Designation: ~~F3316/F3316M – 18~~ F3316/F3316M – 19

Standard Specification for Electrical Systems for Aircraft with Electric or Hybrid-Electric Propulsion[1]

This standard is issued under the fixed designation F3316/F3316M; 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 the electrical systems, electrical equipment, and electrical power distribution aspects of airworthiness and design for aircraft with Electric or Hybrid-Electric Propulsion. This specification was written with the focus on electric propulsion systems with conventional system layout, characteristics, and operation. This specification does not address all of the requirements that may be necessary for possible hybrid-electric configurations where an EPU and a combustion engine are used in combination to provide propulsion. The use of this specification combined with the applicable portions of Specification F3231/F3231M may be necessary for hybrid-electric configurations. This material was developed through open consensus of international experts in general aviation. This material was created by focusing on Normal Category ~~Airplanes.~~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 a means of compliance for design approval ~~must~~shall seek guidance from their respective oversight authority (for example, published guidance from applicable CAAs) concerning the acceptable use and application thereof. For information on which oversight authorities have accepted this standard (in whole or in part) as a Means of Compliance to their regulatory requirements (Hereinafter referred to as "the Rules"), refer to ASTM F44 webpage (www.ASTM.org/COMMITTEE/F44.htm).

1.3 *Units*—This standard may present information in either SI units, English Engineering units, or ~~both; the~~both. The values stated in each system ~~may~~are not ~~be exact equivalents. Each~~ necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the ~~other; combining~~other, and values from the two systems ~~may result in nonconformance with the standard.~~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 *ASTM Standards:*[2]

F2490 – 05 Standard 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 Small Aircraft
F3066/F3066M Specification for Aircraft Powerplant Installation Hazard Mitigation
F3231/F3231M Specification for Electrical Systems for Aircraft with Combustion Engine Electrical Power Generation
F3235 Specification for Aircraft Storage Batteries
F3239 Specification for Aircraft Electric Propulsion Systems

[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 service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the ~~standard's~~standard's Document Summary page on the ASTM website.

F3338 Specification for Design of Electric Propulsion Units for General Aviation Aircraft

2.2 *FAA Standard:*[3]

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

3. Terminology

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

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

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 *Battery Management System (BMS)*—a battery management system is any electronic system that manages a rechargeable battery (cell or battery pack), such as by protecting the battery from operating outside its Safe Operating Area, monitoring its state, calculating secondary data, reporting that data, controlling its environment, authenticating it or balancing it, or both.

~~3.2.4 *Electric Propulsion System (EPS)*—installation that includes at least one EPU and hardware required to produce propulsive thrust. Multiple EPUs may be in different arrangements such as serial or parallel or a combination of the two.~~

3.2.4 *Electric Propulsion Unit (EPU)*—~~the EPU shall as~~ a minimum ~~consist~~ EPU is comprised of the electric motor, associated ~~controllers disconnects and wiring, motor generator, and monitoring gauges and meters.~~electronic controllers, disconnects, wiring, and sensors.

3.2.4.1 *Discussion*—

See Specification F3338 for additional information.

3.2.5 *Energy Storage System (ESS)*—~~any manner that stores some form of~~ a source (component or system) that stores and provides energy that can be drawn upon ~~at a later time to provide energy for propulsion. Typical energy storage devices include but are not limited to: batteries, fuel cells, or capacitors.~~for propulsion.

3.2.5.1 *Discussion*—

See Specification F3239 for additional information.

3.3 *Abbreviations:*

3.3.1 *BMS*—Battery Management System

3.3.2 *EPS*—Electric Propulsion System

3.3.3 *EPU*—Electric Propulsion Unit

3.3.4 *ESS*—Energy Storage System

4. Electrical Systems for Electric Propulsion

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~~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~~4.1.1.2 contain white circles, then that subsection is not applicable; however, for an aircraft with an ATC of 1SRMLDLN, ~~4.1.1~~4.1.1.2 would be applicable since the "M" stall speed column does not contain a white circle.

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~~shall be able to supply the power loads specified in 4.1.1.1 – 4.1.1.3 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.

4.1.1.1 The power sources and the electrical distribution system, when functioning normally, ~~must~~shall be able to support all connected loads.

4.1.1.2 The power sources and the electrical distribution system ~~must~~shall be able to support all essential loads after the failure of any one ESS or primary electrical power source. An EPU designed to be connected to only one ESS is excluded from this requirement.

4.1.1.3 The power sources and the electrical distribution system ~~must~~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 ESS, any one power supply system, any one distribution system, or any other utilization system. An EPU designed to be connected to only one ESS is excluded from this requirement.

TABLE 1 ATC Compliance Matrix, Section 4

Section	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
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4.1																				
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4.1.1.3	○								○					○						
~~4.1.2~~									⊖					⊖						
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4.1.2 The power source and the electrical distribution system used to satisfy the probable duration requirement of 4.1.1 is required to provide electrical power to those loads that are essential to continued safe flight and landing including non-continuous essential loads with enough capacity to meet the requirements of either 4.1.2.1, 4.1.2.2, or 4.1.2.3 as appropriate per Table 1.

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

4.1.2.2 A time period of at least 30 minutes which includes the time to recognize the loss of primary power and to take appropriate load shedding action.

