Designation: F3231/F3231M – 17

Standard Specification for Electrical Systems in Small Aircraft[1]

This standard is issued under the fixed designation F3231/F3231M; 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 covers international standards for the electrical systems aspects of airworthiness and design for "small" aircraft.

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

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

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 Following is a list of external standards referenced throughout this specification; the earliest revision acceptable for use is indicated. In all cases later document revisions are acceptable if shown to be equivalent to the listed revision, or if otherwise formally accepted by the governing civil aviation authority; earlier revisions are not acceptable.

2.2 *ASTM Standards:*[2]

F3060 Terminology for Aircraft

F3061/F3061M Specification for Systems and Equipment in Small Aircraft

F3066/F3066M Specification for Powerplant Systems Specific Hazard Mitigation

F3117/F3117M Specification for Crew Interface in Aircraft

F3235 Specification for Electrical Storage Batteries in Small Aircraft

2.3 *FAA Standard:*

DOT/FAA/AR-00/12 Aircraft Materials Fire Test Handbook[3]

3. Terminology

3.1 Terminology specific to this specification is provided below. For general terminology, refer to Terminology F3060.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *aircraft type code, n*—an Aircraft Type Code (ATC) is defined by considering both the technical considerations regarding the design of the aircraft and the airworthiness level established based upon risk-based criteria; the method of defining an ATC applicable to this specification is defined in Specification F3061/F3061M.

3.2.2 *continued safe flight and landing, n*—continued safe flight and landing as applicable to this specification is defined in Specification F3061/F3061M.

4. Electrical Systems

NOTE 1—Table 1 provides correlation between various Aircraft Type Codes and the individual requirements contained within this section; refer to 3.2.1. For each subsection, an indicator can be found under each ATC character field; three indicators are used:

An empty cell ( ) in all applicable ATC character field columns indicates that an aircraft must meet the requirements of that subsection.

A white circle (○) in multiple columns indicates that the requirements of that subsection are not applicable to an aircraft *only* if all such ATC character fields are applicable.

A mark-out (×) in any of the applicable ATC character field columns indicates that the requirements of that subsection are not applicable to an aircraft if that ATC character field is applicable.

Example—An aircraft with an ATC of 1SRLLDLN is being considered. Since all applicable columns are empty for 4.2.1, that subsection is applicable to the aircraft. Since both the "L" stall speed column and the "D" meteorological column for 4.1.1 contain white circles, then that subsection is not applicable; however, for an aircraft with an ATC of

[1] This specification is under the jurisdiction of ASTM Committee F44 on General Aviation Aircraft and is the direct responsibility of Subcommittee F44.50 on Systems and Equipment.

Current edition approved Feb. 15, 2017. Published March 2017. DOI: 10.1520/F3231_F3231M-17.

[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.

[3] Available from Federal Aviation Administration (FAA), 800 Independence Ave., SW, Washington, DC 20591, http://www.faa.gov.

TABLE 1 ATC Compliance Matrix, Section 4

Section	Airworthiness Level				Number of Engines		Type of Engine(s)		Stall Speed			Cruise Speed		Meteorological Conditions			Altitude		Maneuvers	
	1	2	3	4	S	M	R	T	L	M	H	L	H	D	N	I	L	H	N	A
4																				
4.1																				
4.1.1									○					○						
4.1.1.1									○					○						
4.1.1.2									○					○						
4.1.1.3									○					○						
4.1.1.4									○					○						
4.1.1.5									○					○						
4.1.1.6									○					○						
4.2																				
4.2.1																				
4.2.1.1				×																
4.2.1.2	×	×	×																	
4.2.2																				
4.2.3																				
4.2.4																				
4.2.5																				
4.2.6																				
4.2.7	×	×	×																	
4.2.8	×	×	×																	
4.2.9	×	×	×																	
4.2.10	×	×	×																	
4.2.11	×	×	×																	
4.2.12																				
4.2.12.1																				
4.2.12.2																				
4.2.12.3																				
4.2.12.4																				
4.2.12.5																				
4.2.12.6																				
4.2.12.7																				
4.2.13																				
4.2.13.1																				
4.2.13.2	×	×	×																	
4.2.14																				
4.2.15																				
4.2.16																				
4.2.17									○					○						
4.2.17.1									○					○						
4.2.17.2									○					○						
4.3																				
4.3.1																				
4.3.1.1																				
4.3.1.2																				
4.3.1.3																				
4.3.2																				
4.3.3																				
4.3.4																				
4.3.5																				
4.3.6									○					○				×		
4.3.7									○					○			×			
4.4																				
4.4.1																				
4.4.1.1																				
4.4.1.2																				
4.4.2																				
4.4.3																				
4.4.4																				
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4.5.2																				
4.5.3																				
4.5.4																				
4.5.4.1																				
4.5.4.2																				
4.6																				
4.6.1																				
4.6.2																				
4.7																				
4.7.1																				

