This annex to TCDS No. EASA.A.616 was created to publish selected special conditions and equivalent safety findings that are part of the applicable certification basis:

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Equivalent Safety Finding – CS-22.335 (f)

The definition of VD is based on the report “Concerning the deduction of design maximum speed VD in the airworthiness requirements LFS, LFSM, OSTIVAS and JAR 22”, LBA issued in 2001. In this document, VD is defined as the speed that occurs in the flight polar at a decent rate of 7,81 m/s.

Special Condition applicable to Powered Sailplanes equipped with Electric Propulsion Units

Introductory note:

The hereby presented Special Condition has been classified as an important Special Condition and as such shall be subject to public consultation, in accordance with EASA Management Board decision 12/2007 dated 11 September 2007, Article 3 (2.) of which states: "2. Deviations from the applicable airworthiness codes, environmental protection certification specifications and/or acceptable means of compliance with Part 21, as well as important special conditions and equivalent safety findings, shall be submitted to the panel of experts and be subject to a public consultation of at least 3 weeks, except if they have been previously agreed and published in the Official Publication of the Agency. The final decision shall be published in the Official Publication of the Agency."

Statement of issue

Applicants intend to use electric propulsion units including installation of Li-Po batteries in powered sailplanes. The airworthiness standard applicable to CS-22 aircrafts currently does not

consider Electrical Propulsion Units. The proposed Special Condition amends CS-22 with regard

to the consideration of specific design features of installation of electric propulsion in sailplanes. The Special Conditions is based on the special conditions “Airworthiness Standard for CS-22H Electrical Retractable Engine to be operated in powered sailplanes” for the approval of the electrical engine and “Temporary guidance material for the installation of electric power in powered sailplanes, LBA 19.04.2013” that have been applied in several projects of self-launching electric powered sailplanes.

EASA Position

The proposed use of Li-Batteries has prompted EASA to review the adequacy of the existing battery requirements with respect to that chemistry. Lithium-Ion (Li-Ion) / Lithium Polymer (Li- Po) Batteries, have specific failure and operational characteristics that could affect safety of those battery installations and cause hazards to safety. On the other hand it is understood that the characteristics of existing propulsion systems have contributed to quite a number of accidents and electric propulsion systems with a simple and reliable start procedure can improve safety significantly.

A safety assessment according (CS 2x.1309) is not required for Sailplanes and Powered Sailplanes. The engine control units for these kind of aircraft are normally not qualified according relevant EUROCAE/DO standards. Thus it is difficult to demonstrate that potentially hazardous or catastrophic failures are improbable. It also cannot be expected that the effect of a thermal runaway of Li batteries could be contained without any effect on the structural integrity of a powered sailplane, but with good engineering judgement all potentially critical items should be addressed to reduce the risk.

As the result of this review, EASA has determined that the amended special condition as attached does adequately address installations of electric propulsion units and Li-Batteries and due to the positive effect of reliable and simple electric propulsion units improves overall safety. Additional requirements and notes introduced in this SC should help to identify relevant failure modes and operational characteristics that have to be addressed with good engineering judgment and necessary tests and qualification.

Useful Standards

EN ISO 6469 – Electric Road Vehicles

SAE J2344 - Guidelines for Electric Vehicle Safety

EN ISO 7010 - Graphical symbols — Safety colours and safety signs

ASTM F2480 - Standard Practice for Design and Manufacture of Electric Propulsion Units for Light Sport Aircraft

Scope

This special condition covers the installation of electric propulsion systems in powered sailplanes using rechargeable batteries as energy storage device. For different energy storage technologies (e.g. fuel cells, capacitors) or hybrid propulsion systems the applicability of this special condition needs to be assessed.

The certification of electric motors and propellers is not part of this special condition.

The special condition does not cover or replace applicable regulations for handling, storage, transport and disposal of batteries.

Definitions and Terminology

The terminology for electric and hybrid propulsion systems in aviation is not yet standardized. The following terms and definitions are used in the context of this special condition:

Electric Propulsion Unit (EPU)— electric motor and all associated devices (including energy storage devices) used to provide thrust for an electric powered aircraft.

Electric engine – electric motor that converts electric energy in mechanical energy used for propulsion

Battery cell - electrochemical cells used to store electrical energy

Battery – assembly of (rechargeable or non-rechargeable) battery cells and associated components e.g. control unit, sensors, connectors, circuit breaker, containment.

