Designation: F3114 – 15

Standard Specification for Structures[1]

1. Scope

1.1 This specification addresses the structural requirements that apply to all portions of the airframe regardless of component, system, or structure.

1.2 This specification was originally conceived for small airplanes as defined in the F44 terminology standard but may find broader applicability. Use of the term aircraft throughout this specification is intended to allow the relevant CAA(s) to accept this standard as a means of compliance as they determine it to be appropriate, whether for small airplanes or for other types of aircraft.

1.3 The applicant for a design approval must seek individual guidance from their respective CAA body concerning the use of this standard as part of a certification plan. For information on which CAA regulatory bodies have accepted this standard (in whole or in part) as a means of compliance to their Small Airplane Airworthiness Rules (hereinafter referred to as "the Rules"), refer to ASTM F44 webpage (www.ASTM.org/COMMITTEE/F44.htm) which includes CAA website links.

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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

F3060 Terminology for Aircraft

F3061 Specification for Systems and Equipment in Small Aircraft

F3083 Specification for Emergency Conditions, Occupant Safety and Accommodations

F3093 Specification for Aeroelasticity Requirements

F3115 Specification for Structural Durability for Small Airplanes

F3116 Specification for Design Loads and Conditions

3. Terminology

3.1 See Terminology F3060 for more definitions and abbreviations.

4. Strength

4.1 *Loads*—Strength requirements are specified in terms of limit loads (the maximum loads to be expected in service) and ultimate loads (limit loads multiplied by prescribed factors of safety).

4.2 *Factor of Safety*—Unless otherwise provided, a factor of safety of 1.5 must be used.

4.3 *Strength and Deformation:*

4.3.1 The structure must be able to support limit loads without detrimental, permanent deformation. At any load up to limit loads, the deformation may not interfere with safe operation.

4.3.2 The structure must be able to support ultimate loads without failure for at least three seconds, except local failures or structural instabilities between limit and ultimate load are acceptable only if the structure can sustain the required ultimate load for at least three seconds. However when proof of strength is shown by dynamic tests simulating actual load conditions, the three second limit does not apply.

4.4 *Proof of Structure:*

4.4.1 Compliance with the strength and deformation requirements of 4.3 must be shown for each critical load condition. Structural analysis may be used only if the structure conforms to those for which experience has shown this method to be reliable. In other cases, substantiating load tests must be made. Dynamic tests, including structural flight tests, are acceptable if the design load conditions have been simulated.

4.4.2 Certain parts of the structure must be tested as specified.

4.5 *Vibration and Buffeting*—There must be no vibration or buffeting severe enough to result in structural damage, and each part of the airplane must be free from excessive vibration, under any appropriate speed and power conditions up to V_D/M_D, or V_{DF}/M_{DF} for turbojets.

[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.

4.6 *Canard or Tandem Wing Configurations:*

4.6.1 The forward structure of a canard or tandem wing configuration must:

4.6.1.1 Meet all requirements of this standard, Specifications F3116, F3093, F3083, and F3115 applicable to a wing; and

4.6.1.2 Must meet all requirements applicable to the function performed by these surfaces.

4.7 *Windshields and Windows:*

4.7.1 The internal panels of windshields and windows must be constructed of a nonsplintering material, such as but not limited to:

4.7.1.1 Nonsplintering safety glass; or

4.7.1.2 Synthetic resins.

4.7.2 The design of windshields, windows, and canopies in pressurized airplanes must be based on factors peculiar to high altitude operation, including:

4.7.2.1 The effects of continuous and cyclic pressurization loadings;

4.7.2.2 The inherent characteristics of the material used; and

4.7.2.3 The effects of temperatures and temperature gradients.

4.7.3 On pressurized airplanes, if certification for operation up to and including 25 000 ft is requested, an enclosure canopy including a representative part of the installation must be subjected to special tests to account for the combined effects of continuous and cyclic pressurization loadings and flight loads, or compliance with the fail-safe requirements of 4.7.4 must be shown.

4.7.4 If certification for operation above 25 000 ft is requested, the windshields, window panels, and canopies must be strong enough to withstand the maximum cabin pressure differential loads combined with critical aerodynamic pressure and temperature effects, after failure of any load-carrying element of the windshield, window panel, or canopy.