TABLE 1 *Continued*

Section	Airworthiness Level				Number of Engines		Type of Engine(s)		Stall Speed			Cruise Speed		Meteorological Conditions			Altitude		Maneuvers	
	1	2	3	4	S	M	R	T	L	M	H	L	H	D	N	I	L	H	N	A
4.7.2																				
4.7.3																				
4.7.4																				
4.7.5	×																			
4.7.6																				
4.7.7	×																			
4.7.8	×																			
4.8																				
4.8.1	×																			
4.8.2	×																			
4.8.3	×																			
4.9																				
4.9.1																				
4.9.2																				

1SRMLDLN, 4.1.1 would be applicable since the "M" stall speed column does not contain a white circle. 4.2.1.2 would not be applicable to either aircraft, since it contains an × in the "1" airworthiness level column.

NOTE 2—This section provides specifications for the electrical generation and distribution systems used to power various aircraft systems and equipment. It intentionally does not address any electrical power systems that may be employed in electrically-powered aircraft propulsion systems; such power systems are outside the scope of this section.

4.1 *Power Source Capacity and Distribution:*

4.1.1 Each installation whose functioning is required for type certification or under operating rules and that requires a power supply is an "essential load" on the power supply. The power sources and the system must be able to supply the power loads specified in 4.1.1.1 – 4.1.1.6 in probable operating combinations and for probable durations. The power loads may be assumed to be reduced under a monitoring procedure consistent with safety in the kinds of operation authorized. Loads not required in controlled flight need not be considered for the two-engine-inoperative condition on aircraft with three or more engines.

4.1.1.1 When required by 4.1.1, the power sources and the electrical distribution system, when functioning normally must be able to support all connected loads.

4.1.1.2 When required by 4.1.1, the power sources and the electrical distribution system must be able to support all essential loads after the failure of any one engine.

4.1.1.3 When required by 4.1.1, the power sources and the electrical distribution system must be able to support all essential loads after the failure of any one power converter.

4.1.1.4 When required by 4.1.1, the power sources and the electrical distribution system must be able to support all essential loads after the failure of any one energy storage device.

4.1.1.5 When required by 4.1.1, the power sources and the electrical distribution system must be able to support all essential loads after the failure of any two engines on aircraft with three or more engines.

4.1.1.6 When required by 4.1.1, the power sources and the electrical distribution system must be able to support all essential loads for which an alternate source of power is required, after any failure or malfunction in any one power supply system, any one distribution system, or any other utilization system.

4.2 *Electrical Systems and Equipment:*

4.2.1 Electric power sources, their transmission cables, and their associated control and protective devices must be able to furnish the required power at the proper voltage to each load circuit essential for safe operation.

4.2.1.1 Compliance with 4.2.1 must be shown by an electrical load analysis or by electrical measurements that account for the electrical loads applied to the electrical system in probable combinations and for probable durations.

4.2.1.2 Compliance with 4.2.1 must be shown by an electrical load analysis that accounts for the electrical loads applied to the electrical system in probable combinations and for probable durations.

4.2.2 Each electrical system, when installed, must be free from hazards in itself, in its method of operation, and in its effects on other parts of the aircraft.

4.2.3 Each electrical system, when installed, must be protected from fuel, oil, water, other detrimental substances, and mechanical damage.

