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Technical requirements for small unmanned aircraft electric energy systems

Exigences techniques relatives aux systèmes d'énergie électrique pour petits aéronefs sans pilote

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 16, *Unmanned aircraft systems*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Technical requirements for small unmanned aircraft electric energy systems

1 Scope

This document provides technical requirements and test methods for small unmanned aircraft electric energy systems (EESs).

This document applies to the EES of small unmanned aircrafts (UAs) with the maximum take-off mass (MTOM) less than 25 kg corresponding to unmanned aircraft systems (UASs) at level I, II, III and IV as graded in ISO 21895:2020, and with secondary lithium batteries. This document can apply to new type of batteries to be used in the UA electric energy system in the future.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 21384-2, *Unmanned aircraft systems — Part 2: UAS components*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 60950, *Information technology equipment - Safety*

IEC 62281:2019, *Safety of primary and secondary lithium cells and batteries during transport*

United Nations *Manual of Tests and Criteria, Seventh revised edition, Section 38.3: Lithium Batteries (*2019*)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
electric energy system
EES
software and hardware system that provides the energy required for the unmanned aircraft, and distributes, controls, detects and estimates the energy

3.2
secondary lithium battery
rechargeable unit which incorporates *secondary lithium cells* (3.3) electrically connected in series and/or parallel with or without monitoring and protection circuitry for charging and discharging

Note 1 to entry: It may incorporate adequate housing and a terminal arrangement and may have electronic control devices.

3.3
secondary lithium cell
basic functional electrochemical unit where electrical energy is derived from the reversible oxidation/reduction reaction of lithium between the negative electrode and the positive electrode

Note 1 to entry: The cell typically has an electrolyte that consists of a lithium salt and organic solvent compound in liquid, gel or solid form and has a metal or a laminate film casing. It is not ready for use in an application because it is not yet fitted with its final housing, terminal arrangement and electronic control device.

3.4
reference test current
I_t
current that can be used to discharge a battery with the rated capacity in one hour

Note 1 to entry: The rated capacity (C_2, expressed in A·h) is the quantity of electricity which the battery can deliver when discharged at the reference test current of 0,5 I_t (expressed in A) to a specified final voltage, after charging, storing and discharging under specified conditions.

3.5
state of charge
SOC
ratio of the *electric energy system (EES)* (3.1) current capacity to the full-charge capacity

4 Abbreviated terms

AFE	analogue front end
FCS	flight control system
LED	light-emitting diode
MCU	microcontroller unit
MTOM	maximum take-off mass
RPS	remote pilot station
SOH	state of health
SOP	state of power
UA	unmanned aircraft
UAS	unmanned aircraft system
UFM	unmanned aircraft flight manual

5 System requirements

5.1 General

The functions of the electric energy system (EES) shall include energy supply, signal measurement and analysis, energy estimation, system protection, energy management, control and distribution, as a minimum.

A typical schematic diagram of the EES is shown in Figure 1. The overall workflow and related functions are as follows:

a) The temperature, battery voltages and current through battery are detected by the AFE and transferred to the gauge and the MCU.

b) The gauge processes the signals and calculates the remaining energy amount in the battery, and sends signals to MCU.

c) MCU manages and controls the battery output based on the signals from the gauge, AFE and the algorithm stored in the MCU. The MCU limits the current when it is higher than expected and cuts off the charging process when the voltage is over the protection voltage. It controls also the distribution of energy and power when the temperature is higher than the protection temperature that affects the battery performance, reliability and safety.

d) Connectors between the EES and the UA send an indication of battery status to the FCS of the UA. The UA flight control system controls the flight to protect the battery and itself.

e) The interface includes buttons and visual indicators (e.g. LEDs) to turn on/off the battery and check the remaining energy.

f) When the EES temperature is abnormal (too high or low), the information is sent to the FCS and then a message is sent to the RPS to notify the remote pilot. The flight control of the UA limits the flight attitude or even make the UA to automatically return home for safety reason.