Energy Storage Device (ESD) – device like a battery or fuel cell storing and providing electrical energy

Li-Po batteries - Lithium-ion polymer batteries, polymer lithium ion or lithium polymer batteries (abbreviated Li-poly, Li-Pol, LiPo, LIP, PLI or LiP) are rechargeable batteries.

High voltage (HV) - Classification of an electric component or circuit, if its working voltage is > 60 V and ≤ 1500 V DC or > 30 V and ≤ 1000 V AC root mean square (rms). High voltage sign according UNECE R-100:

Requirements: Installation of electric propulsion units in powered sailplanes

CS 22.1 Applicability

to be read

(2) powered sailplanes the design value W/b^2 (weight to span^2) of which is not greater than 3(W[kg], b[m]) and the maximum weight of which does not exceed 850 kg; and

CS 22.561 General

additionally

(f) If batteries or any other energy storage device are installed in such a way that the pilot(s) could be endangered in the emergency landing case, an ultimate inertia load corresponding to 15 g in the forward direction for the fastening of battery or any other energy storage device shall be assumed.

CS 22.902 Powered sailplanes with retractable power plants or propellers

additionally

(f) When the power plant is in the retracted position and during extension and retraction neither electric spark breaking nor radio disturbances may arise.

CS 22.903 Engines

to be read

(a) The engine must meet the special condition for electrical engines established by the Agency.

CS 22.951 General

(a) Each energy system shall be constructed and arranged in such a way to ensure a flow of energy at a capacity required for the proper engine functioning under any normal operating conditions.

(b) In case of self-launching powered sailplane, the capacity of the energy storage devices must allow at least the Take-off with take-off performance of the engine and climb with maximum continuous power for 5 minutes plus sufficient energy for use of electrical systems during the following un-powered flight continuation.

(c) Each energy storage device shall be designed in such a way that an equal charge of battery cells is ensured. A manual switchover to other sources of energy is allowed.

(d) A protection against overcharge and critical discharge of the batteries or any other energy storage device shall be provided including deep or unbalanced discharge if necessary for the type of battery.

GM 22.951

Potentially critical battery type installations (e.g. Ni-Cd, LiPo) should have a system to control the status of battery cells and provide information and warnings about critical parameter and failures. Engine Control Units and Battery Management Systems should be designed and manufactured following good engineering practice with consideration of electric magnetic interference, environmental and software aspects.

(d) Electric effects of the system in a wind milling condition (e.g. prop brake not effective), when the Engine works as a generator shall be considered.

CS22.361 Engine torque

(c) For electric propulsion systems the system must be able to withstand the maximum torque

provided by the engine.

CS 22.955 Fuel flow

deleted

CS 22.959 Unusable remaining energy quantity

The unusable remaining energy quantity shall be established.

GM CS 22.959

Some designs might prevent using the full energy quantity in order to avoid damaging the energy source; the corresponding energy quantity shall be declared as unusable. Other designs might allow the crew to use the full energy quantity, with or without requiring a specific crew action. In such cases, the cockpit indication should be designed adequately, and proper instructions for continued airworthiness and servicing shall be provided to ensure the energy source capacity is subsequently restored after the flight.

CS 22.963 Batteries or other energy storage devices

(a) The suitability and reliability of batteries or other energy storage devices shall be proved due to experience or tests.

(b) Characteristics of the energy storage devices, including failure modes (e.g. thermal runaway, expansion, explosion, toxic emission) should be identified. Batteries cells and other subcomponents of the system should be assembled and installed minimizing the effects of failures.

GM CS 22.963 (a): Battery cells should be qualified according accepted standards (e.g. EUROCAE/DO 311, UN T 38.3).

CS 22.965 Fuel tank tests

deleted

CS 22.967 Installation of energy storage devices

(a) Each energy storage device shall be installed by observing 22.627. In addition design precautions shall be provided to prevent chafing between its components and with supports or surrounding structure, if such chafing may arise.

(b) If it has not been proved that neither vapours nor fluids may separate out from the energy storage device, its compartment must be ventilated and drained.

(c) If the energy storage device is installed in the personnel compartment, it shall be demonstrated that adequate ventilation and drainage are provided, that the presence of the energy storage device will in no way interfere with the operation of the powered sailplane or the normal movement of the occupants, and that no leaking fluids and vapours will have direct contact to any occupant.

(d) Each energy storage device shall be installed to minimize the effects of the failure mode identified under CS 22.963. Design precautions might include:

- Providing the crew with the relevant information allowing to take proper actions (e.g. temperature or pressure monitoring),
- Mitigating the effect of thermal runaway or fire, and ensuring the surrounding structure might be able to withstand the thermal loads,
- Designing the compartment for the battery in order to cope with overpressure or expansion.

