pressurized fuselage, an obvious partial failure might be detectable through the inability of cabin to maintain operating pressure or controlled decompression after occurrence of the damage.

5.10.4 The following are typical examples of partial failures that should be considered in the evaluation:

5.10.4.1 Detectable skin cracks emanating from the edge of structural openings or cutouts;

5.10.4.2 A detectable circumferential or longitudinal skin crack in the basic fuselage structure;

5.10.4.3 Complete severance of interior frame elements or stiffeners in addition to detectable cracks in the skin;