This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

Designation: F3231/F3231M – 24

Standard Specification for Electrical Systems for Aircraft with Combustion Engine Electrical Power Generation[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 electrical systems, electrical equipment, and electrical power distribution aspects of airworthiness and design for aeroplanes with combustion engine generation of electrical power. The material was developed through open consensus of international experts in general aviation. This information was created by focusing on Normal Category Aeroplanes. The content may be more broadly applicable; it is the responsibility of the applicant to substantiate broader applicability as a specific means of compliance.

1.2 An applicant intending to propose this information as Means of Compliance for a design approval shall seek guidance from their respective oversight authority (for example, published guidance from applicable civil aviation authorities (CAAs)) concerning the acceptable use and application thereof. For information on which oversight authorities have accepted this specification (in whole or in part) as an acceptable Means of Compliance to their regulatory requirements (hereinafter "the Rules"), refer to ASTM Committee F44 web page (www.astm.org/COMMITTEE/F44.htm). Annex A1 maps the Means of Compliance described in this specification to EASA CS-23, amendment 5, or later, and FAA 14 CFR Part 23, amendment 64, or later.

1.3 *Units*—This standard may present information in either SI units, English Engineering units, or both; the values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

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

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

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 CAA; earlier revisions are not acceptable.

2.2 *ASTM Standards:*[2]

F2490 Guide for Aircraft Electrical Load and Power Source Capacity Analysis

F2639 Practice for Design, Alteration, and Certification of Aircraft Electrical Wiring Systems

F3060 Terminology for Aircraft

F3061/F3061M Specification for Systems and Equipment in Aircraft

F3066/F3066M Specification for Aircraft Powerplant Installation Hazard Mitigation

F3117/F3117M Specification for Crew Interface in Aircraft

F3235 Specification for Aircraft Storage Batteries

F3316/F3316M Specification for Electrical Systems for Aircraft with Electric or Hybrid-Electric Propulsion

2.3 *FAA Standards:*[3]

14 CFR Part 23 Airworthiness Standards: Normal Category Airplanes

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

2.4 *EASA Standard:*[4]

CS-23 Normal, Utility, Aerobatic and Commuter Aeroplanes

[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.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at www.astm.org/contact. 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.

[4] Available from European Union Aviation Safety Agency (EASA), Konrad-Adenauer-Ufer 3, D-50668 Cologne, Germany, https://www.easa.europa.eu.

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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.

3.2.3 *distribution system, n*—as used in this specification, includes the distribution buses, their associated feeders, each control, and each protective device.

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 shall 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 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 standard 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 addressed in Specification F3316/F3316M.

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 shall be able to supply the power loads specified in 4.1.1.1 – 4.1.1.7 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 shall 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 shall be able to support all essential loads after the failure of any one generator/alternator.

4.1.1.3 When required by 4.1.1, the power sources and the electrical distribution system shall 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 shall 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 shall be able to support all essential loads after the failure of any one engine on an aeroplane with two engines.

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

4.1.1.7 When required by 4.1.1, the power sources and the electrical distribution system shall 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:*

NOTE 3—Guide F2490 provides information and methodology for an electrical load analysis.

4.2.1 Electric power sources, their transmission cables, and their associated control and protective devices shall 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 shall 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 shall 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, shall 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, shall be protected from fuel, oil, water, other detrimental substances, and mechanical damage.

4.2.4 Each electrical system, when installed, shall 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 shall function properly when connected in combination or independently.