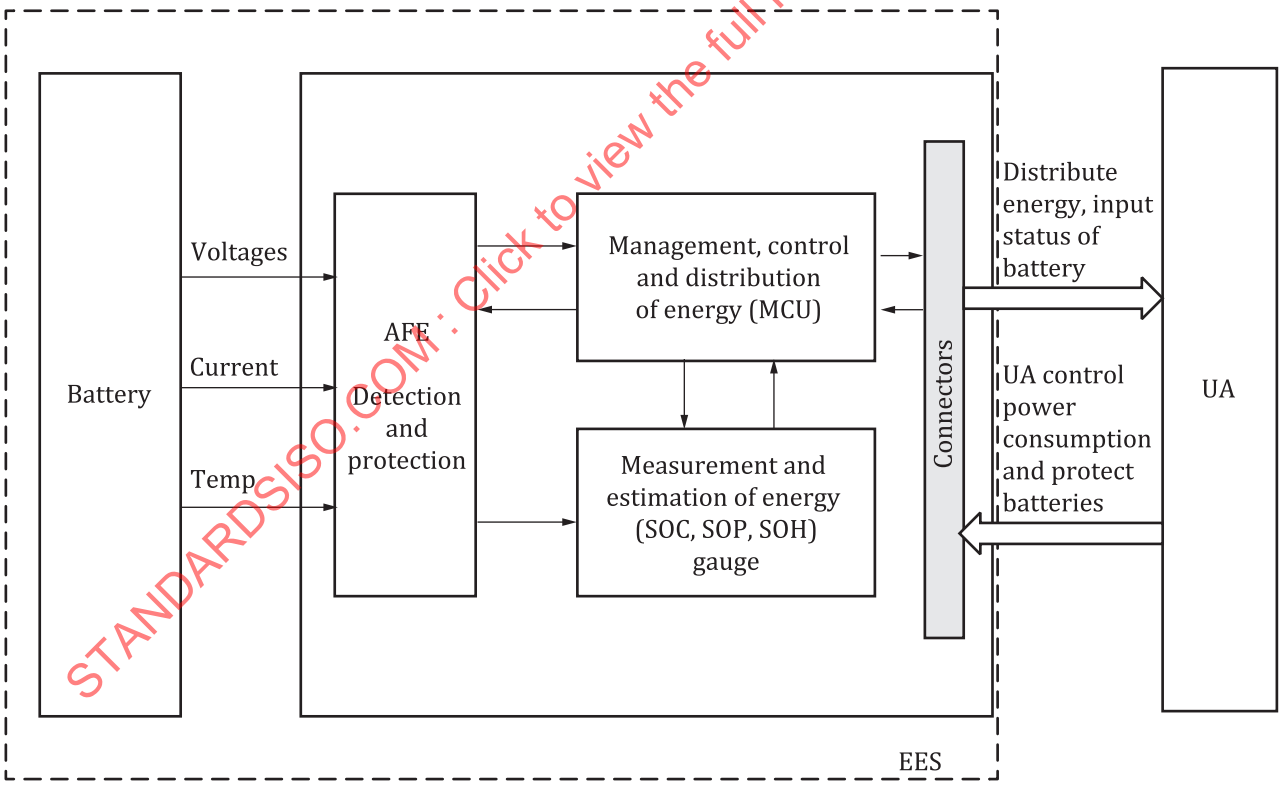

Figure 1 — Typical schematic diagram of electric energy system (EES)

As a minimum, design and installation requirements for the EES shall include:

— It shall be able to provide the necessary voltage and current required by the motor(s) and electrical equipment throughout the operational envelope.

— It shall include electrical protections.

— The electrical connection shall be guaranteed.

— The electrical components shall be designed to accommodate the expected electrical loads.

— It shall be designed to accommodate the risk from the expected operational environments.

— It shall be designed to minimize the risk of electrical shock.

— It shall be able to transmit necessary information and alerts to the UA.

Table 1 is the checklist of the EES requirements, test methods and acceptance criteria.