4.7.5 In the event of any probable single failure, a transparency heating system must be incapable of raising the temperature of any windshield or window to a point where there would be:

4.7.5.1 Structural failure that adversely affects the integrity of the cabin; or

4.7.5.2 A danger of fire.

4.7.6 In addition, for Level 4 airplanes, the following applies:

4.7.6.1 Windshield panes directly in front of the pilots in the normal conduct of their duties, and the supporting structures for these panes, must withstand, without penetration, the impact of a 2-lb bird when the velocity of the airplane (relative to the bird along the airplane's flight path) is equal to the airplane's maximum approach flap speed.

4.8 *Landing Gear:*

4.8.1 For Level 4 airplanes, the following general requirements for the landing gear apply:

4.8.1.1 Each airplane must be designed so that, with the airplane under control, it can be landed on a paved runway with any one or more landing-gear legs not extended without sustaining a structural component failure that is likely to cause the spillage of enough fuel to constitute a fire hazard.

4.8.1.2 Compliance with the provisions of this section may be shown by analysis or tests, or both.

4.9 *Testing*—The suitability of each questionable design detail and part having an important bearing on safety in operations must be established by tests.

4.9.1 *Wings*—The strength of stressed-skin wings must be proven by load tests or by combined structural analysis and load tests.

4.9.2 *Control Surfaces:*

4.9.2.1 Limit load tests of control surfaces are required. These tests must include the horn or fitting to which the control system is attached.

4.9.2.2 In structural analyses, rigging loads due to wire bracing must be accounted for in a rational or conservative manner.

4.9.3 *Pressurization Tests*—Strength test. The complete pressurized cabin, including doors, windows, canopy, and valves, must be tested as a pressure vessel for the pressure differential specified in Specification F3116.

5. Mass and Mass Distribution

5.1 *Load Distribution Limits*—The load distribution limits may not exceed any of the limits at which the structure is proven.

5.2 *Leveling Means*—There must be means for determining when the airplane is in a level position on the ground.

6. Materials, Processes, and Methods of Fabrication

6.1 *Materials and Workmanship:*

6.1.1 The suitability and durability of materials used for parts, the failure of which could adversely affect safety, must:

6.1.1.1 Be established by experience or tests;

6.1.1.2 Meet approved specifications that ensure their having the strength and other properties assumed in the design data; and

6.1.1.3 Take into account the effects of environmental conditions, such as temperature and humidity, expected in service.

6.1.2 Workmanship must be of a high standard.

6.2 *Fabrication Methods:*

6.2.1 The methods of fabrication used must produce consistently sound structures. If a fabrication process (such as gluing, spot welding, or heat-treating) requires close control to reach this objective, the process must be performed under an approved process specification.

6.2.2 Each new aircraft fabrication method must be substantiated by a test program.

6.3 *Material Strength Properties and Design Values:*

6.3.1 Material strength properties must be based on enough tests of material meeting specifications to establish design values on a statistical basis.

6.3.1.1 When the manufacturer is unable to provide satisfactory statistical justification, especially in the case of manufacturing of composite materials, a safety factor may be applied per 8.5.1 to ensure that statistical values are met for Level 1 airplanes with:

(1) Single engine;

