180407 RevA

ETX 900-TSO Lithium Battery User's Manual

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Revision Log

Rev	Description	Date
New	Created New	4/07/2018
А	Update to limitations, DO-311A	8/30/2018



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Overview

EarthX Lithium batteries are designed as a maintenance free replacement for the 12-volt lead-acid or lithium starter batteries. The Starting Battery (Function) is considered Primary in the electrical system for Category I and II part 23 Aircraft. The alternator charging system is considered secondary. Per 14 CFR 23.1309-1E and TSO-C179b, the Failure Condition Classification (FCC) for this TSO Battery is "Major" - unless other installations deem the analysis lessor or greater, dependent on the function in the particular installation Aircraft.

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

Technology Inside

Battery Cells

Our batteries use cells made of Lithium Iron Phosphate (LiFePO₄). This chemistry is one of the highest performance and safest on the market today.

Lithium batteries are fundamentally different than lead-acid batteries. A lithium battery voltage remains relatively constant while discharging, while voltage for a lead-acid battery decreases. As such, 16Ah lithium battery has the equivalent "useable" capacity to a 22Ah lead-acid. Also, a lithium battery's cranking power is stronger, for the voltage while cranking is generally higher.

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LiFePO₄ cells by the nature of their chemistry are 3.3 volt. 12V lithium batteries are created by using 4 cells in series (technically it is a 13.2-volt battery, but nominally full charge voltage is >13.3V). Lead-acid batteries are made with 6 cells in series. Another difference is that lithium cells are a dry cell technology, where the cells are packaged individually. As such, the individual cell's charge level will diverge with repeated charge/discharge cycles and age. This condition reduces the performance of the battery (reduces capacity), for the battery charge level is only as good as the charge level of the weakest cell.

BMS

EarthX's integrated Battery Management System (BMS), part number BMS_DR, monitors each cell's voltage as part of the cell balancing and over-charge protection. If the voltage of a cell exceeds the others, the BMS circuits will work to reduce that cell's charge level. This ensures that the charge level of all the cells remains equal, even with the high discharge (> 100Amps) and charge current (>10Amps) of your aircraft.

The ETX900-TSO BMS has the following features; over-charge protection, over-discharged protection (completely draining the battery), excessive cranking protection, high temperature protection and short-circuit protection. **The BMS was designed to Design Assurance Level (DAL), C (major).**

The BMS disconnects the battery from the load if it is drained to less than 5% remaining charge (an over-discharge condition). An over-discharged battery typically has a voltage less than 11.5V. If the BMS disconnects the battery, the voltage reading of the battery will be zero volts. Excessive cranking protection logic includes temperature monitoring to limit "high current use" (engine cranking) to 10 -30 seconds in any 60 second period. If the battery terminals are "shorted" (or a low impedance load is connected across terminals), which causes the battery volts to instantaneously drop to a very low level, the battery will disconnect from the load to protect the cells and BMS from damage (short circuit protection). If the BMS disconnects due to excessive cranking protection or short circuit protection, the BMS will automatically reconnect after a cooldown period (typically 1-3 minutes). The BMS is designed for short circuit protection > 1000 Amps.

All components associated with main electronic battery disconnect are redundant. The built-in redundancy ensures that no single point failure results in the battery unintentionally disconnecting. The battery also includes a thermal run-away containment system. The design aligns with the requirements for a FAA approved lithium battery as per RTCA performance specification DO-311A and DO-160.

In the event of a charging system failure where the voltage increases to above 15.5V, the resistance to charging current increases, and above 16V the charging current is completely blocked. The time delay for this feature is 2 seconds to allow the aircraft alternator's over voltage protection to activate first (typically less than 100ms). This design offers charge voltage protection greater than 60V. The discharge current (current out of battery) is unaffected in this situation. EarthX requires having automatic over-voltage protection (crowbar or other means of shutoff) for alternator type charging systems.

