180426 RevNew

ETX 900-TSO

Lithium Battery Maintenance & Instructions for Continued Airworthiness (ICA)

FAA Approvals

FAA Office(s)	Name	Date	Signature

Revision Log

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New	Created New	5/12/2018	R.Nicoson/B.Olsen

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Overview – Technology & Purpose

This manual covers TSO aspects of the Article (Part – LRU - Starting Battery) intended to be installed on 14 CFR part 23 Aircraft.

Installations of rechargeable lithium batteries defined herein, are expected to meet the guidance of AC 20-184. This TSO Battery meets the applicable TSO-C179a and is targeted for installation in 14 CFR part 23 Aircraft. Refer to AC 20-184 for full Aircraft installation guidance and requirements not the subject of this manual. This manual is for information in developing Aircraft specific certification plans and documentation for the target Aircraft's TDCS - certification basis requirements, to meet FAA rules for installations.

Rechargeable lithium battery installations must have a system to control the charging of the battery automatically, so as to prevent battery overcharging. The aircraft's voltage regulator must be in proper working order with a setting of 14.0 to 14.5 volts. Additionally, the aircraft charging system must have an over voltage protection device (OVPD).

The EarthX battery fault monitoring output, which is independent of the charging system, must be installed (Indication: LED or EFIS).

Aircraft designers must ensure that operational parameters and the environment in which the battery system is to be used are not more severe than that to which it has been designed and tested. Operation at discharge rates and temperatures exceeding design limits may potentially result in dangerous battery failure.

Additionally, the safety of the aircraft may be compromised, if the battery is not properly sized to provide adequate emergency power, according to the aircraft essential system design load and duration. Rechargeable Lithium battery systems, and the aircraft equipment for which they provide power, must be designed such that no single failure in either can cause a safety hazard to the passengers or crew of the aircraft. Refer to AC 20-184 for guidance.

Airworthiness Limitations

The conditions and tests for TSO approval of this article are minimum performance standards. Those installing this article, on or in a specific type and class of aircraft, must determine that the aircraft installation conditions are within the TSO standards. TSO articles must have separate approval for installation in an aircraft. The article may be installed only according to 14 CFR part 43 or the applicable airworthiness requirements. Below are the installation specific requirements and is not part of the TSO Part (LRU) specific certification under TSO-C179a:

- The maximum charge rating is 80 amps, so the aircraft charging system rated output must be 80 amps or less.

- The maximum voltage output from aircraft charging system shall not exceed 16 volts for greater than 100msec. Thus, automatic over voltage protection device (OVPD) is required on the aircraft charging system.

- Only modern 3-phase alternators or permanent magnet alternators approved for aircraft use are allowed as the charging source for this battery.

- The battery fault monitoring circuit must be installed and tested.

- The aircraft's Low Charge Level Warning, if applicable, must be raised to 12.6 volt (setpoint adjusted to 12.6 volt)

The Airworthiness Limitations section is FAA approved and specifies maintenance required under 43.16 and 91.403 of the Title 14 of the Code of Federal Regulations unless an alternative program has been FAA approved.

FAA APPROVAL:

_____	_____	_____
Printed Name/ Title	Signature	Dated

Instructions for Continued Airworthiness (ICA)

The supplemental Instructions for Continued Airworthiness (ICA) are required by 14 CFR part 23 for this Article (Part) installed on Aircraft. Target Aircraft are part 23 and 14 CFR 23.1529 applies for this application and TSO. AC 20-184 has been used as guidance in development of the supplemental ICA developed herein.

The Starting Battery (Function) is considered Primary in the electrical system for each of the Classes of Airplanes shown in Figure 2 of AC 23.1309-1E. The alternator charging system is considered Secondary for this ICA. Per AC 23.1309-1E and reference TSO-C179a, the Failure Condition Classification (FCC) for this TSO Battery is "Major". For this ICA and Battery there is no complex hardware or software. However, other installations may deem the analysis lessor or greater, dependent on the function in the particular installation Aircraft.

Aircraft Battery Special Care

Special care must be taken in the handling, shipping, and storage of rechargeable lithium batteries. As a result, installers, end users, and personnel involved in the maintenance, and disposal of rechargeable lithium batteries require training in the special characteristics related to rechargeable lithium battery safety. Herein you will find the manufacturers recommendations for maintenance and inspections as well as storage.

Only approved battery chargers shall be used.

