U.S. Department
of Transportation
Federal Aviation
Administration

Advisory Circular

Subject: Proof of Structure

Date: 10/07/14 **AC No:** 25.307-1
Initiated By: ANM-115

This advisory circular describes acceptable means for showing compliance with the requirements of Title 14, Code of Federal Regulations 25.307, *Proof of structure*. Section 25.307 requires structural testing to demonstrate compliance with the strength and deformation requirements of subpart C, unless structural analysis has been shown to be reliable.

If you have suggestions for improving this AC, you may use the feedback form at the end of this AC.

Jeffrey E. Duven
Manager, Transport Airplane Directorate
Aircraft Certification Service

Contents

1 PURPOSE.

This advisory circular (AC) describes acceptable means for showing compliance with the requirements of Title 14, Code of Federal Regulations (14 CFR) 25.307, *Proof of structure*. Section 25.307 requires structural testing to demonstrate compliance with the strength and deformation requirements of subpart C, unless structural analysis has been shown to be reliable.

2 APPLICABILITY.

2.1 The guidance provided in this document is directed to airplane manufacturers, modifiers, foreign regulatory authorities, and Federal Aviation Administration (FAA) transport airplane type certification engineers and their designees.

2.2 The material in this AC is neither mandatory nor regulatory in nature and does not constitute a regulation. While these guidelines are not mandatory, they are derived from extensive FAA and industry experience in determining compliance with the relevant regulations. These means are issued, in the interest of standardization, for guidance purposes and to outline a method that has been found acceptable in showing compliance with the standards set forth in the rule. If, however, we become aware of circumstances that convince us that following this AC would not result in compliance with the applicable regulations, we will not be bound by the terms of this AC, and we may require additional substantiation or design changes as a basis for finding compliance.

2.3 The material in this AC does not change or create any additional regulatory requirements, nor does it authorize changes in, or permit deviations, from existing regulatory requirements.

2.4 Except in the explanations of what the regulations require, the term “must” is used in this AC only in the sense of ensuring applicability of this particular method of compliance when the acceptable method of compliance described in this AC is used.

3 RELATED REGULATIONS.

The following 14 CFR regulations are referenced in this AC. The full text of these regulations can be downloaded at the U.S. Government Printing Office e-CFR. You can order a paper copy by sending a request to the U.S. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402-0001; or by calling telephone number (202) 512-1800; or by sending a request by facsimile to (202) 512-2250.

- Section 25.303, *Factor of safety*.
- Section 25.305, *Strength and deformation*.
- Section 25.651, *Proof of strength*.

4 BACKGROUND.

4.1 In 1964, § 25.307 was recodified from § 4b.202 of Civil Aeronautics Manual 4b. During recodification, the text was revised for the purpose of technical clarification, but the intent of the requirement remained the same.

4.2 In 1970, Amendment 25-23 revised § 25.307 by adding paragraph (d), the requirement for material correction factors that must be used for single load path flight structure substantiated by test. Section 25.307 was further revised by Amendment 25-54, which added the last sentence in § 25.307(a). Amendment 25-72 made further minor revisions, revoking two redundant sections.

4.3 The basic intent of the requirement has remained unchanged since the early 1940s. The regulation required proof of structural compliance with the strength and deformation requirement of part 25 for each critical loading condition. Structural analysis was allowed only if the structure conformed to that which experience had shown the analysis methods to be reliable.

4.4 This AC is the result of an Aviation Rulemaking Advisory Committee (ARAC) task to harmonize the European and U.S. regulations.

5 DEFINITIONS.

5.1 **Detail.**

A structural element of a more complex structural member (for example, joints, splices, stringers, stringer run-outs, or access holes).

5.2 **Sub-Component.**

A major three-dimensional structure that can provide complete structural representation of a section of the full structure (for example, stub-box, section of a spar, wing panel, wing rib, body panel, or frames).

5.3 **Component.**

A major section of the airframe structure (for example, wing, body, fin, horizontal stabilizer) that can be tested as a complete unit to qualify the structure.

5.4 **Full Scale.**

The dimensions of the test article are the same as design; a fully representative test specimen (not necessarily complete airframe).

5.5 **New Structure.**

Structure for which behavior is not adequately predicted by analysis supported by previous test evidence. Structure that uses significantly different structural design concepts such as details, geometry, structural arrangements, and load paths; or materials from previously tested designs.

