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Standard Specification for Aircraft Electric Propulsion Systems[1]

This standard is issued under the fixed designation F3239; 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 addresses airworthiness requirements for the design and installation of electric propulsion systems for aeroplanes. Hybrid-electric propulsion systems are addressed implicitly unless explicitly stated otherwise. This specification was written with the focus on electric propulsion systems with conventional system layout, propulsion characteristics, and operation. 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 must 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 an acceptable Means of Compliance to their regulatory requirements (hereinafter "the Rules"), refer to the 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 *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.*

1.4 *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]

F3060 Terminology for Aircraft
F3061/F3061M Specification for Systems and Equipment in Aircraft
F3062/F3062M Specification for Aircraft Powerplant Installation
F3063/F3063M Specification for Aircraft Fuel Storage and Delivery
F3064/F3064M Specification for Aircraft Powerplant Control, Operation, and Indication
F3065/F3065M Specification for Aircraft Propeller System Installation
F3066/F3066M Specification for Aircraft Powerplant Installation Hazard Mitigation
F3114/F3114M Specification for Structures
F3116/F3116M Specification for Design Loads and Conditions
F3120/F3120M Specification for Ice Protection for General Aviation Aircraft

[1] This specification is under the jurisdiction of ASTM Committee F44 on General Aviation Aircraft and is the direct responsibility of Subcommittee F44.40 on Powerplant.
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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.

F3316/F3316M Specification for Electrical Systems for Aircraft with Electric or Hybrid-Electric Propulsion
F3338 Specification for Design of Electric Engines for General Aviation Aircraft

2.2 *EASA Standard:*[3]
CS-23 Normal, Utility, Aerobatic and Commuter Aeroplanes

2.3 *FAA Standard and Advisory Circular:*[4]
14 CFR Part 23 Airworthiness Standards: Normal Category Airplanes
AC 23-16 Powerplant Guide for Certification of Part 23 Airplanes

3. Terminology

3.1 The following is a selection of relevant terms. See Terminology F3060 for more definitions and abbreviations.

3.2 *Definitions:*

3.2.1 *capacity, n*—total amount between minimum and maximum condition (for example, empty and full).

3.2.2 *electric engine, n*—a type of aircraft engine that converts electric power into mechanical power or thrust used for propulsion, including those components necessary for proper control and functioning.

3.2.2.1 *Discussion*—
In the context of this specification, the minimum essential components of an electric engine are an electric motor and its associated motor controller(s), disconnect(s), wiring, and sensor(s). Other components and accessories necessary for proper control and function are typically considered part of the engine; for example: inverters, liquid cooling components, liquid lubrication components, thrusters, etc.

3.2.3 *electric propulsion system (EPS), n*—the installation of one or more electric engines including each component that is necessary for propulsion or affects the propulsive safety.

3.2.4 *energy distribution system, n*—a system that provides energy for propulsion from the energy storage systems to the engines.

3.2.4.1 *Discussion*—
The energy distribution system is considered equivalent to the fuel system on liquid hydrocarbon based powerplants.

3.2.5 *energy storage system (ESS), n*—a source (component or system) that stores and provides energy that can be drawn upon for propulsion.

3.2.5.1 *Discussion*—
Typical energy storage systems include but are not limited to batteries, fuel cell systems or capacitors and their integrated management systems, if installed. The energy storage system is considered equivalent to a fuel tank on liquid hydrocarbon based powerplants.

3.2.6 *quantity, n*—amount available at the time of measurement.

3.2.7 *usable energy capacity, n*—minimum capacity of an energy storage system between the defined fully charged and the minimum charge state which can be drawn upon at any rate up to maximum rated power of this energy storage system under any likely operating condition.

4. Powerplant Installation

4.1 *General:*

4.1.1 Each powerplant installation shall meet the applicable requirements of Specification F3062/F3062M.

4.1.2 Each propeller system shall meet the applicable requirements of Specification F3065/F3065M.

4.1.3 Each electric engine shall meet the technical requirements of Specification F3338.

[3] Available from European Union Aviation Safety Agency (EASA), Konrad-Adenauer-Ufer 3, D-50668 Cologne, Germany, https://www.easa.europa.eu.
[4] Available from Federal Aviation Administration (FAA), 800 Independence Ave., SW, Washington, DC 20591, http://www.faa.gov.