Batteries other than those authorized/approved for a particular application must not be substituted even though they may be of the same physical dimensions, capacity, and voltage.

Other installation, maintenance and operation actions can have an impact on safe use. For example:

a. Mixing of Batteries – Mixing of batteries of different part numbers or manufacturers, or age is not an acceptable practice. Batteries of different age or capacities in series connection is NOT allowed for it will result in battery(ies) being over-discharged or overcharge.

b. Aircraft vibration may result in poor electrical connections. Applicable installation maintenance procedures must be followed.

c. Battery Polarity - Installing one or more batteries incorrectly, with the battery terminals reversed, will result in the reversed battery being charged by others in the circuit during discharge and discharged by the charging system during charge. This may also result in injury to the installer.

d. Exposed Terminals - Leaving battery output terminals or leads exposed may result in external short-circuiting of the battery during shipping, handling, testing and installation. Terminals of batteries shall be covered with non-conductive protective devices to avoid any possibility of shorting during handling, shipping, and storage.

Failure to follow all application use, installation, charging, and storage instructions may result in battery damage and/or fire!

Aircraft Battery Maintenance Requirements

The ETX900-TSO battery is a maintenance free battery. No inspection or testing is recommended for 24 months after purchase. Thereafter, maintenance to ensure that batteries whose function is required for safe operation of the aircraft, as long as the battery is installed in the aircraft, is necessary.

The following inspections/tests shall be performed on an annual basis (after first 24-month period), typically during annual inspection:

1) Visually inspect the battery for signs of damage; plastic case is cracked, warped or swollen.
2) Verify the battery fault monitoring LED circuit is operational. To do this, use a wire jumper to connect the battery's fault output wire to battery ground, and verify that the battery's internal fault LED is lit and that the external fault LED and/or EFIS indicator (on the instrument panel) is lit or indicating.
3) Ensure the battery is fully charged with an approved battery charger.
4) After fully charging the battery with an appropriate charger (voltage should be greater than 14.4V at end of charge cycle). Verify the battery is "holding a charge" by confirming the voltage is greater than 13.5 volt 24 hours after charging.
5) Verify the battery capacity. A battery's current capacity as compared to its original capacity is an indication of the battery's remaining service life. A battery with greater than 80% of its original "rated" capacity is consider fit for continued service. Alternately, if the batteries tested capacity is capable of supporting the aircraft's emergency load for the required amount of time it is consider fit for continued service. To test the battery capacity:

a. Fully charge the battery with an appropriate charger
b. Turn on all electrical loads for flight operation and start a timer.
c. Measure and record the battery's discharge amps using a DC clamp-on current meter at the positive terminal of the battery.
d. Using the measured amps in the previous step and the battery's nameplate rated capacity (in Ah), calculate the time to discharge the battery to 80%.

$$\text{Time to discharge 80\% (Hours)} = \frac{Rated\ Capacity\ in\ Ah * .8}{Measured\ Discharge\ Amps}$$

For Example (16 Ah Rated Capacity, 5 amp measured discharge rate)

$$\text{Time to discharge 80\%} = \frac{16 * .8}{5} = 2.56 \text{ hours}$$

e. Terminate the test after the number of hours calculated in the previous step has expired or if the battery is over-discharged (shuts off discharge current). If the battery is still supplying power at the termination of the test, then the battery's capacity is greater than 80%. If the battery's capacity is greater than 80% of it rated or capable of supporting the aircraft's emergency load for the required amount of time, then the battery has passed the test.
f. Fully charge the battery with an appropriate charger.

6) Verify battery terminals are clean and terminal screws are properly secured (torque to specification [30-35in-lbs] per the installation & maintenance manual).
7) Verify the vent tubes are not blocked (pinched or kinked).
8) Test complete, record in Aircraft Maintenance Manual or storage log.

Aircraft Battery Charging

Failure to follow these instructions may result in damage to the battery!

Never jump start from a car size battery or larger!

If at any time the vehicle will not start, or the battery seems low, or the voltage is less than 13.2 volt, charge it for the recommended time and charge rates shown below and disconnect the charger when charging is complete. The recommended charge rates are detailed in the specification section above. The maximum charge rate in the specification section is related to the vehicle charging system. Never exceed the maximum charging amps for your battery.

This table shows typical charging times for the battery:

Model	Charging Amps	Charging Time
ETX900-TSO	1 amp	16 hour
	5 amp	3 hour
	20 amp	45 min.

