


Installation & Maintenance Manual (IMM), ETX900- TSO Battery

Revision Log

| Rev | Description | Date |
|-----|---|------------|
| New | Created New | 4/07/2018 |
| A | Update to limitations, DO-311A | 8/30/2018 |
| B | Updated elect.& mech. Installation sections; Incorporate FAA AEG comments. | 11/24/2020 |

ICON KEY

 Valuable information


 Caution

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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.

This manual covers the TSO Article (Part) installation aspects for the ETX900-TSO Battery to be installed on 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 an accompanying manual to Instructions for Continued Airworthiness (ICA) manual.



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.



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.

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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.

Installation Requirements

“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, in-service requirements as identified in EarthX’s AML STC process document 18114-03 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.
- The maximum voltage output from aircraft charging system shall not exceed 16 volts. Thus, an automatic over-voltage protection device (OVPD) is required on the aircraft charging system.
- The battery fault monitoring indicator must be installed and tested.
- The battery vent system must be installed (see installation section of this manual).
- The cranking current demand should not exceed; a Peak Power (Ipp) 800/390 Amps (+23C/-18C), Rated Power (Ipr) 600/365 Amps (+23C/-18C). Note: Old CCA spec is Ipr at -18C.
- The capacity demand (storage requirement) should not exceed 31 Amps for 30 Minutes. Timely pilot identification and load shedding assumed per normal procedures. An Electrical Load Analysis (ELA) is required.
- The battery must be installed in such a manner and or location to limit radiant and convection heating. The maximum short term (30 minute) environmental temperature of battery location should be less than 65°C. The maximum short term (30 minute) environmental temperature of battery location while the aircraft is on the ground shall not exceed 85°C. The battery’s normal operating temperature is -30°C to 60°C.
- The battery should be secured in the existing battery box or battery holder as detailed in this manual and aircraft model specific STC IWD instruction.

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

Specifications

Model: ETX900-TSO-REVx

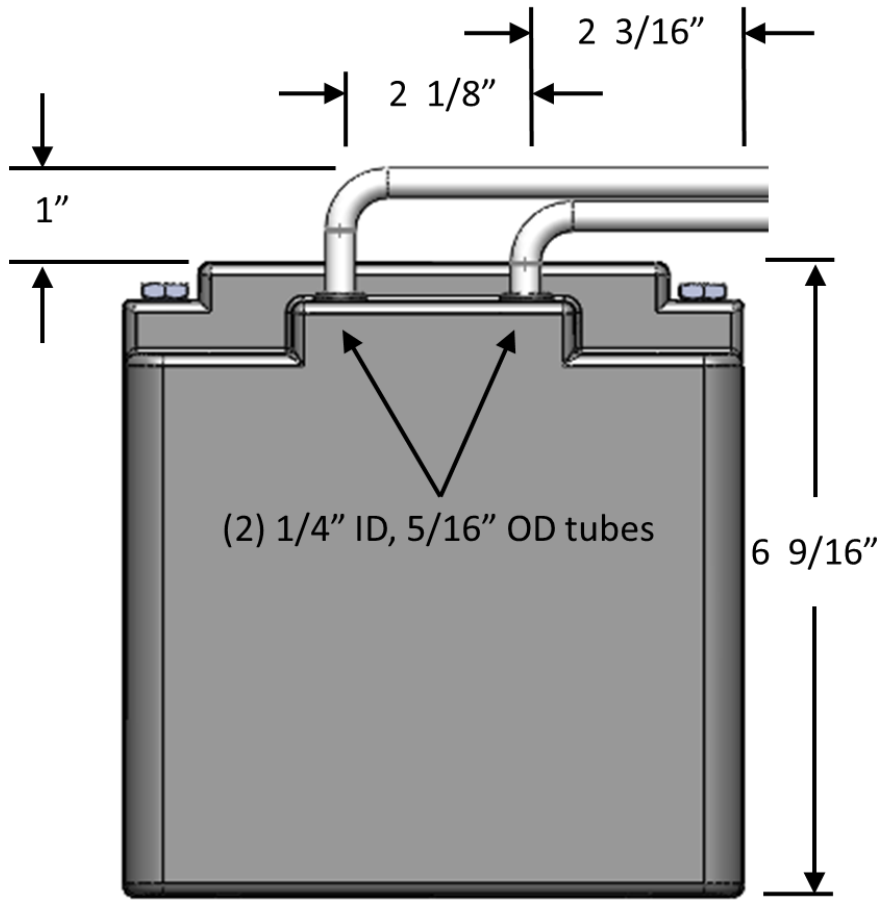
| | |
|------------------------------------|--|
| Voltage | 13.2 V |
| Capacity (1C, 1hour rate at 23 °C) | 15.6Ah @ 1C rate (See below) |
| Capacity vs Temperature | 25 °C = 15.6Ah 0°C = 15.3Ah -30°C = 15.0Ah |

