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# Standard Specification for Structural Durability for Small Aeroplanes[1]

This standard is issued under the fixed designation F3115/F3115M; 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 specification addresses the airworthiness requirements related to structural durability for the design of small aeroplanes. The material was developed through open consensus of international experts in general aviation. This information was created by focusing on Levels 1 through 4 Normal Category aeroplanes. 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 (CAAs), including the guidance noted in Appendix X2 Guidance Material) concerning the acceptable use and application thereof. For information on which oversight authorities have accepted this ~~standard~~specification (in whole or in part) as an acceptable Means of Compliance to their regulatory requirements (hereinafter referred to as "the Rules"), refer to ASTM Committee F44 webpage (www.astm.org/COMMITTEE/F44.htm). Annex A1 maps the Means of Compliance of the ASTM standards to EASA CS-23, amendment 5, or later, and FAA 14 CFR 23, amendment 64, or later, Structural Durability requirements of 23.2240.



1.3 *Units*—~~Units —~~This document may present information in either SI units, English Engineering units, or both; the values stated in each system ~~may~~are not ~~be exact equivalents. Each~~ necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the ~~other; combining~~other, and values from the two systems ~~may result in nonconformance with the standard.~~shall not be combined.

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

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

F3060 Terminology for Aircraft
F3066/F3066M Specification for Aircraft Powerplant Installation Hazard Mitigation
F3116/F3116M Specification for Design Loads and Conditions
~~F3174~~F3174/F3174M Specification for Establishing Operating Limitations and Information for Aeroplanes

[1] This specification 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] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

F3380 Practice for Structural Compliance of Very Light Aeroplanes
2.2 *EASA Standard:*[3]
CS-23, Amendment 5 Certification Specifications for Normal Category Aeroplanes
2.3 *FAA Standard:*[4]
14 CFR 23, Amendment 64 Airworthiness Standards: Normal Category Airplanes

**3. Terminology**

3.1 The following are a selection of relevant terms. See Terminology F3060 for more definitions and abbreviations.

3.2 *Definitions:*

3.2.1 *catastrophic loss or catasrophic failure*—failure condition that is expected to result in fatalities of the occupants, normally with the loss of the aeroplane.

3.2.2 *damage tolerance*—the attribute of the structure that permits it to retain its required residual strength for a period of use after the structure has sustained a given level of fatigue, corrosion, accidental, or discrete source damage.

3.2.3 *fail safe*—the attribute of the structure that permits it to retain its required residual strength for a period of unrepaired use after the failure or partial failure of a structural element.

3.2.4 *fatigue*—the process of progressive localized permanent structural change occurring in a material subjected to conditions that produce fluctuating stresses and strains at some point or points, which may result in damage or complete fracture after a sufficient number of fluctuations.

3.2.5 *life (or load) enhancement factor*—an additional load factor or test duration, or both, applied to structural repeated load tests, relative to the intended design load and life values, used to account for material variability. It is used to develop the required level of confidence in data.

3.2.6 *residual strength*—the strength capability of a structure after the structure has been damaged due to fatigue, corrosion, accidental, or discrete source damage. The residual strength capability includes consideration of static strength, fracture, and stiffness.

3.2.7 *safe life—of a structure*, that number of events, such as flights, landings, or flight hours, during which there is a low probability that the strength will degrade below its design ultimate value due to fatigue-induced damage.

3.2.8 *scatter factor*—or life reduction factor, is a statistically derived divisor applied to fatigue test results to account for the variation in fatigue performance of built-up or monolithic structures and usage variability. A scatter factor can also be used in a fatigue analysis to address the uncertainties inherent in a fatigue analysis.

3.2.9 *S-N or ε-N*—Stress-Life (S-N) or Strain-Life (ε-N) curves depict the magnitude of applied stress (S) or strain (ε) necessary to develop a given level of fatigue damage in a specimen at a given life (N), where N is expressed in the number of cyclic applications of stress or strain.

**4. Evaluation for Aircraft Structure**

4.1 All aircraft structure must be designed to meet the following general durability criteria: avoid fatigue failure during normal service.

4.2 Additionally, aircraft structure whose failure could result in catastrophic loss of the aeroplane within the operational life of the aeroplane are to be evaluated using Sections 5 through 10.

4.2.1 For metallic structure, this must include pressurized cabin, wing, empennage, and associated structure.

[3] Available from European Aviation Safety Agency (EASA), Postfach 10 12 53, D-50452 Cologne, Germany, http://easa.europa.eu
[4] Available from Federal Aviation Administration (FAA), 800 Independence Ave., SW, Washington, DC 20591, http://www.faa.gov.