Lithium batteries have a very low self-discharge rate which means the battery, if disconnected from the aircraft, could "hold its charge" for over a year. However, some Aircraft may have systems that use a small amount of power with the "Master" off. In those cases, we recommend disconnecting a battery cable from the battery during long term storage (greater than 6 months).

The ETX Lithium battery is compatible with most 4cell LiFePO4 battery chargers. The "full charge" voltage for the ETX Lithium battery is 13.9V or higher. Use of a lead-acid battery charger is not permitted unless approved by EarthX.

If the battery has been over-discharged and "disconnected", the voltage at the battery terminal should be near zero volts if the battery still has a load on it. If the battery is disconnected from the load it will automatically reconnect and the terminal voltage will be between 9-12V (remove the load by removing the positive or negative cables from the battery). In this case, simply connect the battery to a charger to restore charge (charge with 5 amps for 20-30 minutes), and then re-check the voltage. If the voltage is 12.8V or greater, the battery should be ok and can be fully charged. If the battery that displays zero volts, check our website for a list of compatible chargers, and specifically chargers that will work for recharging an "over-discharged" battery (referred to as a BMS reset) for which the BMS's over-discharge protection has activated and won't reset automatically when the load is removed.

 **Never charge a faulty battery (a battery that will not accept a charge or hold a charge).**

 **Never use the de-sulfate setting on your charger.** Be sure the charger's output voltage level does not exceed 15V. If the charger does not display the voltage reading, then use a voltmeter to check the voltage while charging.

 **If the battery gets hot while charging, discontinue charging and use.**

 **Do not charge battery in temperatures above 140 degrees F (60C), or in direct sunlight.**

 **When charging a battery, place it on a non-flammable surface, and remove any flammable items nearby.**

 **For maximum battery and starting system life, do not crank an engine for more than 15 seconds within any 1 minute period.**

Aircraft Battery End of Life

The ETX900-TSO battery expected life is 6 years. The following conditions indicate battery end-of-life and the manufacturer recommends replacement to ensure continued airworthiness:

- Insufficient capacity per annual maintenance requirements
- Insufficient power to crank engine
- On-going battery fault indication
- Will not hold a charge per annual maintenance requirements
- 6 years of in aircraft service

At battery end-of-life contact EarthX for replacement options.

Batteries can be recycled at any location accepting lithium ion type batteries. Drain battery and or cover terminals with electrical insulating tape prior to recycling. For recycling information and where to recycle check this website (www.call2recycle.org/).

Airplane Flight Manual Supplement (AFMS) - Information

While in flight the battery fault indicator should be monitored. The fault indicator can annunciate several types of failures, such as battery cell failures, battery electronic failures and or aircraft charging system failures.

If the LED light turns on and remains on solid, it is an indication that the battery management electronics has failed. In this case, the battery should continue to provide power as normal, but the pilot shall pay more attention to the aircraft bus voltage. As long as the bus voltage remains normal, this is not an emergency. However, the battery shall be replaced prior to any future flights.

If the LED slowly cycles on and off, and the aircraft bus voltage is greater than 15V it is an indication that the aircraft's charging system voltage regulator has failed. In this case, the battery is functioning normally, but the pilot shall turn off or isolate the charging system to prevent a bus over-voltage event. Additionally, the pilot should make preparations to land prior to the battery's reserve capacity being depleted.

If the LED slowly cycles on and off, and the aircraft bus voltage is less than 13V it is an indication that the aircraft's charging system has failed. In this case, the battery is functioning normally, but the pilot shall make preparations to land prior to the battery's reserve capacity being depleted. Note, below 13V the battery is already deeply drained (as much as 80%).

If the LED slowly cycles on and off, and the aircraft bus voltage is within its normal range, it is an indication that one or more cells in the battery are failing. In this case the battery should continue to provide power as normal, but the pilot shall pay more attention to the aircraft bus voltage. As long as the bus voltage remains normal, this is not an emergency. However, the battery shall be maintained or replaced prior to any future flights.

Pilot Instruction – Tabular Information for Aircraft Documents

The instructions given here are generic and are NOT the sole pilot instruction for a particular aircraft. For a specific aircraft, refer to the instructions given in the TC or STC (AFMS).