Table 1 — Checklist of the EES requirements, test methods and acceptance criteria

Requirements Category	Items	Requirements	Test methods and acceptance criteria
Performance	Output control	-	-
	Actuation time	5.2.2.1	5.2.2.2
	Shutdown time	5.2.3.1	5.2.3.2
	Rated output power	5.2.4.1	5.2.4.2
	Discharge capacity	5.2.5.1	5.2.5.2
	Cycle life	5.2.6.1	5.2.6.2
	Operational cycle life	5.2.7.1	5.2.7.2
	Recoverable hovering capacity after high temperature storage	5.2.8.1	5.2.8.2
Information and alert		5.3.1	5.3.2
Energy management and electric protection functions	Charge state of charge calculation	5.4.1.1	5.4.1.2
	Discharge SOC calculation	5.4.2.1	5.4.2.2
	Over voltage protection	5.4.3.1	5.4.3.2
	Under voltage protection	5.4.4.1	5.4.4.2
	Over temperature protection	5.4.5.1	5.4.5.2
	Over Current Protection	5.4.6.1	5.4.6.2
	Overload protection	5.4.7.1	5.4.7.2
	Short-circuit Protection	5.4.8.1	5.4.8.2
Structure		5.5.1	5.5.2
Electrical shock		5.6.1	5.6.2
Connector(s)		5.7.1	5.7.2
Enclosure protection		5.8	5.8
Environmental adaptability	High temperature and humidity storage	5.9.1.1	5.9.1.2
	Temperature shock	5.9.2.1	5.9.2.2
	Low pressure	5.9.3	5.9.3
	Salt spray	5.9.4.1	5.9.4.2
	Drop test	5.9.5.1	5.9.5.2
	Vibration test	5.9.6.1	5.9.6.2

5.2 Performance

5.2.1 Output control

In startup mode, the EES shall be working and providing power to the UA. In shutdown mode, the EES shall not provide power.

5.2.2 Actuation time

5.2.2.1 Requirements

The EES manufacturer shall ensure that the total time to reach the rated power shall meet the UA manufacturer's specification. The recommended actuation time should be less than 60 s.

5.2.2.2 Test method and acceptance criteria

The test shall be conducted in the normal test atmospheric conditions as specified in 6.1. The duration from issuing the startup command to the EES starting to generate output shall be recorded.

The test shall be passed if the actuation time is less than 60 s.

5.2.3 Shutdown time

5.2.3.1 Requirements

The shutdown time of EES shall be designed to meet the UA manufacturer's specification. The recommended shutdown time should be less than 2 min.

5.2.3.2 Test method and acceptance criteria

As the EES works on rated power condition, the duration between receiving the power off command and entering power off status shall be recorded.

The test shall be passed if the shutdown time is less than 2 min.

5.2.4 Rated output power

5.2.4.1 Requirements

The EES shall be continuously outputting the rated output power during the operation time declared by the UA manufacturer.

5.2.4.2 Test method and acceptance criteria

The test shall be conducted in the normal test atmospheric conditions as shown in 6.1.

The fully charged EES with the new battery(s) shall run at the rated output power after startup. The EES voltage shall be recorded once per second during the whole operation time declared by the UA manufacturer. The voltage during the whole testing process shall not be below the discharging final voltage declared by the UA manufacturer.

The test shall be passed if the operation time is higher than the UA manufacturer specified.

5.2.5 Discharge capacity

5.2.5.1 Requirements

Nominal capacity shall be included in the specification and be either tested using charge/discharge current at the reference test current of 0,5 I_t or stated by the UA manufacturer.

When the unmanned aircraft is hovering, the discharge capacity shall not be less than 90 % of the nominal capacity.

5.2.5.2 Test method and acceptance criteria

Charging-discharging devices dedicated by the UA manufacturer should be used to make a loop for the EES and keep the current in the loop constant. The discharging time shall be recorded until the voltage of the positive/negative electrodes reaches the discharging final voltage specified by the UA manufacturer, and the corresponding discharge capacity is the initial discharge capacity of the EES.

a) Testing of nominal discharge capacity and high-rate discharge capacity at room temperature shall include the following steps.

   1) Charge the EES according to the methods in 6.2 within the normal conditions in 6.1.

   2) At a temperature of 23 °C ± 3 °C, discharge the EES at a current of 0,5 I_t until it reaches the specified discharging final voltage. Calculate the discharge capacity (A·h).

   3) Repeat steps 1) and 2) at least twice. Record the corresponding discharge capacity and take the average value as the EES nominal discharge capacity at room temperature.

   4) Repeat steps 1) to 3) and discharge the EES using nI_t current (n = 0,5, 1, ..., n_{max}, where n_{max} is the maximum discharging rate used in the UA). Record the discharging current and discharging time.