The battery's micro-controller monitors all failure modes, and reports failures with a built-in LED indicator and discrete output. The discrete output for external fault monitoring is a single wire connection with a ¹/₄" quick connect terminal. The output is a "current sinking" type circuit (see diagram below) that can handle 100mA (connects the discrete output to battery ground if a fault is present). This output can be connected to an external 12V LED or general purpose discrete input of an EFIS. The fault output has three states; fast flashing (2 seconds on/ 2 seconds off), slow flashing (5 seconds on/ 5 seconds off) or solid.

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

The slow flashing fault can indicate an improper state of charge or a problem with the cells internal to the battery. The solid fault indicates a BMS hardware failure.

Limitations

"This article meets the minimum requirements of technical standard order (TSO) C179b. Installation of this article requires separate approval." 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-C179b:

- The maximum charge rating is 80 amps, so the aircraft alternator rated output must be 80 amps or less.
- Automatic over-voltage protection 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 (see installation section of this manual).
- The battery vent system must be installed (see installation section of this manual).
- The aircraft's Low Charge Level Warning, if applicable, must be raised to 12.6 volt (setpoint adjusted to 12.6 volt).
- The battery must be installed in such a manner and or location to limit radiant and convection heating. The maximum short term environmental temperature of battery location should be less than 85°C. The battery should not be placed in close proximity to high temperature surfaces without the use of heat shields and or insulation.
- And other ratings as listed in the Specifications section of this manual.

The installation and maintenance must comply with the requirements of the Instructions for Continued Airworthiness (ICA), a separate document.

Specifications

Model: ETX900-TSO-REVx

Voltage	13.2 V
Capacity (1C, 1hour rate at 23 °C)	15.6Ah @ 1C rate (See below)
Capacity vs Temperature	25 °C = 100%
	$0^{\circ}C = 94\%$
	$-30^{\circ}C = 88\%$
Self-Discharge Rate	<3%/month @ 25°C
Peak Power (Ipp), 23/-18 °C	800 / 600 amps
Rated Power (Ipr), 23/-18 °C	390 / 365 amps
Max Continuous Discharge Amps	15.6A
(Discharging 100% of capacity)	
Standard Charge Voltage	13.9 - 14.6 V
Recommended Charger/Maintainer Amps	1 - 20A
Max Charge Amps	80A (from aircraft charging system)

Life (Charge cycles)	4000 cycles @ 1C discharge rate, 25°C (20%
	depth of discharge)
	2000 cycles @10C discharge rate, 25°C (80%)
	depth of discharge)
Life (Years)	6 Years
Weight	5.4lb
Dimensions	6.5in (L) x 3.1in (W) x 6.6in (H)
	166mm(L)x79mm(W)x168mm(H)
Environmental Rating (resistance to water	IP 66 (wash down with a high-pressure
intrusion)	washer)
Operating Temperature (short term)	-30 °C to +60 °C (+65 °C)
Storage & Ground Survival Temp	-45 °C to +70 °C
Short Term Ground Survival Temp	85 °C
Maximum Altitude	50,000 Ft
Shelf Life	1 year (without charging)
FAA Standard Order	TSO-C179b
Design Assurance Level (DAL)	C (major)
Flammability Rating (case and vent tube)	14CFR 25.853 (a)

Back View



Top View



Discharge Curves

Voltage is not a good indication of the state-of-charge in lithium batteries. The first graph below shows the state-of-charge versus voltage at a 1C discharge rate. Typically, lithium batteries require advanced methods like current counting to track the charge level. As seen from the graph, the voltage only varies .4V for nearly 80% of the discharge cycle at 25 Deg C. 13.4V is a good indication of full charge, while 12.8V is an indication of full discharge at 25 Deg C.

The graph below illustrate that usable Ah is nearly the same regardless of the discharge rate (discharge graph lines are nearly on top of each other), with the voltage remaining above 11.5V for most of the discharge cycle.