The slow flashing fault can indicate:

1. An improper state of charge or a problem with the cells internal to the battery. If the battery voltage is outside the normal range of operation, 12.8V to 14.6V, the battery is over-discharged or over-charged, most likely the result of an issue with the electrical/charging system.
2. If the battery voltage is within the normal operating range, with a slow flashing fault, it is indicating an abnormal condition with a cell, such as one cell's state of charge is very different as compared to the other cells (high cell charge level imbalance).
3. Note: The slow flashing fault may come on briefly during or following periods of high current charging, and is not a concern. But if the fault persist, comes on consistently during changing, or remains (charging or not), the battery will need to be replaced.

The solid fault indicates a BMS hardware failure. For example, if the micro-controller fails the fault indication output is activated (on solid). If the fault persist, comes on and stays on, the battery will need to be replaced.

The fast flashing fault is an indication of high temperature; temperature exceeding the normal operating or storage limits of the battery.

The table below shows the most common fault conditions and possible causes:

LED Light	Voltage	Possible Cause	Recommended Action
Slow Flashing (5s on/5s off)	Less than 12.8V	Battery over-discharged (due to faulty charging system)	Charge battery. Once charged, the light should stop flashing.
Slow Flashing (5s on/5s off)	Less than 13.2V	Weak or failing cell	Charge battery. If voltage drops below 13.2V within a few days, discontinue use, replace battery.
Slow Flashing (5s on/5s off) (> 1 hour time period)	13.2V-14.6V	Weak or failing cell	Discontinue use. If in flight, this is not an immediate issue unless it is in conjunction with a charging system failure.
Slow Flashing (5s on/5s off)	Greater than 15.2V	Over-charging (due to faulty charging system)	If in flight, shutoff charging system immediately. Aircraft over-voltage protection is required for an alternator charging system that is greater than 20 amps requiring an over voltage protection device)

Slow Flashing (5s on/5s off) (< 30 min. time period)	13.2V – 14.6V	Cell to cell charge levels are not balanced	May come on briefly during periods of high current charging until the cells are automatically balanced. Try charging with an Optimate Lithium charger, etc..
Solid Light	Any voltage	BMS electronics issue	Discontinue use. If in flight, this is not an immediate issue unless it is in conjunction with a charging system failure.
Solid Light that turns off after 3 minutes	Any voltage	Short Circuit protection was activated	Nothing needs to be done.
Short Flashing (2s on/2s off)	Any voltage	High battery temperature (> 65°C / 150°F)	Let battery cool down prior to cranking or charging.

A sustained fault can indicate a serious issue with the battery or aircraft charging system that requires immediate attention. Discontinue use until the issue is resolved and the battery no longer indicates a fault. Continued use of a faulty battery can result in a cell rupture, the release of flammable vapors, smoke and/or a fire.

The table below shows the recommended user alerts based on voltages when in flight. The low charge level is very different from a lead acid battery as the lithium battery is completely drained at approximately 11.5V. Additional systems may be installed such as over – under voltage devices. Such a system may include:

Voltage	User Alert
>16V	High Voltage Warning (Red indicator), required for the ETX900-TSO Battery.
<13.5V	Alternator off-line Caution (Amber indicator), typical of an IBP – Power backup system.
<12.6V	Low charge level Warning (Red indicator) If installed, typical of an IPBS. Indicates discharge of a Lithium battery voltage.

Battery Maintenance - Storage & Handling

The MSDS is available on EarthX's website.

Always follow the manufacturers recommended safety precautions and procedures.

If the Aircraft is to be put in storage for an extended period of time, disconnect the battery cable to eliminate drain from the Aircraft's electrical system. A fully charged battery can be put in storage for over a year without charging.

Our batteries can be stored at temperatures between -40°C to +70°C. Our batteries have no liquid inside and will not freeze.

 Do not incinerate or expose to open flames!

Terminology

The following table describes the terminology used in this document.

Ah	Amp-Hour is a unit of measure of charge that can be stored in a battery.
BMS	The Battery Management System refers to the collection of electronics responsible for monitoring and controlling the cell charge level, providing over charge protection and over discharge protection
Cell	A single encased electrochemical unit (one positive and one negative electrode) which exhibits a voltage differential across two terminals.
OEM	Original Equipment Manufacturer
IEC	International Electro-Technical Commission on safety standards.

ETX900-TSO Battery - Part Number Revision

Part Number	Revision	Configuration (Release Date)
EXT900-TSO-REVA* BMS Part # Rev: BMS_DR RevF** Firmware Rev: V8.17C	A	0 (Initial)

* Design Assurance Level, C (major)
** Airborne Electronic Hardware