Designation: F3005 – 22

Standard Specification for Batteries for Use in Small Unmanned Aircraft Systems (sUAS)[1]

This standard is issued under the fixed designation F3005; 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 standard defines the requirements for batteries used in small Unmanned Aircraft Systems (sUAS).

1.2 This standard does not define requirements for the systems in which sUAS battery packs may be utilized.

1.3 This standard is subordinate to Specification F2910.

1.4 If allowed by a nation's GAA, certain sUAS may be exempt from this standard and may use commercial off-the-shelf (COTS) batteries in non-safety-critical payloads (lithium chemistries may not be exempted). Air transport regulations still shall be adhered to when air transport is used for COTS cells or batteries in bulk.

1.5 *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.*

1.6 *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]

F2910 Specification for Design and Construction of a Small Unmanned Aircraft System (sUAS)

F3060 Terminology for Aircraft

F3341/F3341M Terminology for Unmanned Aircraft Systems

2.2 *Other Standards:*

ANSI/ASQ Z1.4-2008 Sampling Procedures and Tables for Inspection by Attributes[3]

UL 1642 Standard for Lithium Batteries[4]

3. Terminology

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

3.2 *Definitions and Acronyms*—The standard terminology for sUAS as defined in higher level standards applies in general to this standard except as noted below.

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *C-rating, n*—maximum steady-state current (amps) at which the battery cell or pack may be discharged without having pack temperature exceed the CTT of its constituent cell(s) or result in a reduction in cell life. C-rating is expressed as a multiple of the capacity. For example, a battery with a nominal capacity of 4 Ah may have a C-rating of 5C, meaning that 20 A would be considered its maximum safe current.

3.3.2 *characteristic thermal threshold, CTT, n*—the temperature beyond which a rechargeable battery cell of particular chemistry and structure will exhibit permanent deterioration of its critical performance parameters as evident upon subsequent charge/discharge cycles. Cell capacity and internal resistance are critical performance parameters. CTT is rated at both upper and lower thresholds.

3.3.3 *depth of discharge, DOD, n*—ratio of cell or pack capacity expended relative to its nominal capacity.

3.3.4 *pack, n*—a single cell or composition of battery cells connected in series or in parallel or both plus monitoring electronics, structure, and connector(s).

[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.

Current edition approved Oct. 1, 2022. Published December 2022. Originally approved in 2014. Last previous edition approved in 2014 as F3005 – 14a. DOI: 10.1520/F3005-22.

[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 American Society for Quality (ASQ), 600 N. Plankinton Ave., Milwaukee, WI 53203, http://www.asq.org.

[4] Applicable only to 5.1 on cell suppliers.

Available from Underwriters Laboratories (UL), 2600 N.W. Lake Rd., Camas, WA 98607-8542, http://www.ul.com.

3.3.5 *pack assembler, n*—that supplier which performs the manufacturing processes that integrate the essential components into a functional pack. In the event that multiple suppliers are involved in the assembly process, the pack assembler is the supplier that performs the final electrical connection(s). One supplier may weld solderable tabs to a batch of cells, a second supplier may connect circuitry, wiring and a connector, and yet a third may install the assembly in a plastic housing. In this example, the second supplier would be the pack assembler.

3.3.6 *shall versus should versus may, v*—use of the word "shall" implies that a procedure or statement is mandatory and must be followed to comply with this standard, "should" implies recommended, and "may" implies optional at the discretion of the supplier, manufacturer, 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" statement 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.

3.3.7 *small unmanned aircraft system, sUAS, n*—composed of the small unmanned aircraft (sUA) and all required on-board subsystems, payload, control station, other required off-board subsystems, any required launch and recovery equipment, and command and control (C2) links between the sUA and the control station. Since any one of the preceding subsystems may affect reliability and thus safety of the sUAS, batteries used in those subsystems shall comply with this standard unless failure of the battery will not compromise safety. For purposes of this standard sUAS is synonymous with small Remotely Piloted Aircraft System (sRPAS), and SUA is synonymous with a small Remotely Piloted Aircraft (sRPA).

3.3.8 *supplier, n*—any entity engaged in the design or production of a battery pack or any component of a pack intended for use in a sUAS. The *cell supplier* is the manufacturer of the fundamental cell(s) constituent in a battery core. Various suppliers contribute to the production of a pack, and any differences between them are described both explicitly and by context throughout the document.