   5) Calculate the current average discharge capacity (A·h) and the ratio to the nominal capacity.

b) Testing of the high-rate discharge capacity in the low temperature shall include the following steps.

   1) Charge the EES according to the methods in 6.2.

   2) Put the EES for 4 h in the lowest operational environment temperature designed for the battery installed in the EES or 0 °C (if not specified).

   3) Discharge the EES at a current of nI_t (n = 0,5, 1, ..., n_{max}, where n_{max} is the maximum discharging rate used in the UA) until it reaches the specified discharging final voltage.

   4) Repeat steps 1) to 3) at least twice. Record the corresponding discharging current and discharging time.

   5) Calculate the average discharge capacity (A·h) in the low temperature and the ratio to the nominal capacity.

c) Testing of the high-rate discharge capacity in the high temperature shall include the following steps.

   1) Charge the EES according to the methods in 6.2.

   2) Put the EES for 4 h in the highest operational environment temperature designed for the battery installed in the EES or 45 °C (if not specified).

   3) Discharge the EES at a current of nI_t (n = 0,5, 1, ..., n_{max}, where n_{max} is the maximum discharging rate used in the UA) until it reaches the specified discharging final voltage.

   4) Repeat steps 1) to 3) at least twice. Record the corresponding discharging current and discharging time.

   5) Calculate the average discharge capacity (A·h) in the high temperature and the ratio to the nominal capacity.

The test shall be passed if the discharge capacity is not less than 90 % of the nominal capacity.

5.2.6 Cycle life

5.2.6.1 Requirements

The cycle life of EES with the battery installed shall be specified and tested in the normal test atmospheric conditions.

After testing, the actual charge and discharge cycle number shall be greater than the cycle life specified by the UA manufacturer.

5.2.6.2 Test method and acceptance criteria

The EES shall be tested with the new battery(ies) in an environment with temperature at (23 ± 3) °C. The dedicated charging-discharging devices shall be used. When the capacity is below 80 % of its initial capacity or below the usable capacity specified by the manufacturer, it indicates the end of life of the EES.

The test shall include the following steps.

a) Charge the EES according to the methods in 6.2.

b) Rest the EES for a minimum of 30 min or the manufacturer specified resting duration, whichever is longer.

c) Discharge the EES at the average hovering current or the cycling current claimed in the specifications until it reaches the specified discharging final voltage.

d) Rest the EES for a minimum of 30 min or the manufacturer specified resting duration, whichever is longer.

e) Repeat steps a) to d) until the discharge capacity is below 80 % of the initial capacity or the specified usable capacity. The cycling numbers are considered as the charge/discharge cycle life of the EES.

The test shall be passed if the discharge capacity is not below 80 % of the initial capacity or the specified usable capacity under the cycle number specified by the UA manufacturer.

5.2.7 Operational cycle life

5.2.7.1 Requirements

The operational cycle life of EES shall be specified in the typical operational condition defined by the UA manufacturer and thus tested to ensure that the EES meets the specified operational cycle life.

After testing, the number of working state cycle shall not be less than the cycle life specified by the UA manufacturer.

5.2.7.2 Test method and acceptance criteria

In order to simulate the EES actual operating state in the UA, the typical operational condition shall be defined by the UA manufacturer. If not, the test conditions in 6.1 are recommended.

The EES shall be tested with the new battery(ies) with dedicated charging-discharging devices. When the capacity is below 80 % of its initial capacity or below the usable capacity specified by the manufacturer, it indicates the end of life of the EES.

The test shall include the following steps.

a) Charge the EES according to the methods in 6.2.

b) Rest the EES for a minimum of 30 min or the manufacturer specified resting duration, whichever is longer.

c) Pulse discharge according to electrical loads characteristics of the UA typical mission profile until it reaches the specified discharging final voltage. Record the discharge capacity.

d) Rest the EES for a minimum of 30 min or the manufacturer specified resting duration, whichever is longer.

e) Repeat steps a) to d) until the discharge capacity is below 80 % of the initial capacity or the specified usable capacity. The cycling numbers are considered as the operational charge/discharge cycle life.

The test shall be passed if the discharge capacity is not below 80 % of the initial capacity or the specified usable capacity under the cycle number specified by the UA manufacturer.