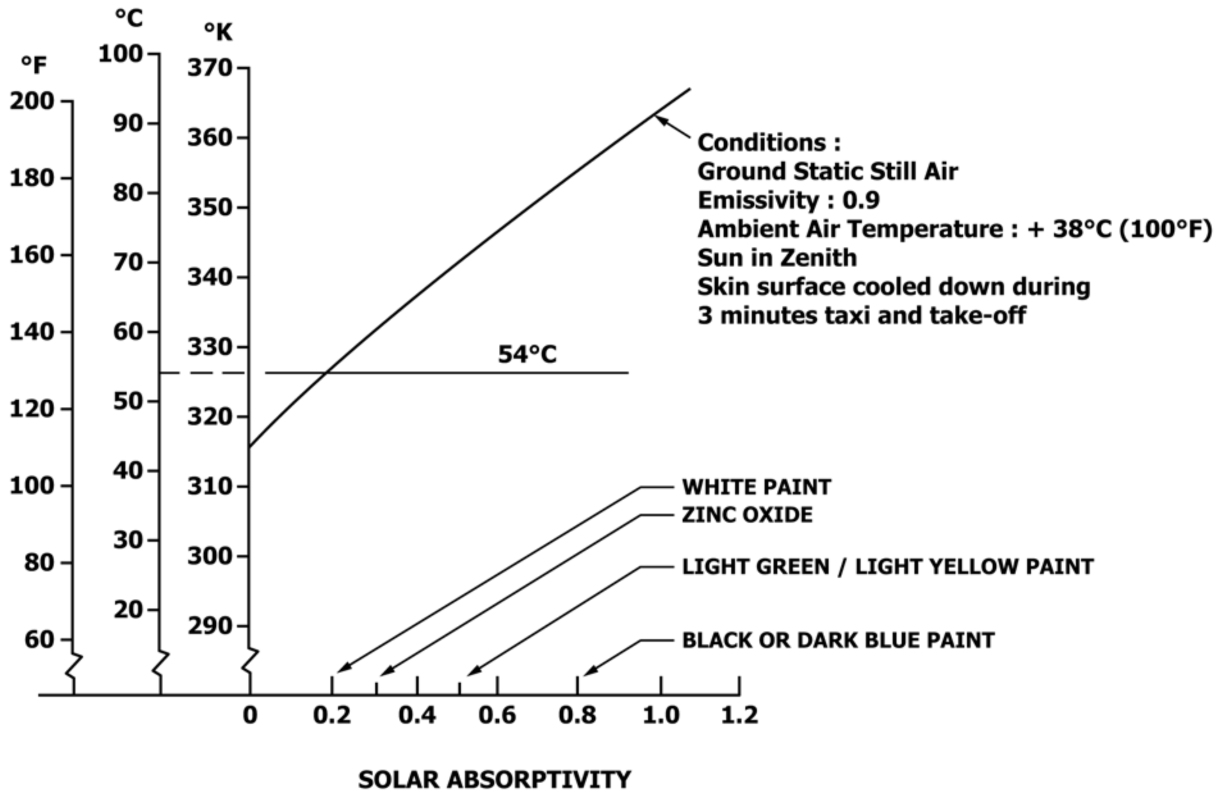

FIG. 1 Test Temperature

(2) Maximum certificated take-off weight of not more than 750 kgf (1654 lbm);

(3) Stalling speed in the landing configuration of not more than 83 km/h (45 knots) (CAS);

(4) Unpressurized fuselage; and

(5) Non aerobatic operation.

6.3.1.2 The following composite materials are applicable for 6.3.1.1:

(1) Glass fiber or carbon fiber construction in epoxy resin; and

(2) Wood construction.[3]

6.3.2 Design values must be chosen to minimize the probability of structural failure due to material variability. Except as provided in 6.3.4 or 6.3.1.1 of this section, compliance with this paragraph must be shown by selecting design values that ensure material strength with the following probability:

6.3.2.1 Where applied loads are eventually distributed through a single member within an assembly, the failure of which would result in loss of structural integrity of the component; 99 % probability with 95 % confidence.

6.3.2.2 For redundant structure, in which the failure of individual elements would result in applied loads being safely distributed to other load carrying members; 90 % probability with 95 % confidence.

6.3.3 The effects of temperature on allowable stresses used for design in an essential component or structure must be considered where thermal effects are significant under normal operating conditions.

6.3.3.1 For airplanes defined in 6.3.1.1 constructed using composite materials defined in 6.3.1.2, compliance can be shown:

(1) At test temperature for white painted surfaces and vertical sunlight of 54°C. Test temperature for other colored surfaces may be determined by the curve in NASA Conference Publication 2036, NASA Contractor Report 3290 shown in Fig. 1.

(2) In lieu of 6.3.1.1*(1)* a safety factor may be applied per 8.5.2 for white painted surfaces at 54°C.

6.3.4 Design values greater than the guaranteed minimums required by this section may be used where only guaranteed minimum values are normally allowed if a "premium selection" of the material is made in which a specimen of each individual item is tested before use to determine that the actual strength properties of that particular item will equal or exceed those used in design.

7. Protection of Structure

7.1 *Fasteners:*

7.1.1 Each removable fastener must incorporate two retaining devices if the loss of such fastener would preclude continued safe flight and landing.