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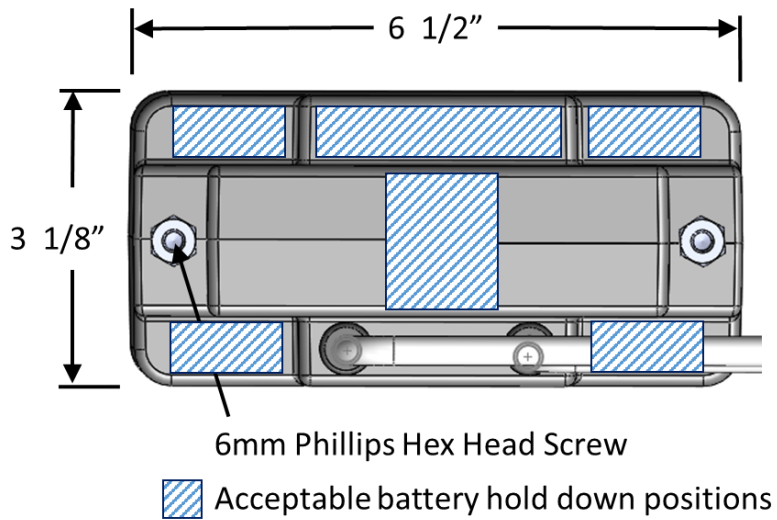
| | |
|---|--|
| Self-Discharge Rate | <3%/month @ 25°C |
| Peak Power (I _{pp}), 23/-18 °C | 800 / 390 amps |
| Rated Power (I _{pr}), 23/-18 °C | 600 / 365 amps |
| Max Continuous Discharge Amps (Discharging 100% of capacity) | 31A |
| Standard Charge Voltage | 13.9 - 14.6 V |
| Recommended Charger/Maintainer Amps | .8 - 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 intrusion) | IP 66 (wash down with a high-pressure 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 (30 minutes) |
| Maximum Altitude | 25,000 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) |