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

4.2.7 Each distribution system shall 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.

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TABLE 1 ATC Compliance Matrix, Section 4

Section	Aeroplane Certification 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					×															
4.1.1.7	○								○					○						
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																				
4.2.11.1																				
4.2.11.2																				
4.2.11.3																				
4.2.11.4																				
4.2.11.5																				
4.2.11.6																				
4.2.11.7																				
4.2.12																				
4.2.12.1				×																
4.2.12.2	×	×	×																	
4.2.13																				
4.2.14																				
4.2.15																				
4.2.15.1																				
4.2.15.2																				
4.2.16	○								○					○						
4.2.16.1	○								○					○						
4.2.16.2	○								○					○						
4.3																				
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4.3.1.2																				
4.3.1.3																				
4.3.2																				
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4.3.4																				
4.3.5																				
4.3.6																				
4.3.6.1																				
4.3.6.2	○								○					○				×		
4.3.6.3	○								○					○			×			
4.3.7																				
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TABLE 1 *Continued*

Section	Aeroplane Certification 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
4.5.4.1																				
4.5.4.2																				
4.6																				
4.6.1																				
4.6.2																				
4.7																				
4.7.1																				
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																				

4.2.8 A means shall be accessible in flight to the appropriate flight crew members for the individual and collective disconnection of the electrical power sources from the distribution system.

4.2.9 The distribution system shall 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 distribution system, particular system, or item of equipment requires two independent sources of electrical power, their electrical energy supply shall 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 There shall be at least one generator/alternator if the electrical system supplies power to load circuits essential for safe operation. In addition, the requirements of 4.2.11.1 – 4.2.11.7 shall be met.

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

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

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

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

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

4.2.11.6 There shall be a means to give immediate warning to the appropriate flight crew members of a failure of any generator/alternator.

4.2.11.7 Each generator/alternator shall 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.

4.2.12 A means shall exist to indicate to appropriate flight crew members the electric power system quantities essential for safe operation.

4.2.12.1 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.

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

4.2.13 Electrical equipment shall be designed and installed so 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.

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

4.2.15 If provisions are made for connecting external power to the aeroplane, and that external power can be electrically connected to equipment other than that used for engine starting, the external power connection shall meet the requirements of 4.2.15.1 through 4.2.15.2.

4.2.15.1 The external power connection shall be located so that its use will not result in a hazard to the aeroplane.

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4.2.15.2 The external power connection shall be located so that its use will not result in a hazard to ground personnel.

4.2.16 It shall 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.

4.2.16.1 In showing compliance with 4.2.16, 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.

4.2.16.2 In showing compliance with 4.2.16, 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 shall maintain safe cell temperatures and pressures during any probable charging and discharging condition.

4.3.1.1 No uncontrolled increase in cell temperature shall 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 shall 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 shall 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 shall 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 shall 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 shall 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 reserve energy shall be capable of providing electrical power to those loads that are essential to continued safe flight and landing including noncontinuous essential loads with enough capacity to meet the requirements of either 4.3.6.1, 4.3.6.2, or 4.3.6.3 in accordance with Table 1.

4.3.6.1 The time needed to complete the function required for continued safe flight and landing.

4.3.6.2 A time period of at least 30 min which includes the time to recognize the loss of generated power and to take appropriate load-shedding action.

4.3.6.3 A time period of at least 60 min which includes the time to recognize the loss of generated power and to take appropriate load-shedding action.

4.3.7 The battery reserve energy requirement of 4.3.6 shall be demonstrated by test or analysis including all loads essential to continued safe flight and landing.

4.4 *Circuit Protective Devices:*

4.4.1 Protective devices, such as fuses or circuit breakers, shall 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.

NOTE 4—On new aircraft designs, thermal fuses are generally not accepted by the CAAs for circuit protection. For changes to existing aircraft systems and equipment installations, the use of circuit protection other than fuses should be considered but it is acknowledged that replacement of existing fuses may not be practicable.

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) shall 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) shall 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 shall 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 shall 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 shall 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 disconnection required by 4.5.1 shall meet the requirements of either 4.5.2.1 or 4.5.2.2.

4.5.2.1 The point of disconnection shall be adjacent to the electrical power sources controlled by the master switch arrangement.

4.5.2.2 Main power cable feeders (for example, generator/alternator cables) from the electrical power source to the point of disconnection shall have fault detection that will automatically de-energize the source when a power cable feeder fault is detected.

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

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