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U.S. Department
of Transportation

Federal Aviation
Administration

ADVISORY CIRCULAR

Subject: COMPOSITE AIRCRAFT STRUCTURE

Date: 4/25/84
Initiated by: AWS-103

AC No: 20-107A
Change:

1. PURPOSE. This advisory circular sets forth an acceptable, but not the only, means of showing compliance with the provisions of Federal Aviation Regulations (FAR), Parts 23, 25, 27, and 29 regarding airworthiness type certification requirements for composite aircraft structures, involving fiber reinforced materials, e.g., carbon (graphite), boron, aramid (Kevlar), and glass reinforced plastics. Guidance information is also presented on associated quality control and repair aspects.

2. CANCELLATION. AC 20-107, Composite Aircraft Structure dated July 10, 1978, is canceled.

3. REGULATIONS AFFECTED. The material contained herein applies to normal, utility, acrobatic, and transport category aircraft type certificated under Civil Aviation Regulations (CARs) 3, 4b, 6, 7; and FARs 23, 25, 27, 29; and produced in compliance with FAR Part 21, sections 21.125, or 21.143 as may be appropriate. The individual FARs applicable to each paragraph are listed in Appendix 1 of this advisory circular.

4. GENERAL

a. The procedures outlined in this advisory circular provide guidance material for composite structures and are considered acceptable to the FAA for showing compliance with certification requirements of civil composite aircraft. This circular is published to aid in the evaluation of certification programs for composite applications and reflects the current status of composite technology. It is expected that this circular will be modified periodically to reflect technology advances. The information contained herein is for guidance purposes and is not mandatory nor regulatory in nature.

b. The extent of testing and/or analysis and the degree of environmental accountability required will differ for each structure depending upon the expected service usage, the material selected, the design margins, the failure criteria, the data base and experience with similar structures, and on other factors affecting a particular structure. It is expected that these factors will be considered when interpreting this advisory circular for use on a specific application.

c. Pertinent definitions are given in Appendix 2.

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5. MATERIAL AND FABRICATION DEVELOPMENT. To provide an adequate design data base, environmental effects on the design properties of the material system should be established.

a. Environmental design criteria should be developed that identify the most critical environmental exposures, including humidity and temperature, to which the material in the application under evaluation may be exposed. This is not required where existing data demonstrate that no significant environmental effects, including the effects of temperature and moisture, exist for the material system and construction details, within the bounds of environmental exposure being considered. Experimental evidence should be provided to demonstrate that the material design values or allowables are attained with a high degree of confidence in the appropriate critical environmental exposures to be expected in service. The effect of the service environment on static strength, fatigue and stiffness properties should be determined for the material system through tests; e.g., accelerated environmental tests, or from applicable service data. The effects of environmental cycling (i.e., moisture and temperature) should be evaluated. Existing test data may be used where it can be shown directly applicable to the material system.

b. The material system design values or allowables should be established on the laminate level by either test of the laminate or by test of the lamina in conjunction with a test validated analytical method.

c. For a specific structural configuration of an individual component (point design), design values may be established which include the effects of appropriate design features (holes, joints, etc.).

d. Impact damage is generally accommodated by limiting the design strain level.

6. PROOF OF STRUCTURE - STATIC. The static strength of the composite design should be demonstrated through a program of component ultimate load tests in the appropriate environment, unless experience with similar designs, material systems and loadings is available to demonstrate the adequacy of the analysis supported by subcomponent tests, or limit load component tests.

a. The effects of repeated loading and environmental exposure which may result in material property degradation should be addressed in the static strength evaluation. This can be shown by analysis supported by test evidence, by tests at the coupon, element or subcomponent level, or alternatively by relevant existing data.

b. Static strength structural substantiation tests should be conducted on new structure unless the critical load conditions are associated with structure that has been subjected to a repeated loading and environmental exposure. In this case either (1) the static test should be conducted on structure with prior repeated loading and environmental exposure, or (2) coupon/element/subcomponent test data should be provided to assess the possible degradation of static strength after application of repeated loading and environmental exposure, and this degradation accounted for in the static test or in the analysis of the results of the static test of the new structure.