3.4 *Acronyms:*

3.4.1 *COTS*—Commercial off the Shelf

3.4.2 *CTT*—Characteristic Thermal Threshold

3.4.3 *DOD*—Depth of Discharge

3.4.4 *IC*—Internal Combustion

3.4.5 *Li*—Lithium

3.4.6 *LiFe*—Lithium Ferrite (commonly used, abbreviated reference to $LiFePO_4$)

3.4.7 *$LiFePO_4$*—Lithium Iron Phosphate

3.4.8 *LiIon*—Lithium Ion

3.4.9 *LiPo*—Lithium Polymer (commonly used term for a package-specific variation of the Lithium Ion chemistry)

3.4.10 *MSDS*—Material Safety Data Sheet

3.4.11 *NiCd*—Nickel Cadmium

3.4.12 *NiMH*—Nickel Metal Hydride

3.4.13 *PCM*—Protective Circuit Module

3.4.14 *PVC*—Polyvinyl Chloride

3.4.15 *SDS*—Safety Data Sheet

3.4.16 *SLA*—Sealed Lead Acid

3.4.17 *sUAS*—Small Unmanned Aircraft System

3.4.18 *UAS*—Unmanned Aircraft System

3.4.19 *UN-GHS*—United Nations Global Harmonization System

4. Applicability

4.1 This standard relates to and is referenced by other sUAS standards at the sUAS system level as listed in Section 2. This standard is mandatory at any point in the sUAS system in which batteries are used, except for payload downlinks that have no effect on flight safety.

4.2 This standard is written for all sUAS that are permitted to operate over a defined area and in airspace defined by a nation's GAA. Unless otherwise specified by a nation's GAA, this standard applies only to UA that have a maximum takeoff gross weight of 55 lb/25 kg.

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

4.3.1 Loss of independent power for flight termination by any means requiring battery power, resulting in inability to terminate the flight safely;

4.3.2 Failure of primary power for the FCS resulting in loss of control to permit safe flight or recovery;

4.3.3 Failure of ignition power (if a battery is utilized instead of a magneto, alternator, generator or the like for internal combustion) or primary power for electric propulsion, creating the inability to return the sUAS to base and creating a ground impact hazard.

5. Cells

5.1 *Responsibility of Cell Suppliers*—As a minimum, the cell supplier shall possess and provide the following:

5.1.1 *Process Control Plan* for the specific cell being provided, including *Quality Control Procedures* and *Recording Methods*.

5.1.2 A *Quality Assurance Plan* for the specific cell being provided, including compliance with UL 1642 requirements for cells.

5.1.3 *MSDS*, also known as SDS per the UN-GHS for chemicals classification.

5.1.4 *Technical Data Sheet* shall be a formal document, not preliminary or informal. The manufacturer's datasheet shall include specification of the upper CTT.

5.1.5 Every cell shall be marked with its *Lot Number* and *Supplier's Name* to aid failure analysis, facilitate traceability, and minimize the extent of a recall should such action become necessary.

5.2 *Responsibility of Pack Assembler:*

5.2.1 *Lot Testing*—A sample from each lot of cells shall be subjected to capacity testing and physical inspections. The capacity test and physical inspections may, but are not required to be performed on the same cells. Sampling shall be in accordance with ANSI/ASQ Z1.4-2008. Any alternate plan must be approved by the GAA. The sampling plan shall accept on zero defects.

5.2.1.1 *Capacity Test*—The sample shall undergo one complete charge-discharge cycle to verify the integrity of the lot. A charge-discharge cycle is defined as a full charge followed by a full discharge to the depth specified by the cell manufacturer or as typical for the subject chemistry.

5.2.1.2 *Physical Inspection*—Physical inspections shall be performed on the sample. A subject cell is to be rejected for any of the following conditions:

(1) Swelling;

(2) Electrolyte leakage;

(3) Out-gassing;

(4) Odor, even in the absence of visible electrolyte leakage, an obvious odor shall be considered evidence of a deteriorated cell;

(5) Deformed or damaged casing;

(6) Punctures;

(7) Tab condition—Seals are to be undamaged, and welds are to be unbroken and of satisfactory quality. If a cell is supplied with a PCM connected, accessible solder connections to the tabs shall also be inspected. If a solder connection is unacceptable, it may be reworked by the pack assembler.