5.6 **Similar New Structure.**

Structure that uses structural design concepts such as details, geometry, structural arrangements, and load paths concepts; and materials that are similar or comparable to an existing tested design.

5.7 **Derivative/Similar Structure.**

Structure that uses structural design concepts such as details, geometry, structural arrangements, and load paths; stress levels; and materials that are nearly identical to those on which the analytical methods have been validated.

5.8 **Previous Test Evidence.**

Testing of the original structure that is sufficient to verify structural behavior in accordance with § 25.305.

6 INTRODUCTION.

6.1 As required by paragraph (a) of § 25.307, the structure must be shown to comply with the strength and deformation requirements of subpart C of part 25. This means that the structure must—

6.1.1 Be able to support limit loads without detrimental permanent deformation, and

6.1.2 Be able to support ultimate loads without failure.

6.2 This implies the need of a comprehensive assessment of the external loads (addressed by § 25.301), the resulting internal strains and stresses, and material design values.

6.3 Section 25.307 requires compliance for each critical loading condition. Compliance can be shown by analysis supported by previous test evidence, analysis supported by new test evidence, or by test only. As compliance by test only is impractical in most cases, a large portion of the substantiating data will be based on analysis.

6.4 There are a number of standard engineering methods and formulas that are known to produce acceptable, often conservative results for structures where load paths are well defined. Those standard methods and formulas, applied with a good understanding of their limitations, are considered reliable analyses when showing compliance with § 25.307. Conservative assumptions may be considered in assessing whether or not an analysis may be accepted without test substantiation.

6.5 The application of methods such as finite element modeling or engineering formulas to complex structures in modern aircraft is considered reliable only when validated by full scale tests (ground and/or flight tests). Experience relevant to the product in the use of such methods should be considered.

7 CLASSIFICATION OF STRUCTURE.

7.1 The applicant should classify the structure into one of the following three categories:

- New structure.
- Similar new structure.
- Derivative/similar structure.

7.2 The applicant should provide justification if seeking to classify structure into either the "similar new" or "derivative/similar" categories. The following elements should be considered in justifying the classification:

7.2.1 The accuracy/conservatism of the analytical methods.

7.2.2 Comparison of the structure under investigation with previously tested structure. Considerations should include, but are not limited to, the following:

7.2.2.1 External loads (bending moment, shear, torque, etc.).

7.2.2.2 Internal loads (strains, stresses, etc.).

7.2.2.3 Structural design concepts such as details, geometry, structural arrangements, load paths.

7.2.2.4 Material properties.

7.2.2.5 Test experience (load levels achieved, lessons learned).

7.2.2.6 Deflections.

7.2.2.7 Deformations.

7.2.2.8 Extent of extrapolation from test stress levels.

8 NEED AND EXTENT OF TESTING.

The following factors should be considered in deciding the need for and the extent of testing, including the load levels to be achieved. Relevant service experience may be included in this evaluation.

8.1 The classification of the structure (as above).

8.2 The consequence of failure of the structure in terms of the overall integrity of the airplane.

8.3 The consequence of the failure to retain interior items of mass and the supporting structure to the safety of the occupants.

9 CERTIFICATION APPROACHES.

The following certification approaches may be selected:

- Analysis supported by new strength testing of the structure to limit and ultimate load.
- Analysis validated by previous test evidence and supported with additional limited testing.
- Analysis supported by previous test evidence.
- Test only.

9.1 Analysis Supported by New Strength Testing of the Structure to Limit and Ultimate Load.

This certification approach is typically the case for new structure.

9.1.1 Substantiation of the strength and deformation requirements up to limit and ultimate loads normally requires testing of sub-components, full-scale components or full-scale tests of assembled components (such as a nearly complete airframe). The entire test program should be considered in detail to assure that the requirements for strength and deformation can be met up to limit load levels as well as ultimate load levels.

9.1.2 Sufficient limit load test conditions should be performed to verify that the structure meets the deformation requirements of § 25.305(a) and to provide validation of internal load distribution and analysis predictions for all critical loading conditions.

9.1.3 Because ultimate load tests often result in significant permanent deformation, choices will have to be made with respect to the load conditions applied. This is usually based on the number of test specimens available, the analytical static strength margins of safety of the structure, and the range of supporting detail or sub-component tests. An envelope approach may be taken, where a combination of different load cases is applied, each one critical for a different section of the structure.