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c. The component static test may be performed in an ambient atmosphere if the effects of the environment are reliably predicted by subcomponent and/or coupon tests and are accounted for in the static test or in the analysis of the results of the static test.

d. The static test articles should be fabricated and assembled in accordance with production specifications and processes so that the test articles are representative of production structure.

e. When the material and processing variability of the composite structure is greater than the variability of current metallic structures, the difference should be considered in the static strength substantiation (1) by deriving proper allowables or design values for use in the analysis, and the analysis of the results of supporting tests, or (2) by accounting for it in the static test when static proof of structure is accomplished by component test.

f. Composite structures that have high static margins of safety (e.g., some rotorblades) may be substantiated by analysis supported by subcomponent, element, and/or coupon testing.

g. It should be shown that impact damage that can be realistically expected from manufacturing and service, but not more than the established threshold of detectability for the selected inspection procedure, will not reduce the structural strength below ultimate load capability. This can be shown by analysis supported by test evidence, or by tests at the coupon, element or subcomponent level.

7. PROOF OF STRUCTURE - FATIGUE/DAMAGE TOLERANCE. The evaluation of composite structure should be based on the applicable requirements of FAR 23.571, 23.572, 25.571, 27.571, and 29.571. The nature and extent of analysis or tests on complete structures and/or portions of the primary structure will depend upon applicable previous fatigue/damage tolerant designs, construction, tests, and service experience on similar structures. In the absence of experience with similar designs, FAA-approved structural development tests of components, subcomponents, and elements should be performed. The following considerations are unique to the use of composite material systems and should be observed for the method of substantiation selected by the applicant. When selecting the damage tolerance or safe life approach, attention should be given to geometry, inspectability, good design practice, and the type of damage/degradation of the structure under consideration.

a. Damage Tolerance (Fail-Safe) Evaluation.

(1) Structural details, elements, and subcomponents of critical structural areas should be tested under repeated loads to define the sensitivity of the structure to damage growth. This testing can form the basis for validating a no-growth approach to the damage tolerance requirements. The testing should assess the effect of the environment on the flaw growth characteristics and the no-growth validation. The environment used should be appropriate to the expected service usage. The repeated loading should be representative of anticipated service usage. The repeated load testing should include damage levels (including impact damage) typical of those

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that may occur during fabrication, assembly, and in-service, consistent with the inspection techniques employed. The damage tolerance test articles should be fabricated and assembled in accordance with production specifications and processes so that the test articles are representative of production structure.

(2) The extent of initially detectable damage should be established and be consistent with the inspection techniques employed during manufacture and in service. Flaw/damage growth data should be obtained by repeated load cycling of intrinsic flaws or mechanically introduced damage. The number of cycles applied to validate a no-growth concept should be statistically significant, and may be determined by load and/or life considerations. The growth or no growth evaluation should be performed by analysis supported by test evidence or by tests at the coupon, element, or subcomponent level.

(3) The extent of damage for residual strength assessments should be established. Residual strength evaluation by component or subcomponent testing or by analysis supported by test evidence should be performed considering that damage. The evaluation should demonstrate that the residual strength of the structure is equal to or greater than the strength required for the specified design loads (considered as ultimate). It should be shown that stiffness properties have not changed beyond acceptable levels. For the no-growth concept residual strength testing should be performed after repeated load cycling.

(4) An inspection program should be developed consisting of frequency, extent , and methods of inspection for inclusion in the maintenance plan. Inspection intervals should be established such that the damage will be detected between the time it initially becomes detectable and the time at which the extent of damage reaches the limits for required residual strength capability. For the case of no-growth design concept, inspection intervals should be established as part of the maintenance program. In selecting such intervals the residual strength level associated with the assumed damages should be considered.

(5) The structure should be able to withstand static loads (considered as ultimate loads) which are reasonably expected during a completion of the flight on which damage resulting from obvious discrete sources occur (i.e., uncontained engine failures, etc.). The extent of damage should be based on a rational assessment of service mission and potential damage relating to each discrete source.

(6) The effects of temperature, humidity, and other environmental factors which may result in material property degradation should be addressed in the damage tolerance evaluation.

b. Fatigue (Safe-Life) Evaluation. Fatigue substantiation should be accomplished by component fatigue tests or by analysis supported by test evidence, accounting for the effects of the appropriate environment. The test articles should be fabricated and assembled in accordance with production specifications and processes so that the test articles are representative of

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production structure. Sufficient component, subcomponent, element or coupon tests should be performed to establish the fatigue scatter and the environmental effects. Component, subcomponent, and/or element tests may be used to evaluate the fatigue response of structure with impact damage levels typical of those that may occur during fabrication, assembly, and in service, consistent with the inspection procedures employed. The component fatigue test may be performed with an as-manufactured test article if the effects of impact damage are reliably predicted by subcomponent and/or element tests and are accounted for in the fatigue test or in analysis of the results of the fatigue test. It should be demonstrated during the fatigue tests that the stiffness properties have not changed beyond acceptable levels. Replacement lives should be established based on the test results. An appropriate inspection program should be provided.