4.2.4 Each electrical system, when installed, must be designed so that the risk of electrical shock to crew, passengers, and ground personnel is reduced to a minimum.

4.2.5 Electric power sources must function properly when connected in combination or independently.

4.2.6 No failure or malfunction of any electric power source may impair the ability of any remaining source to supply load circuits essential for safe operation.

4.2.7 Each system must be designed so that essential load circuits can be supplied in the event of reasonably probable faults or open circuits including faults in heavy current carrying cables.

4.2.8 A means must be accessible in flight to the flight crewmembers for the individual and collective disconnection of the electrical power sources from the system.

4.2.9 The system must be designed so that voltage and frequency, if applicable, at the terminals of all essential load equipment can be maintained within the limits for which the equipment is designed during any probable operating conditions.

4.2.10 If any particular system or item of equipment requires two independent sources of electrical power, their

electrical energy supply must be ensured by means such as duplicate electrical equipment, throwover switching, or by the use of multichannel or loop circuits separately routed.

4.2.11 For the purpose of complying with 4.2.6 – 4.2.10, the distribution system includes the distribution busses, their associated feeders, and each control and protective device.

4.2.12 There must be at least one generator/alternator if the electrical system supplies power to load circuits essential for safe operation. In addition, the requirements of 4.2.12.1 – 4.2.12.7 must be met.

4.2.12.1 Each generator/alternator must be able to deliver its continuous rated power, or such power as is limited by its regulation system.

4.2.12.2 Generator/alternator voltage control equipment must be able to dependably regulate the generator/alternator output within rated limits.

4.2.12.3 Automatic means must be provided to prevent damage to any generator/alternator due to reverse current into the generator/alternator.

4.2.12.4 Automatic means must be provided to prevent adverse effects on the aircraft electrical system due to reverse current into the generator/alternator.

4.2.12.5 A means must be provided to disconnect each generator/alternator from the battery and other generators/alternators.

4.2.12.6 There must be a means to give immediate warning to the flight crew of a failure of any generator/alternator.

4.2.12.7 Each generator/alternator must have an overvoltage control designed and installed to prevent damage to the electrical system, or to equipment supplied by the electrical system that could result if that generator/alternator were to develop and overvoltage condition.

4.2.13 A means must exist to indicate to appropriate flight crewmembers the electric power system quantities essential for safe operation.

4.2.13.1 For aircraft with direct current systems, an ammeter that can be switched into each generator/alternator feeder may be used and, if only one generator/alternator exists, the ammeter may be in the battery feeder.

4.2.13.2 The essential electric power system quantities include the voltage and current supplied by each generator/alternator.

4.2.14 Electrical equipment must be so designed and installed that in the event of a fire in the engine compartment, during which the surface of the firewall adjacent to the fire is heated to 1095°C [2000°F] for 5 min or to a lesser temperature substantiated by the applicant, the equipment essential to continued safe operation and located behind the firewall will function satisfactorily and will not create an additional fire hazard.

4.2.15 If provisions are made for connecting external power to the aircraft, and that external power can be electrically connected to equipment other than that used for engine starting, means must be provided to ensure that no external power supply having a reverse polarity, or a reverse phase sequence, can supply power to the aircraft electrical system.

4.2.16 If provisions are made for connecting external power to the aircraft, and that external power can be electrically connected to equipment other than that used for engine starting, the external power connection must be located so that its use will not result in a hazard to the aircraft or ground personnel.

4.2.17 It must be shown by analysis, tests, or both, that the aircraft can be operated safely in VFR conditions, for a period of not less than 5 min, with the normal electrical power (electrical power sources excluding the battery and any other standby electrical sources) inoperative, with critical type fuel (from the standpoint of flameout and restart capability), and with the aircraft initially at the maximum certificated altitude.

4.2.17.1 In showing compliance with 4.2.17, parts of the electrical system may remain on if a single malfunction, including a wire bundle or junction box fire, cannot result in loss of the part turned off and the part turned on.

4.2.17.2 In showing compliance with 4.2.17, parts of the electrical system may remain on if the parts turned on are electrically and mechanically isolated from the parts turned off.