5.2.8 Recoverable hovering capacity after high temperature storage

5.2.8.1 Requirements

The recoverable hovering capacity shall be estimated for the EES life degradation after stored in the specified high temperature environment. The hovering capacity is measured at the hovering current, which is the current when the UA hovering in the air without wind interference at the normal test environment defined in 6.1.

After testing, the EES shall not fire, explode or leak. The recoverable hovering capacity shall not be less than the value specified by the UA manufacturer.

5.2.8.2 Test method and acceptance criteria

The test includes the following steps.

a) Initial hovering capacity testing: The EES with the new battery(ies) shall be charged according to the charging method in 6.2 in the normal test temperature defined in 6.1. Then the EES shall be discharged at the average hovering current. The discharge capacity is the initial hovering capacity.

b) Storage: The fully charged EES shall be stored in an ambient temperature of 60 °C ± 2 °C for 14 days and then put into the normal test conditions. The changes of the EES thickness shall be recorded before and after storage.

c) Recoverable hovering capacity testing: Then the EES shall be charged according to the charging method in 6.2 in the normal test temperature and discharged at the average hovering current to the specified final voltage. The discharge time shall be recorded after discharging.

The test shall be passed if the recoverable hovering capacity is not less than the value specified by the UA manufacturer without fire, explosion or leakage.

5.3 Information and alert

5.3.1 Requirements

The system shall include a communication interface that can transmit information such as remaining capacity, power, voltage, temperature and abnormal status between the EES and the UA, and the reading errors shall be less than 3 %.

The RPS interface shall display the energy system related information (SOC, voltage, temperature) and inform the remote pilot of the SOC of EES.

The RPS interface shall provide the EES related warnings and/or alerts of the emergency conditions, such as the following.

a) Warning messages shall be displayed on the user interface to notify the remote pilot when the electric protections have been activated.

b) Low battery warnings or alerts shall be presented by audible and visual alerts for a predefined immediate recovery actions (e.g. returning home or emergency landing) when the SOC is close to the limitation.

5.3.2 Test method and acceptance criteria

The reading errors shall be tested according to the following procedures.

a) Read the parameters through the communication interface.

b) Calculate the error between the read value and the actual value.

The energy system related warnings and alerts shall be tested according to the emergency procedure specified in the UFM; and during testing, the warnings and alerts shall be check if they are presented correctly.

The test shall be passed if the information and alerts at RPS interface is consistent with the actual situation.

5.4 Energy management and electrical protection functions

5.4.1 Charge state of charge (SOC) calculation

5.4.1.1 Requirements

The EES shall provide the real-time charge capacity to UA. The SOC accuracy of the EES shall be detected. The calculated SOC is 100 % at the cut-off charging state; and the error between the SOC calculated by the protection circuit and the true value shall be less than the UA manufacturer's specification.

5.4.1.2 Test method and acceptance criteria

The EES shall be tested with the new battery(ies) and the test shall include the following steps.

a) Discharge and charge the EES successively according to the methods in 6.3 and 6.2.

b) Record the charge capacity and the SOC calculated by the EES algorithm.

c) Calculate the true SOC.

The test shall be passed if the error between the SOC calculated by the protection circuit and the true value is less than the UA manufacturer's specification.

5.4.2 Discharge SOC calculation

5.4.2.1 Requirements

The EES shall provide the accurate real-time capacity to UA to ensure flight safety. The accuracy of SOC calculation shall be detected when the EES is discharged. The error between the SOC calculated by the EES algorithm and the true value shall be less than the UA manufacturer's specification.

5.4.2.2 Test method and acceptance criteria

5.4.2.2.1 The protection circuit has a SOC calculation function. The testing temperature is as follows:

a) normal temperature: 23 °C ± 3 °C;

b) low temperature: the lowest temperature specified in specification or 0 °C (if not specified);

c) high temperature: the maximum temperature specified in specification or 45 °C (if not specified).

5.4.2.2.2 The EES shall be tested with the new battery(ies) and the test shall include the following steps.

a) Fully charge the EES according to the methods in 6.2.

b) Rest the EES at the testing temperature for 2 h.

c) Discharge with the average hovering current at the testing temperature (normal temperature, low temperature and high temperature shown above) to the specified final voltage.

d) Record the EES discharge capacity and the SOC calculated by the EES protection algorithm.

e) Calculate the true SOC at the corresponding testing temperature using dedicated charging-discharging devices.