8. PROOF OF STRUCTURE - FLUTTER. The effects of repeated loading and environmental exposure on stiffness, mass and damping properties should be considered in the verification of integrity against flutter and other aeroelastic mechanisms. These effects may be determined by analysis supported by test evidence, or by tests at the coupon, element or subcomponent level.

9. ADDITIONAL CONSIDERATIONS.

a. Impact Dynamics. The present approach in airframe design is to assure that occupants have every reasonable chance of escaping serious injury under realistic and survivable impact conditions. Evaluation may be by test or by analysis supported by test evidence. Test evidence includes but is not limited to element or subcomponent tests and service experience. Analytical comparison to conventional structure may be used where shown to be applicable.

b. Flammability.

(1) The existing requirements for flammability and fire protection of aircraft structure attempt to minimize the hazard to the occupants in the event ignition of flammable fluids or vapors occur. In addition, components exposed to heat, flames or sparks should withstand these effects. The use of composite structure should not decrease this existing level of safety. Compliance may be shown by analysis supported by test evidence that aircraft interior material subjected to these hazards can withstand fire and heat as required in FAR 25.

(2) Certain aircraft structure is required to be fire resistant. The following test is considered acceptable for demonstrating compliance for aircraft exterior structure and engine compartment materials that are to be fire resistant. A comparison test should be made between the specimen and an aluminum alloy sheet of the thickness normally used for the intended installation. The structure and materials should be tested by subjecting a specimen sheet 24 inches by 24 inches positioned perpendicular to a 2000° F plus or minus 150° F flame produced by a modified oil burner consuming two gallons of kerosene per hour. The burner should be positioned so that the time required for the flame to penetrate the aluminum alloy sample would be approximately five minutes. The test specimen should be positioned at the same distance from the burner flame as the aluminum alloy sheet. The specimen will be considered satisfactory if it resists flame penetration for a time period equal to or greater than the aluminum alloy sheet.

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c. Lightning Protection.

(1) Some composites are susceptible to lightning damage, and do not dissipate P-static electrical charges or provide electromagnetic shielding. Therefore it should be demonstrated by analysis support by test evidence that the structure can dissipate P-static electrical charges, provides electromagnetic protection where required and provides an acceptable means of diverting the resulting electrical current (as a result of a lightning strike) so as not to endanger the aircraft.

(2) Consideration should be given possible deterioration and undetected damage to the lightning protection system.

d. Protection of Structure. Weathering, abrasion, erosion, ultraviolet radiation, and chemical environment (glycol, hydraulic fluid, fuel, cleaning agents, etc.) may cause deterioration in a composite structure. Suitable protection against and/or consideration of degradation in material properties should be provided for and demonstrated by test.

e. Quality Control. The overall plan required by the certifying agency should involve all relevant disciplines, i.e., engineering, manufacturing and quality control. This quality control plan should be responsive to special engineering requirements that arise in individual parts or areas as a result of potential failure modes, damage tolerance and flaw growth requirements, loadings, inspectability, and local sensitivities to manufacture and assembly.

f. Production Specifications. Specifications covering material, material processing, and fabrication procedures should be developed to ensure a basis for fabricating reproducible and reliable structure. The discrepancies permitted by the specifications should be substantiated by analysis supported by test evidence, or tests at the coupon, element or subcomponent level.

g. Inspection and Maintenance. Maintenance manuals developed by manufacturers should include appropriate inspection, maintenance and repair procedures for composite structures.

h. Substantiation of Repair. When repair procedures are provided in FAA approved documents or the maintenance manual, it should be demonstrated by analysis and/or test that methods and techniques of repair will restore the structure to an airworthy condition.

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APPENDIX 1. APPLICABLE FARs AND RELATED ADVISORY CIRCULARS

Text Paragraphs	FAR 23	FAR 25	FAR 27	FAR 29
1. PURPOSE		Not Applicable		
2. CANCELLATION		Not Applicable		
3. REGULATIONS AFFECTED		Not Applicable		
4. GENERAL		Not Applicable		
5. MATERIAL AND FABRICATION DEVELOPMENT				
	.603	.603	.603	.603
	.613	.613	.613	.613
	.615	.615		
6. PROOF OF STRUCTURE - STATIC	.305	.305	.305	.305
	.307(a)	.307(a)	.307(a)	.307(a)
7. PROOF OF STRUCTURE - FATIGUE/DAMAGE TOLERANCE				
	.571	.571	.571	.571
	.572		AC 20-95	AC 20-95
8. PROOF OF STRUCTURE - FLUTTER	.629	.629	.629	.629
9. ADDITIONAL CONSIDERATIONS				
a. Impact Dynamics	.561	.561	.561	.561
	.601	.601		
	.785	.721	.601	.601
		.783(c)(g)	.785	.783(d)
	.787(e)	.785	.787(c)	.785
	.807(b)(4)	.787(a)(b)	.801	.787(c)
	.967(e)	.789	.807(b)(4)	
		.801	.965	.801
		.809		.803(c)(1)
		.963(d)		