4.3 *Storage Battery Design and Installation:*

4.3.1 Each storage battery design and installation must maintain safe cell temperatures and pressures during any probable charging and discharging condition.

4.3.1.1 No uncontrolled increase in cell temperature may result when the battery is recharged (after previous complete or most critical discharge) at maximum regulated voltage or power.

4.3.1.2 No uncontrolled increase in cell temperature may result when the battery is recharged (after previous complete or most critical discharge) during a flight of maximum duration.

4.3.1.3 No uncontrolled increase in cell temperature may result when the battery is recharged (after previous complete or most critical discharge) under the most adverse cooling condition likely to occur in service.

4.3.2 Compliance with 4.3.1 must be shown by tests unless experience with similar batteries and battery management systems or installations has shown that maintaining safe cell temperatures and pressures presents no problem.

4.3.3 Each storage battery must be designed and installed such that no explosive or toxic gases emitted by any battery in normal operation, or as the result of any probable malfunction in the charging system or battery installation, may accumulate in hazardous quantities within the aircraft.

4.3.4 Each storage battery design and installation must prevent damage to surrounding structures or adjacent essential equipment from corrosion fluids or gases that may escape from the battery.

4.3.5 In addition to the applicable requirements of this specification, electrical storage battery installations shall comply with the technology-specific provisions of Specification F3235.

4.3.6 In the event of a complete loss of the primary electrical power generating system, the battery must be capable of providing electrical power to those loads that are essential to continued safe flight and landing for at least 30 min (which includes the time to recognize the loss of generated power and to take appropriate load shedding action).

4.3.7 In the event of a complete loss of the primary electrical power generating system, the battery must be capable

of providing electrical power to those loads that are essential to continued safe flight and landing for at least 60 min (which includes the time to recognize the loss of generated power and to take appropriate load shedding action).

4.4 *Circuit Protective Devices:*

4.4.1 Protective devices, such as fuses or circuit breakers, must be installed in all electrical circuits.

4.4.1.1 The provisions of 4.4.1 do not apply to main circuits of starter motors used during starting only.

4.4.1.2 The provisions of 4.4.1 do not apply to circuits in which no hazard is presented by their omission.

4.4.2 A protective device for a circuit essential to flight safety may not be used to protect any other circuit.

4.4.3 Each resettable circuit protective device ("trip free" device in which the tripping mechanism cannot be overridden by the operating control) must be designed so that a manual operation is required to restore service after tripping.

4.4.4 Each resettable circuit protective device ("trip free" device in which the tripping mechanism cannot be overridden by the operating control) must be designed so that if an overload or circuit fault exists, the device will open the circuit regardless of the position of the operating control.

4.4.5 If the ability to reset a circuit protective device or replace a fuse is essential to safety in flight, a means must be provided so that it can be readily reset or replaced in flight; refer to Specification F3117/F3117M.

4.4.5.1 For fuses identified as replaceable in flight, there must be onboard one spare of each rating or 50 % spare fuses of each rating, whichever is greater.

4.5 *Master Switch Arrangement:*

4.5.1 There must be a master switch arrangement to allow ready disconnection of each electric power source from power distribution systems, except as provided in 4.5.4.

4.5.2 The point of disconnection required by 4.5.1 must be adjacent to the sources controlled by the master switch arrangement.

4.5.3 If separate switches are incorporated into the master switch arrangement required by 4.5.1, a means must be provided for the switch arrangement to be operated by a single action; refer to Specification F3117/F3117M.

4.5.4 Load circuits may be connected so that they remain energized when the master switch is open if the circuits are isolated, or physically shielded, to prevent their igniting flammable fluids or vapors that might be liberated by the leakage or rupture of any flammable fluid system, and the requirements of either 4.5.4.1 or 4.5.4.2 are met.

4.5.4.1 The circuits are required for continued operation of the engine.

4.5.4.2 The circuits are protected by circuit protective devices with a rating of five amperes or less adjacent to the electric power source. Two or more circuits must not be used to supply a load of more than five amperes.