Discharge Capacity



Discharge Time

Discharge Versus Temperature

We use a similar Cold Cranking Amp test standard as the lead acid battery manufacturers (SAE test performed at 0°F, but 3 second discharge time vs 30 second). As such, our battery with a similar CCA rating as a lead acid battery should provide the same cranking performance at 0°F. But, below 0°F an equivalent lead acid battery will outperform a lithium battery (see the graph below).



Self-discharge Rates

The self-discharge rate is dependent on temperature. At high temperatures (>25°C), the cell internal resistance decreases so the self-discharge rate increases. See the graph below for self-discharge rates (in % per month) versus temperature.



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Like lead acid batteries, lithium batteries' discharge performance is lower as the temperature decreases, meaning the voltages and the Ah are lower. Note: there can be as much as a 15% decrease in Ah and discharge voltage at -30deg C as compared to 25 deg C.

Installation

The instruction given here is generic and is NOT the sole installation instruction for a particular aircraft. For a specific aircraft, refer to the installation instruction given in the STC.



Remove all metal objects from your person before handling the battery and use insulated tools for installation.

Battery Installation Location

The ETX900-TSO is designed to be mounted in a variety of locations within the aircraft including the engine compartment, baggage compartment or cabin as long as the environmental condition in those locations do not exceed the battery's specifications (see the specifications section and environmental qualification section of this manual). The battery can be mounted in any position.

Battery Installation

Lithium Iron Phosphate batteries are very robust, but if mishandled or misused they can rupture and they can burn. Never disassemble the battery or disable the built-in Battery Management System (BMS). Never expose the battery to fire or temperatures above 185° F or 85° C. Never short-circuit the positive and negative terminals of the battery. It is recommended you check the voltage before installing. If the voltage is below 13.2V, charge the battery before installing. Follow these steps to properly and safely install your new ETX Lithium battery.

- 1. Remove the old battery, while paying attention to the routing and placement of wires, cables and protective covers.
- 2. Check the battery cables and connectors for corrosion or damage. Pay special attention to the positive battery cable (red cable), checking for cuts or wear marks in the insulation. Clean and or replace the battery cables as required.
- 3. Connect the positive (red) cable first. Make sure the Phillips screw is securely fastened (30-35in-lbs), but do not over-tighten. Next, connect the negative (black) cable. Do not connect the battery in reverse polarity (positive to negative or negative to positive).
- 4. Re-install the battery holder or strap and tighten securely. Re-secure all the wires and cables with zip-ties or other fasteners. See specification section above for battery dimensions and for recommended battery hold down bracket positions on the battery.



Be careful that the positive battery terminal does not or will not touch any metal parts of the aircraft.

Battery Vent Installation

The ETX900-TSO includes a thermal run-away containment system. The containment system includes vent tubes designed to carry vapor or smoke to the exterior of the aircraft in the event of a thermal run-away condition. There are no emissions during normal operation. Both tubes exiting the battery are for outflow and both are required. Follow the below guidelines for properly installing the vent tubes.

- Route the vent tubes to the outside of the aircraft or a compartment sealed-off from the passenger cabin that is vented to the outside. Be sure emitted gases will not be directed to cabin air intakes.
- Secure the vent tubes within 12" of the battery and within 12" of the aircraft exit
- Be careful not to crush or restrict flow through the tubing.
- The minimum bend radius is 3"; tighter bends could cause the tubing to kink.
- Only EarthX supplied tubing should be used. The tubing is chemical resistant and rated for 500°F (1/4" ID, 5/16" OD Teflon tubing).

The supplied stainless steel elbows allow the vent tubes to be routed to the left or right side of the battery with minimal headroom requirements (1" above the battery height). The tube stubs on the battery are cut to different lengths so the tubing can be routed one on top of the other. To install the supplied elbows, it is helpful to heat the tubing to a couple hundred degrees F before pressing them into the tubes. Be sure the entire barbed part of the elbow is completely inserted into the tubing. Other barbed fittings may be used as long as they do not restrict flow.