5. Energy Distribution Systems

5.1 *General:*

5.1.1 Each energy distribution system shall meet the applicable requirements of Specification F3063/F3063M and F3316/F3316M.

5.1.2 Each energy distribution system shall safely provide sufficient power to each electric engine under the most critical operating conditions.

5.1.3 The combined usable energy capacity of all energy storage systems shall be enough to maintain maximum continuous power of the electric engine for a minimum of 30 minutes. For hybrid systems this may be accomplished with any combination of generation and energy storage.

NOTE 1—Operational rules for which the aeroplane is intended to be used may require greater endurance.

5.2 *Independence:*

5.2.1 For aeroplanes with multiple electric engines, the energy distribution system shall be designed so that, in at least one system configuration, the failure of any one component will not result in the loss of power of more than one electric engine or require immediate action by the pilot to prevent the loss of power of more than one electric engine.

NOTE 2—Refer to AC23-16 for guidance on the independence of energy distribution systems.

5.3 *Energy Storage System:*

5.3.1 *General:*

5.3.1.1 Each energy storage system shall meet the requirements of an accepted specification appropriate to the application.

5.3.1.2 Each energy storage system shall be installed in accordance with the applicable installation instructions.

5.3.1.3 Each energy storage system shall be designed to safely deliver the required power under the conditions specified in 5.1.2 when drawn upon.

5.3.2 *Installation:*

5.3.2.1 Each energy storage system shall be supported to withstand the vibration and inertia loads to which it may be subjected in operation.

5.3.2.2 Each energy storage system shall have access provisions for maintenance.

5.3.2.3 Design precautions shall be taken to minimize the hazards to the aircraft in the event of a fire or sudden discharge which could result in damage to components, structure, or flight controls near the storage area.

5.3.2.4 The energy storage system installation shall protect the occupants and the critical airframe and systems from a single cell thermal runaway.

5.3.3 *Compartments:*

5.3.3.1 Each energy storage system shall be ventilated and drained as necessary to prevent accumulation of hazardous, flammable, or corrosive fluids or vapors.

5.3.3.2 Each energy storage system shall be isolated from personnel compartments by an enclosure that is vented and drained to the exterior of the aeroplane.

5.3.3.3 Any enclosure required by 5.3.3.2 shall sustain any personnel compartment pressurization loads without permanent deformation or failure under the conditions defined in Specifications F3116/F3116M and F3114/F3114M.

5.3.3.4 For energy storage systems in compartments adjacent to fire zones there shall be sufficient clearance or insulation between the compartment and the firewall to prevent ignition or malfunction of the energy storage system as a result of fire in the fire zone.

5.3.4 *Energy Capacity:*

5.3.4.1 The usable energy capacity for each energy storage system shall be established.

5.3.4.2 The available remaining energy quantity information shall be provided.

5.3.5 *Charging System:*

5.3.5.1 The charging connection and system shall be designed to minimize hazards to personnel.

5.3.5.2 The charging connection shall be designed to ensure correct connection of the charging connector.

5.3.5.3 The charging system shall be designed to protect the aeroplane from a charging source with incorrect voltage including high voltage, low voltage, incorrect polarity, effects of shorting, and type of current (AC/DC).

5.3.6 *Pilot-replaceable Energy Storage Systems:*

5.3.6.1 Each energy storage system location where electrical components can be replaced shall be marked.

5.3.6.2 Design precautions shall be taken to prevent incorrect installation of components when replaced in operation.

6. Control and Indication

6.1 *General:*

6.1.1 Each powerplant installation shall meet the applicable requirements of Specification F3064/F3064M.

6.1.2 For any energy storage system that should not be depleted in normal operation, there shall be a separate indication to the flight crew when less than approximately 30 minutes of usable energy quantity or 50 % of the usable energy capacity remains in the energy storage system, whichever is less.

6.2 *Controls:*

6.2.1 There shall be a means to provide separate power control for each electric engine, unless it can be shown that multiple electric engines operated by a single control will not prevent the isolation of a failed engine, and the control of the remaining engines to ensure continued, safe flight and landing.

