



Designation: F3547 – 24

Standard Specification for Fuel Cell Power Systems for Use in Small Unmanned Aircraft Systems (sUAS)¹

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1. Scope

1.1 This specification defines the requirements for fuel cells and fuel cell based power systems, including hydrogen-based fuel storage and refueling systems used in electric small Unmanned Aircraft Systems (sUAS). While many requirements specified by this document may apply to larger Unmanned Aircraft Systems (UAS) and manned aircraft, safe operation of these aircraft require additional requirements outside the scope of this document. Fuel cell systems for use in sUAS may be used in both ground operations and in aircraft. Fuel cells used in ground operations are outside the scope of this specification.

1.2 This specification does not define requirements for the systems in which aircraft fuel cells may be utilized, but may require additional functionality in those systems to support fuel cell operations.

1.3 The entity declaring conformance to this specification will typically be the integrator of the fuel cell into the UAS, as many requirements apply to not only the fuel cell itself, but how it interacts with the UAS and with the operator.

1.4 The values stated in SI units are to be regarded as standard. In some cases, non-SI units are used for clarity.

1.5 The regulations of the Civil Aviation Authorities (CAA) remain applicable.

1.6 *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.*

1.7 *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.*

¹ This specification is under the jurisdiction of ASTM Committee F38 on Unmanned Aircraft Systems and is the direct responsibility of Subcommittee F38.01 on Airworthiness.

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2. Referenced Documents

2.1 ASTM Standards:²

C1055 Guide for Heated System Surface Conditions that Produce Contact Burn Injuries

F3060 Terminology for Aircraft

F3341/F3341M Terminology for Unmanned Aircraft Systems

2.2 Other Standards:

DOT-CFFC Basic Requirements for Fully Wrapped Carbon-Fiber Reinforced Aluminum Lined Cylinders³

DOT 49 CFR Part 172 Hazardous Materials Table, Special Provisions, Hazardous Materials Communications, Emergency Response Information, Training Requirements, and Security Plans⁴

EN 12245 Transportable Gas Cylinders - Fully Wrapped Composite Cylinders⁵

EUROCAE ED-14/RTCA DO-160 Environmental Conditions and Test Procedures for Airborne Equipment⁶

EUROCAE/SAE WG80/AE-7AFC (AIR6464) Hydrogen Fuel Cells Aircraft Fuel Cell Safety Guidelines⁷

IEC 60050-485:2020 International Electrotechnical Vocabulary (IEV) - Part 485: Fuel Cell Technologies⁸

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 the Pipeline and Hazardous Materials Safety Administration (PHMSA), U.S. Department of Transportation, 1200 New Jersey Ave, SE, Washington, DC 20590, <https://transportation.gov>.

⁴ Available from the Office of the Federal Register (OFR), the National Archives and Records Administration, 8601 Adelphi Road, College Park, MD 20740, <https://www.ecfr.gov>.

⁵ Available from European Committee for Standardization (CEN), Rue de la Science 23, B-1000, Brussels, Belgium, www.en-standard.eu.

⁶ Available from EUROCAE, 9-23 rue Paul Lafargue, "Le Triangle" building, 93200 Saint-Denis, France, <https://www.eurocae.net/>. Also available from Radio Technical Committee for Aeronautics (RTCA), 1150 18th NW, Suite 910, Washington, D.C., 20036, <https://www.rtca.org/>.

⁷ Available from EUROCAE, 9-23 rue Paul Lafargue, "Le Triangle" building, 93200 Saint-Denis, France, <https://www.eurocae.net/>. Also available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096, <http://www.sae.org>.

⁸ Available from International Electrotechnical Commission (IEC), 3, rue de Varembe, 1st floor, P.O. Box 131, CH-1211, Geneva 20, Switzerland, <https://www.iec.ch>.