CS 22.969 to 22.1017 inclusive

deleted

CS 22.1041 Cooling - General

The cooling provisions shall be able to maintain the temperatures of all components, units and systems of the propulsion system within the established temperature limits during all likely operating conditions.

CS 22.1047 Cooling test procedure for engine-powered sailplanes

(a) To show compliance with the requirements in CS 22.1041, cooling tests shall be carried out according to the recommended take-off or climb procedure.

To be measured:

(1) Take-off with take-off performance of the engine, to be continued for one minute or 5 minutes climb with maximum power in case of self-sustaining sailplanes

(2) The climb shall be continued with the maximum continuous power until reaching the maximum temperature indication, and afterwards for 5 minutes or until reaching the minimum energy level according 22.959.

(b) The flight required under (a) shall be carried out at a speed not being higher than the best rate of climb speed with maximum continuous power.

(c) The maximum anticipated air temperature is to be fixed at 38°C at sea-level (hot-day conditions).

(d) The temperature of the engine, its units and systems shall be corrected in that way that the difference between the maximum anticipated air temperature and the ambient temperature at the time of the first occurrence of the maximum recorded temperature of the components shall be added to the latter.

CS 22.1091 Air induction for engine cooling

Air induction for engine cooling shall be ensured under all likely operating conditions.

CS 22.1093

deleted

CS 22.1103 Induction system ducts

(a) If induction system ducts are installed, they shall have a drain to prevent the accumulation of moisture in the normal ground and flight attitudes of the powered sailplane.

(b) Induction system ducts connected to components between which relative motion could arise shall have flexible connections.

CS 22.1105 Induction system screens

deleted

CS 22.1121 General

deleted

CS 22.1125 Exhaust manifold

(a) If an exhaust manifold exists, it shall be attached in such a way to withstand any dynamic stress and inertia forces, to which it may be subjected during normal operation.

(b) Parts of the manifold connected to components between which relative motion may exist, shall have flexible connections.

CS 22.1141 General

The part of each power plant control in the engine compartment that is required to be operated in the event of fire shall at least be of a fire-resistant material.

CS 22.1145 Engine master switch

The system should be protected against an inadvertent engine run.

CS 22.1149 Propeller speed and pitch controls

(a) Propeller speed and pitch shall be limited to values that ensure safe operation under normal operating conditions.

(b) Propellers that may not be controlled in-flight, shall meet the following requirements:

> (1) During take-off and initial climb at V_Y, the propeller must limit the engine speed at full constant speed drive or power regulator to a value not exceeding the maximum allowable take- off speed, and during a glide at V_{NE} or at a maximum allowable speed with power plant extended, with closed constant speed drive or power regulator or with power plant

„off“, the propeller must not permit the engine to achieve a rotational speed greater than 110 % of the maximum continuous speed.

(c) Propeller that may be controlled in-flight, but do not have constant speed controls must be designed in such a way that

(1) CS 22.1149 (b) (1) is met with the lowest possible pitch

selected and

(2) CS 22.1149 (b) (2) is met with the highest possible pitch selected.

(d) Controllable pitch propellers with constant speed control must comply with the following conditions:

(1) With the control unit in operation, there must be a device to limit the maximum engine speed to the maximum allowable take-off speed, and

(2) with the control unit being inoperative, there must be a device to limit the maximum engine speed to 103 % of the maximum allowable continuous speed with the propeller blades at the lowest possible pitch and the powered sailplane being stationary with no wind.

CS 22.1165 Engine ignition systems

deleted

CS 22.1191 Firewalls

(a) The engine shall be separated from the other parts of the powered sailplane by firewalls, casings or any other equivalent devices when there is the risk of a sustaining fire.

(b) Firewalls and casings shall be designed in such a way that no dangerous quantity of liquids, gases or flames may pass from the engine compartment into other parts of the powered sailplane.

(c) Firewalls and casings must at least be fire-resistant and protected against corrosion.

CS 22.1193 Engine cowling and nacelle

(a) Engine cowlings shall be designed and attached in such a way that they may withstand any stresses due to vibrations, masses and aerial forces, to which they may be exposed under operation.

(b) If leakage substances may arise, devices shall be provided to ensure a rapid and complete drainage of leakage substances from all parts of the cowling in the normal ground and flight attitudes. The drainage of leakage substances may not happen where they may cause a fire hazard.

