AC NO: 20-107

DATE: 7/10/78

ADVISORY CIRCULAR

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

SUBJECT: COMPOSITE AIRCRAFT STRUCTURE

1. PURPOSE. This advisory circular sets forth an acceptable means of compliance with the provisions of Federal Aviation Regulations, Parts 23, 25, 27 and 29 dealing with the certification requirements of composite aircraft structures, involving fiber reinforced materials, e.g., graphite, boron and glass reinforced plastics. Guidance information is also presented on associated quality control and repair aspects, as well as on a suggested continuing surveillance program to obtain long term data on the characteristics of materials.

2. REGULATIONS AFFECTED. The material contained herein applies to normal, utility, acrobatic, transport and restricted category aircraft under CARs 3, 4b, 6, 7; FARs 23, 25, 27, 29, 21.25 (a)(1), 21.125, and 21.143 as may be appropriate. The individual FARs applicable to each paragraph are listed in the appendix of this advisory circular.

3. 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 near-term composite applications and reflect 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 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.

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4. 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. Experimental evidence should be provided to demonstrate that the material allowables are attained with a high degree of confidence in the most critical environmental exposures, including moisture and temperature, to be expected in service. The effect of moisture absorption on static strength, fatigue and stiffness properties, for the operational temperature range, should be determined for the material system through tests. The impact of moisture absorption and temperature cycling on the material system properties should be evaluated. Existing test data may be used where it can be shown directly applicable to the material system. Where existing data demonstrate that no significant temperature and moisture effects exist for the material system and construction details, within the bounds of moisture and temperature being considered, moisture and temperature studies need not be considered.

b. The material system 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.

5. 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.

a. The component ultimate load 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.

b. Structural static testing of a component may be conducted on either new structure or structure previously subjected to repeated loads. If new structure is used to determine proof of compliance, coupon test data should be provided to assess the possible material property degradation of static strength after the application of repeated loads and should be accounted for in the results of static test of the new structure.

c. Composite designs that have low operational stresses, relative to ultimate strength or designed by fatigue may be substantiated by analysis supported by subcomponent and/or coupon testing.

6. PROOF OF STRUCTURE-FATIGUE. The evaluation of composite structure should be based on achieving a level of safety at least as high as that currently required for metal structure. All structure required to be evaluated should be evaluated in accordance with (a) or (b) below:

a. Damage Tolerance (Fail-Safe) Evaluation. The nature and extent of tests on complete structures and/or portions of the primary structure will depend upon applicable previous damage tolerant design, construction, tests, and service experience on similar structures. Experience with FAA-approved designs should be available in the long term to demonstrate the adequacy of the damage tolerant approach.

(1) In the absence of experience with similar designs, FAA-approved structural development tests of components and subcomponents should be performed. The tests should demonstrate that the residual strength of the structure can withstand the specified limit loads (considered as ultimate) with a damage extent consistent with initial detectability and subsequent growth under repeated loads including the effects of temperature and humidity. Growth rate data should be used in establishing a recommended inspection program.

(2) The effects of moisture and temperature could be accounted for by adjustment of the test load spectrum or damage growth time from the results of separate repeated load tests of subcomponents or coupons. The residual strength tests to the specified limit loads should be performed on the development test component with appropriate damage simulation.

(3) 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, hail stones, etc.). The extent of damage should be based on rational assessment of service mission and potential damage relating to each discrete source.

b. Fatigue (Safe-Life) Evaluation. Fatigue substantiation should be accomplished by full-scale component fatigue tests accounting for the effects of the appropriate environment. Sufficient component, subcomponent or coupon tests should be performed to establish the fatigue scatter and the environmental effects. The scatter factor determined should provide equivalent safety to that of conventional metal components. It should be demonstrated during the fatigue tests that the component stiffness has not changed to the extent that safety of the aircraft would be impaired.

7. ADDITIONAL CONSIDERATIONS.

a. Crashworthiness. The present approach to crashworthiness of the airframe is to assure that occupants have every reasonable chance of escaping serious injury under realistic and survivable crash conditions. The use of composite structure in areas where failure would create a hazard to occupants should be shown to have crashworthiness capability equivalent to conventional structure materials in dimensions appropriate for the purpose for which they are used. In general, this equivalency would be shown by comparative analysis supported by tests as required.

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.

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 supported 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 allowables should be provided for and demonstrated by test.

e. Quality Control. In order to ensure that structure will enter service with design strength, a comprehensive quality control plan should be established and implemented. The 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 defect growth requirements, loadings and local configuration, inspectability and as a result of local sensitivities to manufacture and assembly.

f. Fabrication Specifications. Specifications covering material, material processing, and fabrication procedures should be developed to ensure a basis for fabricating reproducible and reliable structure.

g. Repair. When repair procedures are provided in 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.

h. Continuing Surveillance. Consideration should be given to periodic inspection and test of high time service components to evaluate the long term effects of the environment on structural integrity.

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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. REGULATIONS AFFECTED	Not Applicable			
3. GENERAL	Not Applicable			
4. MATERIAL AND FABRICATION DEVELOPMENT	.603	.603	.603	.603
	.613	.613	.613	.613
	.615	.615		
5. PROOF OF STRUCTURE - STATIC	.305	.305	.305	.305
	.307(a)	.307(a)	.307(a)	.307(a)
6. PROOF OF STRUCTURE - FATIGUE	.571	*.571	.571	.571
	.572	.573	AC 20-95	AC 20-95
7. ADDITIONAL CONSIDERATIONS				
(a) Crashworthiness	.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)		

* Note NPRM 77-15 proposed to amend FAR 25.

Text Paragraphs	FAR 23	FAR 25	FAR 27	FAR 29
ADDITIONAL CONSIDERATIONS:				
Crashworthiness (cont'd)		**	.1413	.963(b)
				.967(f)
				.809
(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)
	.1191	.967(e)	.1193(d)(e)	.1185
	.1189(b)(2)	.1121(c)	.1194	.1013(e)
	.1193(c)(d)(e)	.1181		.1121(c)
		.1182		.1183(a)
		.1183		.1185
		.1185		.1189(a)(2)
		.1189(a)(2)		.1191
		.1191		.1194
		.1193(c)(d)(e)		

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

Text Paragraphs	FAR 23	FAR 25	FAR 27	FAR 29
7. ADDITIONAL CONSIDERATIONS:				
Flammability (cont'd)				.1193(c)(d)(e)
(c) Lightning Protection	.867	.581	.609	.609
	.609	.609		
(d) Protection of Structure	.609	.609	.609	.609
(e) Quality Control	21.125	21.125	21.125	21.125
	21.143	21.143	21.143	21.143
(f) Fabrication Specifications	.605	.605	.605	.605
(g) Repair	.1529	.1529	.1529	.1529