The two $\frac{1}{4}$ " tubes may also be combined into a single tube with a minimum ID of $\frac{3}{8}$ ". Fittings must be brass or stainless if installed within 2 feet from the battery ($\frac{1}{4}$ " tube length of 2 feet). For fittings more than 2 feet from the battery they may be polyethylene or nylon. See figure below for tubing connections to the battery and clearances.

Installation of the battery in the cockpit is not recommended, unless the battery is properly vented over-board.

Fault Monitoring Installation

The ETX Hundred Series batteries have a discrete output that can be connected to many aircraft Electronic Flight Instrument System (EFIS) electronics or to a remote mounted LED. The diagrams below detail the required connections for both type installations.

To test the internal LED and or external LED, touch the fault monitoring wire to battery negative.

The discrete output for external fault monitoring is a single wire with 1/4" quick connect terminal. The 1/4" quick connect terminal is an insulated "female" type and should be compatible with most other manufacturers insulated male 1/4" quick connect terminals. The following two examples detail how to connect the fault monitoring output to an EFIS general purpose discrete input. The EFIS DC source negative must be referenced to the battery negative (this is the standard configuration).



Fault Monitoring Connection to Dynon Avionics

Configure the input as "active low", "alarm" type. Note; when Dynon power is off the LED inside battery may be dimly lit (less than 120uA, too small to drain the battery).



Fault Monitoring Connection to Garmin EFIS

Configure the digital input (contact input) as "active low", "user defined alert" type.



Fault Monitoring Connection to 12V LED

Voltage Monitoring Alert Recommendation

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, for a lithium battery is completely drained at approximately 11.5V.

Note: this table is for voltage level warning equipment supplied by others. This is not the Fault monitoring LED.

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Voltage	User Alert
>15V	High voltage warning (red indicator)
<13.5V	Alternator off-line alert (yellow indicator)
<12.6V	Low charge level warning (red indicator)

Accessory Parts

- Additional ¹/₄" tubing: 5239K13_G12 (12 feet length)
- Tee Tube Fitting: 180512

Replaceable Parts

There are no replaceable parts.

Installer Supplied Parts

- Vent port
- Hold down hardware

Operating Instruction

The instruction given here are generic and are NOT the sole pilot instruction for a particular aircraft. For a specific aircraft, refer to the instruction given in the STC.

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Normal Operation

Under normal operating conditions the battery performs as any lead acid battery, storing energy from the charging system and suppling it when the charging system is off.

Abnormal Operation

Under abnormal conditions that exceed the operating limits of the battery the battery may stop supplying power. Two such important examples are over-discharge and overtemperature. The over discharge protection shuts off outgoing power when the battery is 95% discharged (supplied 95% of its available energy). The over-temperature protection shuts off outgoing power when cells and electronics get too hot as the result of excessive cranking (i.e. cranking the engine for more than 15 seconds within a 1-minute period).

Monitoring

The slow flashing fault can indicate 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. 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). 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.

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 will 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.
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.

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

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 a plugin charger, like an Optimate Lithium charger.
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
Solid Light	Any voltage	BMS electronic 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. If in flight, this is not an immediate issue, but if it continues on subsequent flights, investigate and mitigate high temperature at battery location.



A sustained fault can indicate a serious issue with the battery or aircraft charging system that requires 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, and the release of flammable vapors, and or smoke (through vent system).

Maintenance

The ETX900 battery is a maintenance free battery with no internal replaceable components. Charging is only required as needed (see charging section in this manual). Inspection and testing is required annually:

- Visually inspect the battery for signs of damage; plastic case is cracked, warped or swollen.
- Test the fault indicator: to test, touch the fault wire output of the battery to ground the internal battery LED should on as well as the cockpit indicator.
- Ensure the terminal screws are tight (properly torqued)
- Capacity check: the battery should have a capacity greater than 80% of it rated or be capable of supporting the aircraft's emergency load for the required amount of time.

For more details, see the Instructions on Continued Air Worthiness (ICA) manual.

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.

1 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.

Storage

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 $+70^{\circ}$ C. Our batteries have no liquid inside and will not freeze.