The test shall be passed if the error between the SOC calculated by the EES algorithm and the true value shall be less than the UA manufacturer's specification.

5.4.3 Over voltage protection

5.4.3.1 Requirements

If the EES includes the charging protection, when the EES charging voltage exceeds the specified upper voltage limit, the system shall activate the over voltage protection to remove the input current or issue a warning indication.

During the flight, the over voltage protection of EES shall not affect the UA operational safety.

The whole procedure of over voltage protection shall not cause fire, explosion or leakage.

5.4.3.2 Test Method and acceptance criteria

The EES shall be tested in an explosion-proof box with the new battery(ies). The test shall include the following steps.

a) Charge the EES according to the methods in 6.2 using dedicated charging-discharging devices.

b) Keep charging at the maximum charging current specified by the manufacturer until the voltage of any single battery reaches 1,5 times of the specified nominal charging final voltage or the circuit protection activation.

c) Observe for 1 h.

d) Discharge the EES according to the methods in 6.3 using dedicated charging-discharging devices.

e) Charge the EES at a constant current of 1,5 times the maximum charging current specified by the manufacturer until the voltage of any single battery reaches the nominal charging final voltage or the circuit protection activation.

f) Observe the EES for 1 h.

The test shall be passed if there is no fire, explosion, or leakage.

5.4.4 Under voltage protection

5.4.4.1 Requirements

If the EES includes the discharging protection, when the EES discharging voltage is lower than the specified lower voltage limit, the system shall issue a warning message to the UA and then the UA may active the emergency landing procedure.

During the flight, the under-voltage protection of EES shall not affect the UA operational safety.

The whole procedure of under voltage protection shall not cause fire, explosion, or leakage.

5.4.4.2 Test Method and acceptance criteria

The fully charged EES shall be tested in an explosion-proof box with the new battery(ies). The test shall include the following steps.

a) Keep discharging according to the methods in 6.3 until the circuit protection is activated.

b) Observe for 1 h.

The test shall be passed if there is no fire, explosion, or leakage.

5.4.5 Over temperature protection

5.4.5.1 Requirements

If the EES includes the charging protection, when the EES temperature in the charging process exceeds the maximum temperature limit specified in the battery specification, the EES shall issue a warning indication and/or protect automatically.

During the flight, the EES shall not automatically protect and affect the UA operational safety.

5.4.5.2 Test method and acceptance criteria

The EES shall be tested in an explosion-proof box with the new battery(ies). The test shall include the following steps:

a) Connect the EES with the dedicated charging-discharging device in the normal test conditions in 6.1.

b) Discharge the EES according to the methods in 6.3.

c) Charge the EES at the manufacturer recommended current to a 50 % SOC while the temperature shall be increased to 5 °C above specified maximum operational temperature.

d) Keep charging until the EES issues a warning indication and/or circuit protection activation.

e) Observe the EES for 1 h.

f) Check the functions of EES.

The test shall be passed if there is no fire, explosion, or leakage and the EES functions correctly.

5.4.6 Over current protection

5.4.6.1 Requirements

If the EES includes the charging protection, when the EES charging current exceeds the specified current threshold for a specified duration, it shall protect automatically.

The whole procedure of over current protection shall not cause fire, explosion or leakage.

5.4.6.2 Test Method and acceptance criteria

The EES shall be tested in an explosion-proof box with the new battery(ies). The test shall include the following steps.

a) Connect the EES with the dedicated charging-discharging device in the normal test conditions in 6.1.

b) Discharge the EES according to the methods in 6.3.

c) Charge the EES at a constant current higher than the charging protection current threshold specified in the battery specification.

d) Activate the circuit protection after the specified duration in the battery specification.

e) Observe the EES for 1 h.

f) Check the functions of EES.

The test shall be passed if there is no fire, explosion, or leakage and the EES functions correctly.

5.4.7 Overload protection

5.4.7.1 Requirements

If the EES includes the discharging protection, when the EES is overloaded and the discharging current in the test exceeds the specified discharging current threshold for a specified duration, the system shall issue a warning indication and/or protect automatically.

5.4.7.2 Test method and acceptance criteria

First, run the EES in the normal working condition, and then apply a load that exceeds the set overload protection value. Then, observe whether the system provides a warning indication or protects automatically (e.g. returning home automatically activated).