4.1.2.3 A time period of at least 60 minutes which includes the time to recognize the loss of primary power and to take appropriate load shedding action.

4.1.3 The electrical capacity duration requirement of 4.1.2 shall be demonstrated by test or analysis including all loads essential ~~to~~for continued safe ~~flight.~~flight and landing.

4.2 *Electrical Systems and Equipment:*

4.2.1 Electric power sources, their transmission cables, and their associated control and protective devices, ~~must~~shall be able to furnish the required power at the proper voltage and frequency, if applicable to each load circuit essential for safe operation and maintained within the limits for which the equipment is designed during any probable operating conditions.

4.2.2 Compliance with 4.2.1 ~~must~~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.

NOTE 2—Guide F2490 provides information and methodology for an electrical load analysis.

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

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

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

4.2.6 Electric power sources ~~must~~shall function properly when connected in combination or independently.

4.2.7 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.

4.2.8 Each electrical system ~~must~~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.

4.2.9 A means ~~must~~shall be accessible in flight to the appropriate flight crewmembers for the individual and rapid disconnection of the electrical power sources from the distribution system which includes the distribution busses, their associated feeders, each control device, and each protective device.

4.2.10 If any particular system or item of equipment requires two independent sources of electrical power, their electrical energy supply ~~must~~shall be ensured by means such as duplicate electrical equipment, throw over switching, or by the use of multichannel or loop circuits separately routed.

4.2.11 There ~~must~~shall be a means to give immediate warning to the appropriate flight crew members of a failure of any primary electrical power source.

4.2.12 Each electrical power source ~~must~~shall have a means to prevent damage to the electrical system, or to equipment supplied by the electrical system that could result if the power source provided electrical power outside the qualified limits that would damage the electrical system or equipment.

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

4.2.14 If provisions are made for connecting external power to the aeroplane, a means ~~must~~shall be provided to ensure that no external power supply having an over voltage, an under voltage, 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, the external power connection must be located so that its use will minimize the hazard to the aeroplane and ground personnel.~~

4.2.15 If provisions are made for connecting external power to the ~~aeroplane to charge the aeroplane battery, a means must be provided to automatically disconnect the external power in the event of a~~aeroplane, the external power connection shall meet the requirements of 4.2.15.1 ~~malfunction~~through 4.2.15.3~~of the aeroplane battery or battery management system.~~.

4.2.15.1 The external power connection shall be located so that its use will minimize the hazard to the aeroplane.

4.2.15.2 The external power connection shall be located so that its use will minimize the hazard to ground personnel.

4.2.15.3 If the external power connection is utilized to charge the aeroplane battery, a means shall be provided to automatically disconnect the external power in the event of a malfunction of the aeroplane battery or battery management system.

4.2.16 If equipped with a combustion engine that is part of the Hybrid-Electric Propulsion System, electrical equipment ~~must~~shall be ~~so~~ designed and installed such that in the event of a fire in the combustion engine compartment, during which the surface of the firewall adjacent to the fire is heated to ~~1095°C [2000°F]~~1095 °C [2000 °F] for five minutes or to a lesser temperature substantiated by the applicant, the equipment essential to continued safe operation and located ~~behind the firewall~~ on the opposite side of the firewall from the combustion engine compartment will function satisfactorily and will not create an additional fire hazard.

4.3 *Circuit Protective Devices:*

4.3.1 Circuit protective devices ~~must~~shall be installed in all electrical circuits other than circuits in which no hazard is presented by their omission.

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

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

4.3.4 Each resettable circuit protective device (“trip free” device in which the tripping mechanism cannot be overridden by the operating control) ~~must~~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.

4.3.5 If the ability to reset a circuit protective device is required for continued safe flight and landing, a means ~~must~~shall be provided so that it can be readily reset in flight.

4.4 *Master Switch Arrangement:*

4.4.1 There ~~must~~shall be a master switch or equivalent functional arrangement to allow ready disconnection of each electric power source from power distribution systems, except as provided in ~~4.4.3~~4.4.2.

4.4.1.1 If separate switches are incorporated into the master switch arrangement required by 4.4.1, a means shall be provided for the switch arrangement to be rapidly operated by the appropriate flight crew member.

4.4.1.2 The master switch or equivalent functional arrangement shall be protected against inadvertent operation.

~~4.4.2 If separate switches are incorporated into the master switch arrangement required by 4.4.1, a means must be provided for the switch arrangement to be operated by a single action.~~

4.4.2 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 circuits are required for continued operation of a combustion engine that is part of the Hybrid-Electrical Propulsion System.

4.5 *Switches:*

4.5.1 Each switch ~~must~~shall be able to carry its rated current.

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

4.6 *Electrical Cables and Equipment:*

4.6.1 Each electric connecting cable ~~must~~shall be of adequate capacity.

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

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

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

4.6.5 Electrical Power cables in the fuselage ~~must~~shall 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.

4.6.6 Means of identification ~~must~~shall be provided for electrical cables, terminals, and connectors.

4.6.7 Electrical cables ~~must~~shall be installed such that the risk of mechanical damage or damage caused by fluids, vapors, or sources of heat, or a combination thereof, is minimized.

4.6.8 Where an electrical power cable cannot be protected by a circuit protection device or other overload protection, it ~~must~~shall not cause a fire hazard under fault conditions.