(c) Engine cowlings must be at least fire-resistant when there is the risk of a sustaining fire.

CS 22.1305 Power plant monitoring instruments

Powered sailplanes with electric propulsion units shall be equipped with the following monitoring instruments:

(a) a tachometer for RPM indication or an output meter

(b) an indicator for the remaining energy quantity in the energy storage device

(c) an engine temperature indicator (or internal cooling indicator) (d) if a liquid cooling is installed, a coolant temperature indicator (e) an elapsed time indicator

CS 22.1337 Power plant monitoring instruments

deleted

CS 22.1353 Design and installation of energy storage devices

additionally

(d) Batteries or any other energy storage devices shall be installed in such a way that the occupants may not be endangered in case of a forced landing.

(e) Warnings, placards and procedures reducing the risk to ground personnel (rescue teams) should be provided.

(f) Energy storage devices should be contained in rugged casings or separate compartments to resist air, ground, and emergency landing loads and minimize identified hazards depending on the battery cell chemistry.

(g) Energy storage devices and the high voltage system should be adequately protected from probable leaking of fuel or water ballast and moisture in ventilated compartments.

(g) Batteries should include a main fuse directly at the energy storage device to isolate the system in case of a short circuit. A mechanical shutoff and/or battery isolation relays to disconnect both poles of high voltage batteries should be considered. A mechanical shut-off should not rely on any processor or software actions to provide electrical isolation of the battery.

CS 22.1365 Electric cables and equipment

additionally

(d) Electric cables shall be installed in such a way that electromagnetic and reciprocal influencing do not endanger safe operation (e.g. due to induction).

(e) The design and construction of the electric cable installation including routing, attachments and connectors shall minimize the risk of electric shock in high voltage systems (HV). The design shall incorporate electrical isolation-insulation materials capable of shielding the occupants and ground personnel from electrical shock under all operating conditions, e.g. flight in rain. No pins of connectors in high voltage systems should be exposed while under battery voltage. High voltage cables should be separated from fuel lines, control systems and low voltage cables.

(f) A ground fault detection system that provides the pilot or ground personnel a warning if the airframe is no longer fully electrically isolated should be installed for any electrical system in which the voltage can exceed 50 Vrms (AC) or 120 V (DC) under normal conditions and under single-fault conditions. Available devices may have two threshold indications: warning and critical.

(g) High Voltage cables have to be clearly identifiable and colour coded in bright orange. Warning placards marking HV components should be considered.

GM CS 22.1365 (e)

Automatic safety systems to ensure safety of pilot, maintenance and handling personnel and rescue personnel should be provided for HV systems. A shut-down circuit (interlock) which runs through all safety relevant parts of the system should disable the HV circuit (i.e. disconnect the battery isolation relays). It should be possible to activate the HV system only when the shut-down circuit is closed. If the shut-down circuit is interrupted at any point, the HV batteries should be disconnected by opening the battery isolation relays. An Automatic Shutoff should not create an additional hazard regarding a safe flight.

These safety relevant parts are HV master switch, emergency shut-down button, isolation monitoring device and all connectors in the HV power lines.

After opening the battery isolation relays, the voltage in the HV circuit should automatically drop to a safe level in a reasonable time (5-10 sec). An indication may be considered to show (to pilot and maintenance personnel) when the voltage in the HV circuit is above the low voltage limit.

An acceleration sensor might also be an option to interrupt the shut-down circuit in case of an emergency, reacting to forward acceleration like in an ELT, to provide automatic shut-down of the HV circuit in case of a crash landing.

CS 22.1553 Energy quantity indicator

An energy quantity indicator should inform the pilot of the remaining energy in the energy storage device.

a) The information shall be intuitive to the pilot, preferably have a coloured arc, colour coded bars or similar warning system denoting minimum energy reserves in accordance with CS 22.959, and

b) have a corresponding numerical readout showing remaining energy as suitable unit equivalent to the energy level.

c) Additional information needed to determine the quantity and availability of energy has to be provided.

d) For self-launching sailplanes it must be clearly identifiable if sufficient energy is available to perform a self-launch and climb according CS.951(b).

AMC CS 22.1553 (b)

Suitable units might kWh, per cent of capacity, remaining engine time or any other suitable unit equivalent to the energy level.

GM CS 22.1553 (c)

If required by the battery technology additional information on energy storage device status, such as temperatures might be needed, e.g. a cold battery might need to be heated prior engine start or charging.

END