[3] Reference information related to design values of wood structures can be found in ANC-18, "Design of Wood Aircraft Structures," issued June 1951 by the Air Force-Navy-Civil Committee on Aircraft Design Criteria (USA).

7.1.2 Fasteners and their locking devices must not be adversely affected by the environmental conditions associated with the particular installation.

7.1.3 No self-locking nut may be used on any bolt subject to rotation in operation unless a non-friction locking device is used in addition to the self-locking device.

7.2 *Protection of Structure*—Each part of the structure must:

7.2.1 Be suitably protected against deterioration or loss of strength in service due to any cause, including:

7.2.1.1 Weathering;

7.2.1.2 Corrosion; and

7.2.1.3 Abrasion; and

7.2.2 Have adequate provisions for ventilation and drainage.

7.3 *Accessibility Provisions*—For each part that requires maintenance, inspection, or other servicing, appropriate means must be incorporated into the aircraft design to allow such servicing to be accomplished.

7.4 *Fire Protection of Engine Mounts, and Other Flight Structure:*

7.4.1 Engine mounts, and other flight structure located in designated fire zones, or in adjacent areas that would be subjected to the effects of fire in the designated fire zones, must be constructed of fireproof material or be shielded so that they are capable of withstanding the effects of a fire.

7.4.2 Engine vibration isolators must incorporate suitable features to ensure that the engine is retained if the non-fireproof portions of the isolators deteriorate from the effects of a fire.

8. Special Factors of Safety

8.1 *Special Factors*—The factor of safety prescribed in 4.2 must be multiplied by the highest pertinent special factors of safety prescribed in 8.2 through 8.5 for each part of the structure whose strength is:

8.1.1 Uncertain;

8.1.2 Likely to deteriorate in service before normal replacement; or

8.1.3 Subject to appreciable variability because of uncertainties in manufacturing processes or inspection methods.

8.2 *Casting Factors:*

8.2.1 *General*—The factors, tests, and inspections specified in 8.2.2 through 8.2.4 must be applied in addition to those necessary to establish foundry quality control. The inspections must meet approved specifications. Sections 8.2.3 and 8.2.4 apply to any structural castings except castings that are pressure tested as parts of hydraulic or other fluid systems and do not support structural loads.

8.2.2 *Bearing Stresses and Surfaces*—The casting factors specified in 8.2.3 and 8.2.4:

8.2.2.1 Need not exceed 1.25 with respect to bearing stresses regardless of the method of inspection used; and

8.2.2.2 Need not be used with respect to the bearing surfaces of a part whose bearing factor is larger than the applicable casting factor.

8.2.3 *Critical Castings*—For each casting whose failure would preclude continued safe flight and landing of the airplane or result in serious injury to occupants, the following apply:

8.2.3.1 Each critical casting must either:

(1) Have a casting factor of not less than 1.25 and receive 100 % inspection by visual, radiographic, and either magnetic particle, penetrant or other approved equivalent non-destructive inspection method; or

(2) Have a casting factor of not less than 2.0 and receive 100 % visual inspection and 100 % approved non-destructive inspection. When an approved quality control procedure is established and an acceptable statistical analysis supports reduction, non-destructive inspection may be reduced from 100 %, and applied on a sampling basis.

8.2.3.2 For each critical casting with a casting factor less than 1.50, three sample castings must be static tested and shown to meet:

(1) The strength requirements of 4.3 at an ultimate load corresponding to a casting factor of 1.25; and

(2) The deformation requirements of 4.3 at a load of 1.15 times the limit load.

8.2.3.3 Examples of these castings are structural attachment fittings, parts of flight control systems, control surface hinges and balance weight attachments, seat, berth, safety belt, and fuel and oil tank supports and attachments, and cabin pressure valves.

8.2.4 *Non-Critical Castings*—For each casting other than those specified in 8.2.3 or 8.2.5, the following apply:

8.2.4.1 Except as provided in 8.2.4.2 and 8.2.4.3, the casting factors and corresponding inspections must meet the following table:

Casting Factor	Inspection
2.0 or more	100 % visual
Less than 2.0 but more than 1.5	100 % visual, and magnetic particle or penetrant or equivalent non-destructive inspection methods
1.25 through 1.50	100 % visual, magnetic particle or penetrant, and radiographic, or approved equivalent non-destructive inspection methods

8.2.4.2 The percentage of castings inspected by nonvisual methods may be reduced below that specified in 8.2.4.1 when an approved quality control procedure is established.