Do not incinerate or expose to open flames!

Part Number Revision

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

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

Warranty

EarthX, Inc. (Manufacturer) warrants its ETX lithium batteries (hereafter referred to as Battery or Batteries) to be free of defects in material and workmanship for a period of two years. A dealership is not authorized to issue a replacement battery without prior authorization from EarthX, Inc.

The applicable Warranty period begins from the date of purchase with original receipt, or, if no receipt is available, from the manufacturing date on the battery. The warranty is nontransferable and for the original purchaser. Batteries determined to meet the conditions of this warranty will be replaced free of charge one time. Batteries for warranty replacement consideration are to be returned to: EarthX, Inc., P.O. Box 767, Windsor, CO 80550 after receiving an RMA from EarthX. EarthX's acceptance of any items shipped to EarthX for warranty replacement shall not be deemed an admission that the item(s) are defective. For international warranty returns, customer will pay the shipping expenses. Batteries replaced under the warranty provisions will carry only the remainder of the original applicable Warranty period.

See our website at <u>www.earthxbatteries.com</u> for details.

Troubleshooting

The ETX Lithium battery is an extremely reliable battery with a longer useful life than comparable lead-acid batteries.

Despite the high reliability, you may encounter situations where the battery does not operate as expected. Go to <u>www.earthxbatteries.com</u> and review the FAQ section for the most up to date comprehensive troubleshooting information.

Regulations / Standards

The ETX Hundred Series (ETX900-TSO), is designed and tested to the following safety regulations as outlined in:

- FAA Technical Standard Order TSO-C179b
- RTCA DO-311A, RTCA DO-160, DO-254
- IEC 62133-2
- CE EU consumer safety, health and environmental regulations.
- UN 38.3

These standards set the level of safety required for lithium batteries. The standard addresses normal and abnormal operating conditions.

Lithium batteries have special requirements for transportation (shipping) per UN 38.3 and Title (part) 49 of the Code of Federal Regulations or CFR's. Title 49 CFR Sections 100-185 of the U.S. Hazardous Materials Regulations (HMR).

Terminology

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.

The following table describes the terminology used in this document.

Appendix A

DO-311A Test Summary

Test Description	Section	Reportable Information
Physical Examination	2.4.4.1	Passed functional performance per DO-311A, Section 2.2.1.1
ATP	2.4.4.2	Passed functional performance per DO-311A, Section 2.2.1.2
Insulation Resistance	2.4.4.3	N/R - Plastic non-conductive case, no heaters
Handle Strength	2.4.4.4	N/R, no handle on battery
Capacity	2.4.4.5	Passed functional performance per DO-311A, Section 2.2.1.5
Capacity at Low & High Temperatures	2.4.4.6	Passed functional performance per DO-311A, Section 2.2.1.6
Constant Voltage Discharge for High Rate Batteries	2.4.4.7	Passed functional performance per DO-311A, Section 2.2.1.7
Charge Acceptance	2.4.4.8	Passed functional performance per DO-311A, Section 2.2.1.8
Charge Retention	2.4.4.9	N/R - EUT is energy category 3, test only required on category 4
Cycle Test for High Rate Batteries	2.4.4.10	N/R, -EUT is energy category 3, test only required on category 4
Rapid Discharge at Short Time Operating High Temperature	2.4.4.11	Passed functional performance per DO-311A, Section 2.2.1.11
Short Circuit with Protection Enabled	2.4.4.12	Passed functional performance per DO-311A, Section 2.2.1.12
Overdischarge	2.4.4.13	Passed functional performance per DO-311A, Section 2.2.1.13
Overcharge	2.4.4.14	Passed functional performance per DO-311A, Section 2.2.1.14
Short Circuit of a Cell	2.4.5.1	Passed functional performance per DO-311A, Section 2.2.2.1
Short Circuit without Protection	2.4.5.2	Passed functional performance per DO-311A, Section 2.2.2.1
Over discharge without Protection	2.4.5.3	Passed functional performance per DO-311A, Section 2.2.2.2
Single Cell Thermal Runaway Containment	2.4.5.4	N/R, this test is not required when thermal runaway containment testing is done with two or more cells in thermal runaway
Battery Thermal Runaway Containment	2.4.5.5	Passed functional performance per DO-311A, Section 2.2.2.4
Explosion Containment	2.4.5.6	Passed functional performance per DO-311A, Section 2.2.2.5
Drop Impact Test	2.4.5.7	N/R, this battery is not for a portable device