9.1.4 These limit and ultimate load tests may be supported by detail and sub-component tests that verify the adequacy of material design values (tension, shear, compression) of the structure and often provide some degree of validation for ultimate strength.

9.2 Analysis Validated by Previous Test Evidence and Supported with Additional Limited Testing.

This certification approach is typically the case for similar new structure.

9.2.1 The extent of additional limited testing (number of specimens, load levels, etcetera) will depend upon the degree of change, relative to the elements of paragraphs 7.2.1 and 7.2.2 of this AC.

9.2.2 For example, if the changes to an existing design and analysis necessitate extensive changes to an existing test-validated finite element model (for example, different rib

spacing), additional testing may be needed. Previous test evidence can be relied upon whenever applicable.

9.2.3 These additional limited tests may be further supported by detail and sub-component tests that verify the adequacy of material design values (tension, shear, compression) of the structure and often provide some degree of validation for ultimate strength.

9.3 **Analysis Supported by Previous Test Evidence.**

This certification approach is typically the case for derivative/similar structure.

9.3.1 The applicant should provide justification for this approach by demonstrating how the previous static test evidence validates the analysis and supports showing compliance for the structure under investigation. Elements that need to be considered are those defined in paragraphs 7.2.1 and 7.2.2 of this AC.

9.3.2 If the changes to the existing design and test-validated analysis are evaluated to assure they are relatively minor, and the effects of the changes are well understood, then the original tests may provide sufficient validation of the analysis and further testing may not be necessary. For example, if a weight increase results in higher loads along with a corresponding increase in some of the element thickness and fastener sizes, and materials and geometry (overall configuration, spacing of structural members, etc.) remain generally the same, the revised analysis could be considered reliable based on the previous validation.

9.4 **Test Only.**

9.4.1 Sometimes, no reliable analytical method exists, and testing must be used to show compliance with the strength and deformation requirements. In other cases, an applicant may elect to show compliance solely by tests, even if there are acceptable analytical methods. In either case, testing by itself can be used to show compliance with the strength and deformation requirements of part 25, subpart C. In such cases, the test load conditions should be selected to assure all critical design loads are encompassed.

9.4.2 If tests only are used to show compliance with the strength and deformation requirements for single load path structure that carries flight loads (including pressurization loads), the test loads must be increased to account for variability in material properties, as required by § 25.307(d). In lieu of a rational analysis, a factor of 1.15 applied to the limit and ultimate flight loads may be used for metallic materials. If the structure has multiple load paths, no material correction factor is required.

10 INTERPRETATION OF DATA.

10.1 Interpretation of the substantiation analysis and test data requires an extensive review of all of the following:

- The representativeness of the loading.
- The instrumentation data.

- Comparison of test results with analytical predictions.
- Representativeness of the test article(s).
- Test set-up (fixture, load introductions).
- Load levels and conditions tested.
- Test results.

10.2 Testing is used to validate analytical methods except when showing compliance by test only. If the test results do not correlate with the analysis, the reasons should be investigated and appropriate action taken. This should be accomplished whether or not a test article fails below ultimate load. This investigation should include a review of the test specimen and loads, analytical loads, and the structural analysis. This may lead to adjustment in analysis/modeling techniques and/or part redesign and may result in the need for additional testing. Should a failure occur below ultimate load, an investigation by the applicant should be conducted to reveal the cause of this failure. The need for additional testing to ensure ultimate load capability depends on the degree to which the failure is understood and the analysis can be validated by the test.

Advisory Circular Feedback

If you find an error in this AC, have recommendations for improving it, or have suggestions for new items/subjects to be added, you may let us know by (1) emailing this form to 9-AWA-AVS-AIR500-Coord@faa.gov or (2) faxing it to the attention of the Aircraft Certification Service Directives Management Officer at (202) 267-3983.

Subject: (insert AC title/number here) Date: Click here to enter text.

Please check all appropriate line items:

☐ An error (procedural or typographical) has been noted in paragraph Click here to enter text. on page Click here to enter text..

☐ Recommend paragraph Click here to enter text. on page Click here to enter text. be changed as follows:

Click here to enter text.

☐ In a future change to this AC, please cover the following subject:
(Briefly describe what you want added.)

Click here to enter text.

☐ Other comments:

Click here to enter text.

☐ I would like to discuss the above. Please contact me.

Submitted by: _____ Date: _____