5.2.2 *Received-Voltage Test*—The pack assembler shall measure this voltage on every cell in the lot. The measurement shall be made before any load or charge has been applied to the cell. The measurement is taken directly at the cell tab, bypassing any protection circuitry that may be connected. In the event that a cell's received voltage is outside limits that are normal or recoverable for the particular chemistry, the cell shall be rejected. The received voltage shall not vary significantly from what is considered the typical chemistry-specific storage/shipping voltage or the mean measurement for the bulk of the lot. The received voltage for a lot will typically vary little from cell to cell and certainly should remain within a 10 % window. (For example, a LiPo will normally be shipped in a half-charge state, holding at about 3.8 V). If the cell is outside the storage/shipping voltage, the cell shall undergo the capacity test and physical inspections of 5.2.1 to ensure its integrity. The received-voltage test may be performed as part of the assembly process rather than as an incoming test if the lot will be utilized for production before significant self-discharge occurs.

5.2.3 *Records and Certifications*—The pack assembler shall obtain and make available to the GAA and the procuring entity pertinent information regarding the pack assembly. These data shall be available so long as that pack model is marketed or sold and for a minimum of three years thereafter. These data shall either be shipped with the pack(s), provided upon request or be accessible by other means such as the pack assembler's website:

5.2.3.1 *The technical data sheet from the cell supplier for cells used in the pack*;

5.2.3.2 *The MSDS (also known as SDS per the UN-GHS for chemicals classification) for the cell type used in the pack*;

5.2.3.3 *The data items, by lot*, listed under 5.1.3 – 5.1.5 (that is, the pack assembler is to carry forward the data provided by the cell supplier);

5.2.3.4 *Pack assembler's specified shipping/storage voltage*—These data are not intended to be a record of measured voltage for each pack but to stipulate the voltage range that the procuring entity can expect to measure upon receipt of a pack for the particular chemistry;

5.2.3.5 *The lot number of constituent cells used in a pack traceable to the pack serial number*;

5.2.3.6 *Date of manufacture of the pack*—As defined in Section 6, the date may be codified in the serial number.

5.2.4 *Pack Assembly Requirements*—A multi-cell pack shall not contain cells from more than one lot. An exception may be made if three conditions are met: *(1)* the date of manufacture of the cells are within a six-month span; *(2)* all cells to be used in the pack are tested for capacity and found to be within 5 % of each other; and *(3)* all of the cells were manufactured recently enough to be considered acceptable for use in new construction for the particular chemistry.

5.2.5 *Final Test*—As a minimum, each completed pack shall be subjected to two charge-discharge cycles, following which the pack shall be charged to its appropriate, chemistry-specific shipping/storage voltage. A charge-discharge cycle is defined as a full charge followed by a full discharge to the depth specified by the cell manufacturer or as typical for the subject chemistry. The pack shall demonstrate its rated capacity by means of this testing to be acceptable for delivery to the procuring entity.

6. Mechanical Design and Assembly

6.1 *In-Process Quality*—The assembly process shall be devised such that it is conducive to observation of the physical conditions listed in 5.2.1.2. This requirement does not stipulate inspection of cells beyond lot testing but rather is intended to maximize exposure of the cells to visual scrutiny during assembly.

6.2 *Cell Connections*—Cells shall be interconnected using techniques that minimize failure caused by vibration and impact. If tab-to-tab connection of individual cells is used to form a pack, the connection shall be resistance-welded to the individual cell terminal. If cells are interconnected using double-sided printed circuit connecting boards, these boards shall have plated-through tab slots or holes.

6.3 *Wiring*—All power and cell-sensing wiring shall be strain relieved at the junction with the cell or interconnect tabs and secured at a point before exiting the pack.

6.4 *Vibration*—The pack assembly may be surrounded with impact and vibration-absorbent material such that the assembled pack meets governing-body requirements for shipment by air.

6.5 *Puncture Resistance*—An assembled pack having one or more non-rigid cells shall be housed in a protective material that provides resistance to mechanical penetration beyond that of the bare, unprotected cell. LiPo cells are one such example