4.2.2 For composite structure, this must include each wing (including canards, tandem wings, and winglets), empennage, their carry-through and attaching structure, moveable control surfaces and their attaching structure, fuselage and pressure cabin.

4.3 Evaluation of a particular structure is not required if it is shown that the structure, operating stress level, materials and expected uses are comparable, from a fatigue standpoint, to a similar design (including design details) that has had extensive satisfactory service experience. For composite structure, additional similarity must be shown for the cure process, quality process, and ply layup.

## 5. Load Considerations

5.1 The evaluations (except for evaluations defined in 6.2.2, 6.3, and 7.2.5) must:

5.1.1 Include expected loading spectra (for example, taxi, ground-air-ground cycles, maneuver, gust, aerodynamic configuration changes such as deploying flaps or slats);

5.1.2 Account for any significant effects due to the mutual influence of aerodynamic surfaces; and

5.1.3 Consider any significant effects from the following:

5.1.3.1 Propeller slipstream loading,

5.1.3.2 Vibration, and

5.1.3.3 Buffeting.



5.2 Severe usage limitations must be either identified and addressed in accordance with 10.2 or included in the expected loading spectra. Examples of severe usage include pipeline and utility patrol, instruction, and short duration commuter and air taxi flights.

## 6. Metallic Structure Evaluations

6.1 Metallic components must be evaluated using one of the following methods:



6.1.1 For Level 1, 2, or 3 aeroplanes, the methods described in 6.2 or 6.3 or 6.4.

6.1.2 For Level 4, the method described in 6.4.

6.1.3 If certification for operation above 12,500 m [41,000 ft] is requested, the damage tolerance evaluation of 6.4 must be conducted for the fuselage pressure boundary.

6.1.4 For aeroplanes evaluated to the damage tolerance criteria of 6.4: if it is shown that damage-tolerance criteria is impractical for a particular structure, the structure must be evaluated in accordance with the methods described in 6.2.

6.2 *Fatigue Strength Evaluation:*

6.2.1 The structure must be shown by test, or by analysis supported by test evidence, to be able to withstand the repeated loads of variable magnitude (or equivalent) expected in service. Using this data, a safe life limit must be established for the structure, defined by the cyclic mean fatigue life divided by appropriate scatter factors. Exceptions are noted in 6.2.2.

6.2.2 In lieu of a cyclic test, a safe life limit can be established for a complete airframe based on a strength evaluation of critical structure for very light aeroplanes. This method and limitations are presented in Practice F3380.

6.3 *Fail Safe Strength Evaluation:*

6.3.1 The structure must be shown by analysis, test, or both, that catastrophic failure of the structure is not probable after failure of a principal structural element. Modes of damage should be identified in the analysis to show the extent of damage evaluated.

6.3.2 The damage extent must be shown to be obvious, such that it would be detectable before the next flight, and is large enough to be detected by obvious visual indications during walk around or by indirect means such as cabin pressure loss, cabin noise, or fuel leakage.

6.3.3 Additional procedures must be used to prevent loss of fail-safe capability with damaged structural components until damage is found. This would include aircraft maintenance manual instructions for detecting failures in fail-safe structure within 50 flights.

6.3.4 The evaluation must show that the remaining structure is able to withstand the residual strength loads in Section 8 multiplied by a factor of 0.75, where the factor is applied to critical limit flight loads, not pressure loads or 1g loads. In addition, a factor of 1.15 must be applied unless the dynamic effects of failure under static load are otherwise considered. For a pressurized cabin, the normal operating pressures combined with the expected external aerodynamic pressures must be applied simultaneously with the flight loading conditions.

6.4 *Damage Tolerance Evaluation:*

6.4.1 An evaluation of the strength, detail design, and fabrication must show that catastrophic failure due to fatigue, corrosion, manufacturing defects, or accidental damage will be avoided throughout the operational life of the aeroplane. The evaluation must be analysis supported by test evidence and, if available, service experience.

6.4.2 Damage at multiple sites due to fatigue must be included where the design is such that this type of damage can be expected to occur.

6.4.3 Modes of damage should be identified in the analysis to show the extent of damage evaluated.

6.4.4 The extent of damage for residual strength evaluation at any time within the operational life of the aeroplane must be consistent with the initial detectability and subsequent growth under repeated loads.

6.4.5 The residual strength evaluation must show that the remaining structure is able to withstand the residual strength loads in Section 8 with the extent of detectable damage consistent with the results of the damage tolerance evaluations.