4.6 *Switches:*

4.6.1 Each switch must be able to carry its rated current.

4.6.2 Each switch must be constructed with enough distance or insulating material between current carrying parts and the housing so that vibration in flight will not cause shorting.

4.7 *Electrical Cables and Equipment:*

4.7.1 Each electric connecting cable must be of adequate capacity.

4.7.2 Any equipment that is associated with any electrical cable installation and that would overheat in the event of circuit overload or fault must be flame resistant.

4.7.3 Any electrical cables or equipment that would overheat in the event of circuit overload or fault must not emit dangerous concentrations of toxic fumes.

4.7.4 Main power cables (including generator/alternator cables) in the fuselage must be designed to allow a reasonable degree of deformation and stretching without degradation or failure.

4.7.5 Main power cables (including generator/alternator cables) in the fuselage must be separated from flammable fluid lines, or be shrouded by means of electrically insulated flexible conduit (or equivalent) which is in addition to the normal cable insulation.

4.7.6 Means of identification must be provided for electrical cables, terminals, and connectors.

4.7.7 Electrical cables must be installed such that the risk of mechanical damage or damage cased by fluids, vapors, or sources of heat, or both, is minimized.

4.7.8 Where a cable cannot be protected by a circuit protection device or other overload protection, it must not cause a fire hazard under fault conditions.

4.8 *Electrical System Fire Protection:*

4.8.1 Each component of the electrical system must meet the applicable fire protection requirements of Specifications F3061/F3061M and F3066/F3066M.

4.8.2 Electrical cables, terminals, and equipment in designated fire zones that are used during emergency procedures must be fire-resistant.

4.8.3 Insulation on electrical wire and electrical cable must be self-extinguishing when tested at an angle of 60° in accordance with the applicable portions of DOT/FAA/AR-00/12, or other approved equivalent methods. The average burn length must not exceed 76 mm [3 in.] and the average flame time after removal of the flame source must not exceed 30 s. Drippings from the test specimen must not continue to flame for more than an average of 3 s after falling.

4.9 *Electronic Equipment:*

4.9.1 Radio and electronic equipment, controls, and wiring must be installed so that operation of any unit or system of units will not adversely affect the simultaneous operation of any other radio or electronic unit, or system of units, required by the rules of the governing civil aviation authority.

4.9.2 If installed communication equipment includes transmitted "off-on" switching, that switching means must be designed to return from the "transmit" to the "off" position when it is released and ensure that the transmitter will return to the off (non-transmitting) state.

5. Keywords

5.1 battery; electrical; power

APPENDIX

(Nonmandatory Information)

X1. SUPPORTING INFORMATION FOR REVISIONS

X1.1 Revisions to Section 4.2.17

X1.1.1 *Revision 16a to Previous Location (Speciifcation F3061/F3061M, Section 5.2.17):*

X1.1.1.1 *Discussion*—In the original Part 23 Amdt 62 material, the content of 5.2.17.1 and 5.2.17.2 were "AND" ed together; that is, both conditions must be met simultaneously. The current language in the standard could be interpreted to be "OR" conditions; that is, either condition being independently met would be acceptable. This is an unintentional change in application that needs to be corrected.

X1.1.1.2 *Proposal*—Correct the language to make it clear that both conditions must be simultaneously met.

X1.1.1.3 *Rationale for Change(s)*—The proposal is for modification of the language to clarify and recapture the original regulatory intent; no technical content within this standard is being changed; the ability to misinterpret the language is being mitigated.

X1.2 Revisions to Section 4.3.3

X1.2.1 *Revision 16a:*

X1.2.1.1 *Discussion*—The term "hazardous" is used in very specific ways within the context of classification of failure events. It would enhance the clarity of the standards if this term was not used colloquially in other locations, since this may be lead to confusion for the user of the standard. Further, the use of the term is often open to interpretation; utilizing more specific language would be preferable.

X1.2.1.2 *Proposal*—Replace the term "hazardous" with more descriptive language to better reflect the intent of the requirement.

X1.2.1.3 *Rationale for Change(s)*—The proposal is for clarity improvement of the current language; there is no desire to change the current intent, only to better describe the concerns to be addressed.