8.2.4.3 For castings procured to a specification that guarantees the mechanical properties of the material in the casting and provides for demonstration of these properties by test of coupons cut from the castings on a sampling basis:

(1) A casting factor of 1.0 may be used; and

(2) The castings must be inspected as provided in 8.2.4.1 for casting factors of "1.25 through 1.50" and tested under 8.2.3.2.

8.2.5 *Non-Structural Castings*—Castings used for non-structural purposes do not require evaluation, testing or close inspection.

8.3 *Bearing Factors:*

8.3.1 Each part that has clearance (free fit), and that is subject to pounding or vibration, must have a bearing factor large enough to provide for the effects of normal relative motion.

8.3.2 For control surface hinges and control system joints, compliance with the factors prescribed in Specification F3061 meets 8.3.1.

8.4 *Fitting Factors*—For each fitting (a part or terminal used to join one structural member to another), the following apply:

8.4.1 For each fitting whose strength is not proven by limit and ultimate load tests in which actual stress conditions are simulated in the fitting and surrounding structures, a fitting factor of at least 1.15 must be applied to each part of:

8.4.1.1 The fitting;

8.4.1.2 The means of attachment; and

8.4.1.3 The bearing on the joined members.

8.4.2 No fitting factor need be used for joint designs based on comprehensive test data (such as continuous joints in metal plating, welded joints, and scarf joints in wood).

8.4.3 For each integral fitting, the part must be treated as a fitting up to the point at which the section properties become typical of the member.

8.4.4 For each seat, berth, safety belt, and harness, its attachment to the structure must be shown, by analysis, tests, or both, to be able to withstand the inertia forces prescribed in Specification F3083 multiplied by a fitting factor of 1.33.

8.5 *Configuration Based Factors:*

8.5.1 The following may be used to satisfy the safety factor requirement of 6.3.1.1:

8.5.1.1 An additional factor of 1.2 for moisture conditioned specimen tested at maximum service temperature, providing that a well established manufacturing and quality control procedure is used.

8.5.1.2 An additional factor of 1.5 for specimen tested with no specific allowance for moisture and temperature.

(1) For room temperature cured structures it may be assumed that the completed structure is fully moisture conditioned.

(2) The factor in 8.5.1.1 may be varied based on the coefficient of variation that the manufacturer is able to show for this product (see Table 1).

(a) Definition: Coefficient of Variation—For a population with mean M and standard deviation s, the coefficient of variation, Cv, is defined by:

$$Cv = \sigma / M \tag{1}$$

(b) The coefficient of variation is frequently expressed as a percentage, in which case:

TABLE 1

Coefficient of Variation %	Test Factor
5	1.00
6	1.03
7	1.06
8	1.10
9	1.12
10	1.15
12	1.22
14	1.30
15	1.33
20	1.55

$$Cv(\%) = 100\,\sigma / M \tag{2}$$

(c) Additional Advisory Material—When the population of coefficient of variation is estimated from tests of critical structural features, the results from tests of at least 6 specimens should be used.

(d) The sample coefficient of variation should be adjusted to obtain a 95% confidence estimate of the population coefficient of variation which may be used in Table 1.

(e) In the absence of a more rational method, this may be done by multiplying the sample coefficient of variation by a Factor F, defined by:

$$F = \frac{1 + U_P\left\{\frac{1}{2_f}\left(1 - \frac{c^2 U_{P^2}}{n}\right) + \frac{c^2}{n}\right\}^{1/2}}{1 - \frac{c^2 U_{P^2}}{n}} \tag{3}$$

where:

U_P = the standardised normal variate corresponding to the confidence level being used (for 95% confidence, U_P = 1.6452),

n = the number of specimens in the Sample,

f = the number of statistical degree of freedom [=(n-1)], and

c = the population coefficient of variation. The value of the factor F is relatively insensitive to the value of c used; in the absence of more rational data, a value of 0.2 should be used.

8.5.2 An additional factor of 1.25 can be used for white painted surfaces at 54°C for compliance with 6.3.1.1*(1)*.