**7. Composite Structure Evaluations**



7.1 Composite components must be evaluated as follows:



7.1.1 For Level 1, 2 and 3 non-aerobatic aeroplanes, the methods described in 7.2 or 7.3.

7.1.2 For Level 4 or any aerobatic aeroplanes, the method described in 7.3.

7.1.3 For aeroplanes evaluated to the damage tolerance criteria of 7.3: if it is shown that damage tolerance is impractical for a particular structure, the structure may be evaluated in accordance with the methods described in 7.2.

7.1.4 For all aeroplane levels, the effects of material variability and environmental conditions on the strength and durability properties of the materials must be considered.

7.1.5 For all aeroplane levels, the evaluations in either 7.2 or 7.3 must show that catastrophic failure due to fatigue, environmental effects, manufacturing defects, or accidental damage will be avoided throughout the operational life of the aircraft.

7.2 *Fatigue Strength Evaluation:*

7.2.1 The structure must be shown by test, or by analysis supported by test evidence, to be able to withstand the repeated loads of variable magnitude (or equivalent) expected in service. A safe life limit must be established using appropriate load enhancement factors (LEF) or life factors (N), or both. Exceptions are noted in 7.2.5.

7.2.2 Test or test evidence data must be obtained from an assembled component cyclic test article for the same or similar configuration, or tests at the coupon, element or subcomponent level with the appropriate analytical justification.

7.2.3 The fatigue test must include damage typical of those that may occur during fabrication, assembly, and in service, consistent with the inspection procedures employed. Other allowed manufacturing and service defects, which would exist for the life of the structure, should also be included in the fatigue testing. It should be demonstrated during the fatigue test that the stiffness properties have not changed beyond acceptable levels. Ultimate strength testing at the end of the cyclic test must demonstrate the ability of the structure to retain ultimate load capability with threshold of detectability damage present for the life of the aircraft structure.

7.2.4 General inspection procedures must be established to ensure damage beyond threshold of detectability is found during the safe life of the aeroplane.

7.2.5 In lieu of a cyclic test, a safe life limit can be established for a complete airframe based on a strength evaluation of critical structure for very light aeroplanes. The method and limitations are presented in Practice F3380.

7.3 *Damage Tolerance Evaluation:*

7.3.1 It must be demonstrated by tests, or by analysis supported by tests, that the structure is capable of carrying ultimate load with damage up to the threshold of detectability considering the inspection procedures employed.

7.3.2 The growth rate or no-growth of damage that may occur from fatigue, environmental effects, manufacturing flaws or impact damage, under repeated loads expected in service, must be established by tests or analysis supported by tests.

7.3.3 The residual strength evaluation must show that the remaining structure is able to withstand the residual strength loads in Section 8 with the extent of detectable damage consistent with the results of the damage tolerance evaluations. For slow or arrested growth of damage, the residual strength demonstrated for inspectable damage shall be sufficiently above the limit loads in Section 8. This level should account for material variability, inspection technique and interval, damage growth rate, and environmental effects. It does not need to be greater than ultimate load.



7.3.4 The damage growth, between initial detectability and the value selected for residual strength demonstrations, factored to obtain inspection intervals, must allow development of an inspection program suitable for application by operation and maintenance personnel.

## 8. Residual Strength Loads

8.1 The structure must be shown to be able to withstand critical limit flight loads, considered as ultimate.



8.2 For pressurized cabins, the following loads must be withstood:

8.2.1 Critical limit flight loads with the combined effects of normal operating pressure and expected external aerodynamic pressure.

8.2.2 The expected external aerodynamic pressures in 1g flight combined with a cabin differential pressure equal to 1.1 times the normal operating differential pressure without any other load.

## 9. Substantiation of Bonded Structure

9.1 For any bonded joint (including cobond and secondary bonds in composite and metallic airframe structure), the failure of which could result in catastrophic loss of the aeroplane, the limit load capacity must be substantiated by one of the following methods:

9.1.1 The maximum disbonds of each bonded joint consistent with the capability to withstand the residual strength loads in Section 8 must be determined by test, or analysis, supported by test. Disbonds of each bonded joint greater than this must be prevented by design features; or

9.1.2 Proof testing must be conducted on each production article that will apply the critical limit design load to each critical bonded joint; or

9.1.3 Repeatable and reliable non-destructive inspection techniques must be established that ensure the strength of each joint; or

9.1.4 A strength evaluation of critical structure for very light aircraft. This assessment is addressed in Practice F3380.