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APPENDIX 1. APPLICABLE FARs AND RELATED ADVISORY CIRCULARS

Text Paragraphs	FAR 23	FAR 25	FAR 27	FAR 29
ADDITIONAL CONSIDERATIONS				
a. Impact Dynamics (cont'd)				
		*	.1413	.809 .963(b) .967(f)
b. Flammability	.609(a)	.609(a)	.609(a)	.609(a)
	.787(d)	.853	.853	.853
	.853	.855	.855	.855
	.859	.859	.859	.859
	.865	.863	.861	.861
	.1121(c)	.865	.1183	.863
	.1182	.867	.1185	.903(c)
	.1183	.903(c)	.1191	.967(e)
	.1189(b)(2)	.967(e)	.1193(d)(e)	
	.1191	.1121(c)	.1194	.1013(e)
	.1193(c)(d)(e)	.1181		.1121(c)
		.1182		.1183
		.1183		.1185
		.1185		.1189(a)(2)
		.1189(a)(2)		.1191
		.1191		.1193(c)(d)(e)
		.1193(c)(d)(e)		.1194

* Special Conditions have been issued in the past on wide body airplanes concerning emergency wheels up landing.

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APPENDIX 1. APPLICABLE FARs AND RELATED ADVISORY CIRCULARS

Text Paragraphs	FAR 23	FAR 25	FAR 27	FAR 29
ADDITIONAL CONSIDERATIONS				
c. Lightning Protection	.609	.581	.609	.609
	.867	.609		
d. Protection of Structure	.609	.609	.609	.609
e. Quality Control	**	**	**	**
f. Production Specifications	.603	.603	.603	.603
	.605	.605	.605	.605

** A new Advisory Circular on Quality Control for Composites is under development.

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APPENDIX 2. DEFINITIONS

Design values - material, structural element, and structural detail properties that have been determined from test data and chosen to assure a high degree of confidence in the integrity of the completed structure [reference FAR 25.613(b)].

Allowables - material values that are determined from test data at the laminate or lamina level on a probability basis, e.g., A or B base values [reference FAR 25.615(a)].

Laminate level design values or allowables - established from multi-ply laminate test data and/or from test data at the lamina level and then established at the laminate level by test validated analytical methods.

Lamina level material properties - established from test data for a single ply or multi-ply single-direction oriented lamina layup.

Point design - an element or detail of a specific design which is not considered generically applicable to other structure for the purpose of substantiation, e.g., lugs and major joints. Such a design element or detail can be qualified by test or by a combination of test and analysis.

Environment - external, non-accidental conditions (excluding mechanical leading), separately or in combination, that can be expected in service and which may affect the structure (e.g., temperature, moisture, UV radiation, and fuel).

Degradation - the alteration of material properties (e.g., strength, modulus, coefficient of expansion) which may result from deviations in manufacturing or from repeated loading and/or environmental exposure.

Discrepancy - a manufacturing anomaly allowed and detected by the planned inspection procedure. They can be created by processing, fabrication or assembly procedures.

Flaw - a manufacturing anomaly created by processing, fabrication or assembly procedures.

Damage - a structural anomaly caused by manufacturing (processing, fabrication, assembly or handling) or service usage. Usually caused by trimming, fastener installation or foreign object contact.

Impact damage - a structural anomaly created by foreign object impact.

Coupon - a small test specimen (e.g., usually a flat laminate) for evaluation of basic lamina or laminate properties or properties of generic structural features (e.g., bonded or mechanically fastened joints).

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APPENDIX 2. DEFINITIONS

Element - a generic element of a more complex structural member (e.g., skin, stringers, shear panels, sandwich panels, joints, or splices).

Detail - a non-generic structural element of a more complex structural member (e.g. specific design configurated joints, splices, stringers, stringer runouts, or major access holes).

Subcomponent - a major three-dimensional structure which can provide complete structural representation of a section of the full structure (e.g. stub-box, section of a spar, wing panel, wing rib, body panel, or frames).

Component - a major section of the airframe structure (e.g., wing, body, fin, horizontal stabilizer) which can be tested as a complete unit to qualify the structure.