- IEC 62282-5-100:2018 Fuel cell technologies - Part 5-1: Portable fuel cell power systems - Safety⁸
- ISO 14687:2019 Hydrogen Fuel Quality—Product Specification⁹
- ISO 11119-1 Gas Cylinders—Design, Construction and Testing of Refillable Composite Gas Cylinders and Tubes—Part 1: Hoop Wrapped Fibre Reinforced Composite Gas Cylinders and Tubes up to 450 L⁹
- ISO 11119-2 Gas Cylinders—Design, Construction and Testing of Refillable Composite Gas Cylinders and Tubes—Part 2: Fully Wrapped Fibre Reinforced Composite Gas Cylinders and Tubes up to 450 L with Load-Sharing Metal Liners⁹
- ISO 11119-3 Gas Cylinders—Design, Construction and Testing of Refillable Composite Gas Cylinders and Tubes—Part 3: Fully Wrapped Fibre Reinforced Composite Gas Cylinders and Tubes up to 450 L with Non-Load-Sharing Metallic or Non-Metallic Liners or Without Liners⁹
- NFPA 2 Hydrogen Technologies Code¹⁰
- NSS 1740.16 NASA Safety Standard for Hydrogen and Hydrogen Systems: Guidelines for Hydrogen System Design, Materials Selection, Operations, Storage, and Transportation¹¹
- UN 38.3 T1-T8 Recommendations on the Transport of Dangerous Goods¹²

3. Terminology

3.1 *Unique and Common Terminology*—Terminology used in multiple standards is defined in Terminology F3341/F3341M, UAS Terminology Standard, and Terminology F3060, Aircraft Terminology Standard. Terminology that is unique to this specification is defined in this section.

3.1.1 Common terminology can be found at <https://member.astm.org/standard/terminology>.

3.2 “*Shall*” Versus “*Should*” Versus “*May*”—Use of the word “shall” implies that a procedure or statement is mandatory and must be followed to comply with this specification, “should” implies recommended, and “may” implies optional at the discretion of the supplier, manufacturer, integrator, or operator. Since “shall” statements are requirements, they include sufficient detail needed to define compliance (for example, threshold values, test methods, oversight, reference to other standards). “Should” statements are provided as guidance toward the overall goal of improving safety and could include only subjective statements. “Should” statements also represent parameters that could be used in safety evaluations and could lead to development of future requirements. “May” statements are provided to clarify acceptability of a specific item or practice and offer options for satisfying requirements.

⁸ Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandinnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, <https://www.iso.org>.

¹⁰ Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471, <http://www.nfpa.org>.

¹¹ Available from the National Aeronautics and Space Administration (NASA), 300 E. Street SW, Suite 5R30, Washington, DC 20546, <http://www.nasa.gov>.

¹² Available from the United Nations Economic Commission for Europe (UNECE), Palais des Nations, CH-1211 Geneva 10, Switzerland, <https://unece.org>.

4. Applicability

4.1 This specification relates to and is referenced by other sUAS and aircraft standards at the system level as listed in Section 2. This specification is mandatory at any point in the aircraft system in which fuel cells or hydrogen storage systems, or both, are used.

4.2 Criticality of this specification is derived from safety risk analysis. The following failures are critical and are listed hierarchically, the first being the most critical:

4.2.1 Catastrophic failure of hydrogen containment combined with ignition source, resulting in fire and possible injury to ground refueling or operations personnel, or both;

4.2.2 Loss of both fuel cell and hybrid battery power output for flight termination, resulting in inability to terminate the flight safely or in a controlled manner; and

4.2.3 Failure of the fuel cell power output (but not the hybrid or reserve battery) to the aircraft control systems, necessitating an emergency landing in a potentially unsafe area.

4.3 In performing a hazard analysis of a fuel cell power system in an aircraft, the following should be considered:

4.3.1 Potential for fire in refueling, storage, and flight operations;

4.3.2 Potential for combustion resulting from electrostatic discharge, in flight and on the ground;

4.3.3 Redundancy of fuel cell and hybrid battery, and degraded performance levels that permit safe landing under failure conditions; and

4.3.4 Other hazards specific to the aircraft, fuel storage, fuel cell system, or recommended mission that are applicable.

5. Batteries and Battery Charging

5.1 Most fuel cell systems used in aircraft will include rechargeable or primary batteries for startup, peaking, or power redundancy, or combinations thereof. All batteries or battery subsystems used as part of a compliant fuel cell system shall be compliant with applicable battery standards for the sUAS or aircraft.

5.2 If the fuel cell system charges one or more hybrid batteries, the charger shall incorporate cell balancing and monitoring appropriate to the battery chemistry being used.

5.3 If the fuel cell system charges one or more hybrid batteries, the charger shall incorporate capabilities to assure that the batteries are charged only when they are within the safe charging temperature for the chemistry being used.

5.4 Any battery used by the system shall be actively monitored for critical operating conditions during flight and ground operations. These conditions may include battery voltage, current, temperature, or other parameters appropriate to the battery chemistry used.

5.5 If the power system detects a battery outside its critical operating conditions, it shall indicate this condition to the avionics or ground control station to permit safe termination of flight.