6.2.2 *Shutoff Controls:*

6.2.2.1 There shall be an independent, simple, and reliable means to disconnect each energy storage system.

6.2.2.2 If the electric engine or energy storage system is installed in a fire zone, there shall be a means to allow appropriate flight crew members to rapidly shut off, in flight, the energy supply to the electric engines and energy storage system individually.

6.2.2.3 No shutoff means may be on the fire zone side of any firewall.

6.2.2.4 There shall be a means to guard against inadvertent operation of each shutoff means.

6.2.2.5 There shall be a means to allow appropriate flight crew members to reopen the shutoff means rapidly after it has been closed.

6.3 *Powerplant Operational Characteristics and Installation:*

6.3.1 *General:*

6.3.1.1 Electric propulsion systems shall have no adverse characteristics during normal or emergency operation within the

operating limitations. This investigation shall consider the results of inadvertent energy storage system overcharging or limited energy dumping capability, or both, during propeller windmilling and reversing operation.

6.3.2 *Cooling Test Requirements:*

6.3.2.1 For showing compliance with the general cooling requirements of Specification F3064/F3064M the aeroplane shall be flown in the configurations, at the speeds, and following the procedures recommended in the Aeroplane Flight Manual that correspond to the applicable performance requirements that are critical to cooling.

6.3.3 *Starting and Stopping:*

6.3.3.1 The design of the installation shall be such that risk of fire or mechanical damage to the electric engine or the aeroplane, because of starting the electric engine in any conditions in which starting is to be permitted, is reduced to a minimum. Any techniques and associated limitations shall be established and included in the Aeroplane Flight Manual, approved manual material, or applicable operating placards.

6.3.3.2 There shall be a means for stopping the rotation of any electric engine or component, if continued rotation would cause a hazard to the aeroplane.

6.3.3.3 If hydraulic propeller feathering systems are used for stopping the electric engine, the hydraulic feathering lines or hoses shall be fire resistant under the operating conditions expected during feathering.

6.3.3.4 *Restart Envelope*—An altitude and airspeed envelope shall be established for the aeroplane for inflight engine restarting, and each installed electric engine shall have a restart capability within that envelope.

6.3.3.5 *Restart Capability*—No unsafe condition may arise from re-engaging any electric engine after a shutdown either on ground or in flight.

6.3.4 *Powerplant Limitations:*

6.3.4.1 The powerplant limitations shall be established so that they do not exceed the corresponding limits of the electric engines, the energy storage systems, and associated equipment.

7. Hazard Mitigation

7.1 *General:*

7.1.1 Each powerplant installation shall meet the applicable requirements of Specification F3066/F3066M.

7.1.1.1 For compliance with the engine isolation requirements of Specification F3066/F3066M “an energy storage system, if only one energy storage system is installed” is considered “a fuel tank, if only one fuel tank is installed.”

7.2 *High Energy Rotors:*

7.2.1 Each high energy rotor shall meet the applicable requirements for high energy rotors of Specification F3061/F3061M.

NOTE 3—Depending on the specific design, electric motors may qualify as high energy rotors.

7.3 *Fire Protection:*

7.3.1 *Designated Fire Zones:*

7.3.1.1 The electric engine or ESS section is a designated fire zone, if a fire hazard exists.

7.3.2 *Fire Detection:*

7.3.2.1 There shall be means that ensure the prompt detection of a fire in each fire zone that is not visible to the crew.

7.3.3 *Lightning Protection:*

7.3.3.1 For level 1 aircraft intended for night VFR and IFR operation and for level 2 or higher aircraft, each energy storage system shall be designed and arranged to prevent the ignition of flammable vapor or contents within the system by corona or streamering at vent outlets and ESS areas.

7.4 *Ice Protection:*

7.4.1 Each air inlet of the powerplant installation shall be protected from ice accumulation, when operated in the conditions for which it is to be certified as defined in Specification F3120/F3120M.

8. Keywords

8.1 electric aircraft; electric engine; electric propulsion; ESS; powerplant

ANNEX

(Mandatory Information)

A1. CORRELATION OF STANDARD – CONTENT AND THE RULES

A1.1 Means of Compliance Correlation Sorted by Standard Section

NOTE A1.1—The Specification sections shown in the Specification column will be at the highest level at which everything below that level is applicable to that rule paragraph.