The fully charged EES shall be tested in an explosion-proof box with the new battery(ies). The test shall include the following steps.

a) Discharge the EES at a constant current higher than the discharging protection current threshold specified in the battery specification.

b) Activate the circuit protection after the specified duration in the battery specification.

c) Observe the EES for 1 h.

d) Check the functions of EES.

The test shall be passed if there is no fire, explosion, or leakage and the EES functions correctly.

5.4.8 Short-circuit protection

5.4.8.1 Requirements

When the positive and negative electrodes of the EES is in short circuit status, the short-circuit protection shall be automatically activated and shall not cause fire or explosion.

5.4.8.2 Test method and acceptance criteria

The EES shall be tested in an explosion-proof box with the new battery(ies) in the normal test condition as shown in 6.1. The test shall include the following steps.

a) Short-circuit the EES by connecting the positive and negative terminals with a total external resistance of 80 mΩ ± 20 mΩ.

b) Switch on the circuit for 10 min or until the circuit protection is activated.

The test shall be passed if there is no fire or explosion.

5.5 Structure

5.5.1 Requirements

The structure shall have a certain strength and reserve the expansion space. The appearance shall not be deformed after specified cycle life and high temperature storage.

5.5.2 Test method and acceptance criteria

After the tests of cycle life in 5.2.6.2 and high temperature and humidity storage in 5.9.1.2, the EES shall be checked if the structure is deformed due to the inner cell swelling.

The test shall be passed if the expansion ratio of the EES is less than the UA manufacturer's specification.

5.6 Electrical shock

5.6.1 Requirements

If the EES voltage is larger than 60 V DC, it shall meet the electric safety requirements according to IEC 60950 and shall not cause electrical shock hazard to the user.

5.6.2 Test method and acceptance criteria

The test methods shall conform to IEC 60950.

The test shall be passed if the EES does not cause electrical shock hazard to the user.

5.7 Connector(s)

5.7.1 Requirements

The connector(s) shall be able to maintain a stable and reliable connection under the UA flight envelope. Its design shall prevent misalignment and reverse polarity.

The connector(s) shall be able to charge and discharge normally after 1 000 times hot swapping, without visible degradation or loss of electrical performance (e.g. without sparking or blackening).

5.7.2 Test method and acceptance criteria

The test shall include the following steps.

a) Install the EES into the UA in the normal test conditions in 6.1.

b) Disassemble the EES from the UA.

c) Repeat a) and b) 1 000 times and checking connector(s) state.

The test shall be passed if the connector(s) does not spark or blacken.

5.8 Enclosure protection requirements

The EES or the UA with the EES shall meet the enclosure protection degree (e.g. IP67) claimed by the UA specifications or by the energy system specification. The protection degree definition and test methods shall conform to IEC 60529 and be conducted on the EES itself or on the unmanned aircraft with the EES.

5.9 Environmental adaptability

5.9.1 High temperature and humidity storage

5.9.1.1 Requirements

The stored EES shall not fire, explode or leak under high temperature and high humidity environment. After the test, the EES shall work normally.

5.9.1.2 Test method and acceptance criteria

The fully charged EES shall be tested in an explosion-proof box with the new battery(ies). The test shall include the following steps.

a) Place the EES in a high-temperature and high-humidity test chamber with the temperature of 70 °C ± 3 °C and humidity between 90 % and 95 % for 12 h.

b) Put the EES in the normal test condition as defined in 6.1 for 2 h.

c) Check the appearance of the EES.

The test shall be passed if there is no fire, explosion, or leakage and the EES functions correctly.

5.9.2 Temperature shock

5.9.2.1 Requirements

The EES shall be capable to resist the extreme temperature environment specified by the UA manufacturer and thus tested to ensure the EES safety within the specified extreme temperature environment.

After testing, the EES shall not fire, explode or leak.

5.9.2.2 Test method and acceptance criteria

The fully charged EES with the new battery(ies) shall be tested in an explosion-proof thermal cycling chamber. The temperature and the temperature change rate of the chamber shall be adjusted according to Table 2; and the whole procedure shall be repeated for 10 times.

The test shall be passed if there is no fire, explosion or leakage.