Remarks

There is no deviation to the test requirements. If test is marked N/R, it is not required due to the battery construction or battery energy category.

DO-160 Environmental Qualification Form

The following table is the DO-160 testing Environmental Qualification form.

Nomenclature: Rechargeable Lithium Battery System Model: ETX900-TSO Manufacturer's Specification: N/A Manufacturer: EarthX Address: 1111 Diamond Valley Dr, Windsor, CO 80550

TSO Number:

Revision & Change Number of DO-160: G, Dec8, 2010

Date Tested: Dec 22, 2017

Conditions	Section	Description of Tests Conducted
Temperature and Altitude	4.0	Equipment tested to Categories B3, A3
Low Temperature	4.5.1	
Loss of Cooling	4.3.2&4.3.3	Equipment identified as Category X, no
	4.6.1	auxiliary cooling
Altitude	4.6.1	Equipment tested to Cat. B5
Decompression	4.6.2	Equipment tested to Cat. A3, 50,000ft
Overpressure	4.6.3	Equipment tested to Cat. A3, -15,000ft
Temperature Variation	5	Equipment tested to Categories B
Humidity	6	Equipment tested to Categories B
Operational Shock and Crash Safety	7	Equipment tested to Categories B
Vibration	8	Equipment tested to Category R,S, and U aircraft zone 1 and 2 for fixed wing turbojet engine aircraft, fixed wing unducted turbofan engine aircraft, helicopters, and fixed wing reciprocating/turbojet engine aircraft (multi or single engine) less than 5,700kg using vibration test curves B,B1,C,C1,G,G1,L,M,R and F
Explosive Atmosphere	9	Equipment identified as Category X, no test performed
Waterproofness	10	Equipment tested to Categories R
Fluid Susceptibility	11	Equipment tested to Categories F Equipment spray tested
Sand and Dust	12	Equipment identified as Category X, no test performed
Fungus	13	Equipment identified as Category X, no test performed
Salt Fog	14	Equipment tested to Categories S
Magnetic Effect	15	Equipment tested to Categories X, no test performed
Power Input	16	Equipment tested to Categories B(RX), loss of power or low voltage tests not applicable for the equipment is a power source
Voltage Spike	17	Equipment tested to Categories A

Audio Frequency Conducted Susceptibility	18	Equipment tested to Categories B
Induced Signal Susceptibility	19	Equipment tested to Categories B(CX)
Radio Frequency Susceptibility	20	Equipment tested for conducted susceptibility to Categories R and for radiated susceptibility to Category R
Radio Frequency Emission	21	Equipment tested to Categories M
Lightning Induced Transient Susceptibility	22	Equipment tested to pin test waveform set A, level 2. Cable bundle test Category XXXX, no test performed
Lightning Direct Effects	23	Equipment identified as Category X, no test performed
Icing	24	Equipment identified as Category X, no test performed
Electrostatic Discharge	25	Equipment tested to Categories A
Fire Flammability	26	Equipment identified as Category X, no test performed
Other Tests: Flammable Material		Fire resistance tests were conducted in accordance with FAA regulations Part 25, Appendix F

Remarks

- A critical frequency was identified at 49-55 Hz (Y axis, battery in upright position), and was consistent throughout testing with no change.

-Fluid susceptibility test was conducted with the following fluids: piston engine fuel, synthetic hydraulic fluid, mineral based lubricating oil, isopropyl alcohol solvent, ethylene glycol, and insecticide.