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Back View



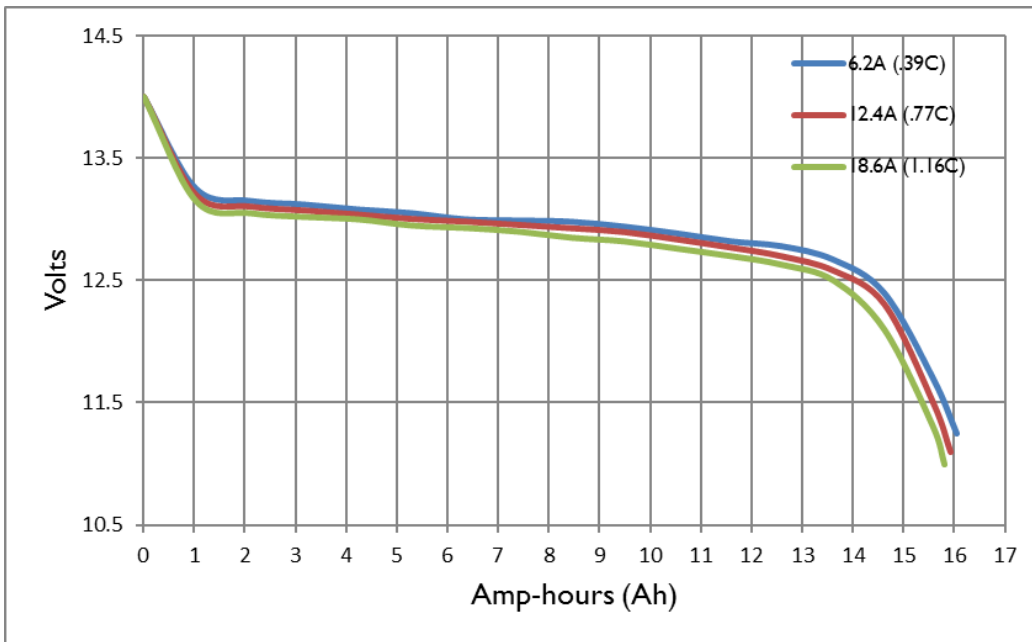
Top View



Discharge Curves

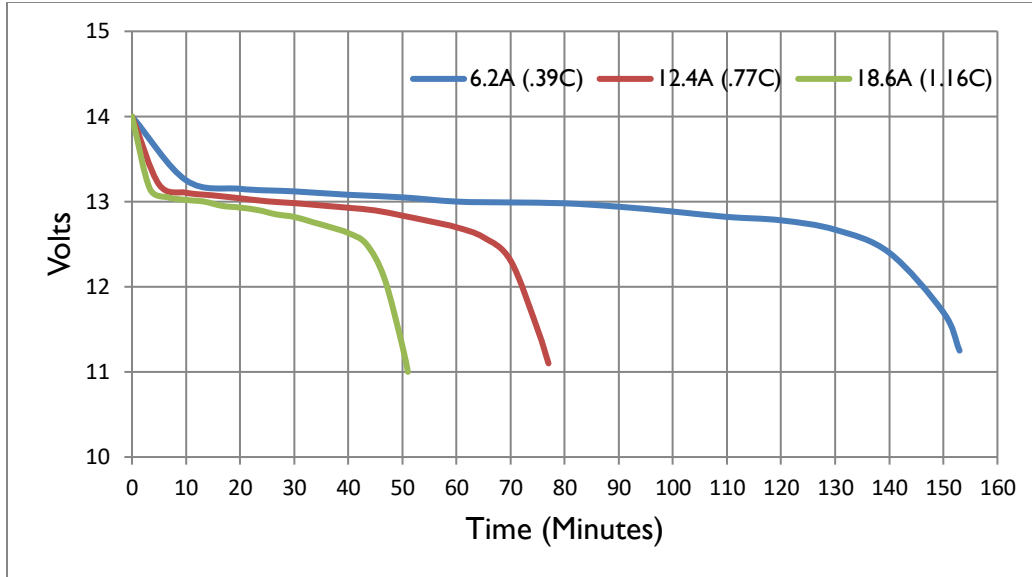
Voltage is not a good indication of the state-of-charge in lithium batteries. The first graph below shows the state-of-charge versus voltage at a 1C discharge rate. Typically, lithium batteries require advanced methods like current counting to track the charge level. As seen from the graph, the voltage 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

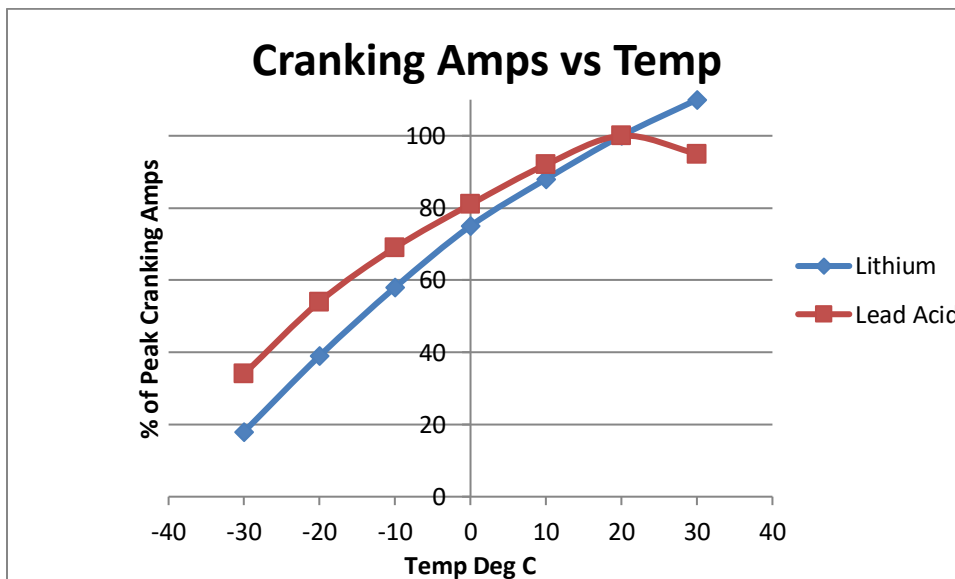
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Discharge Time

Discharge Versus Temperature

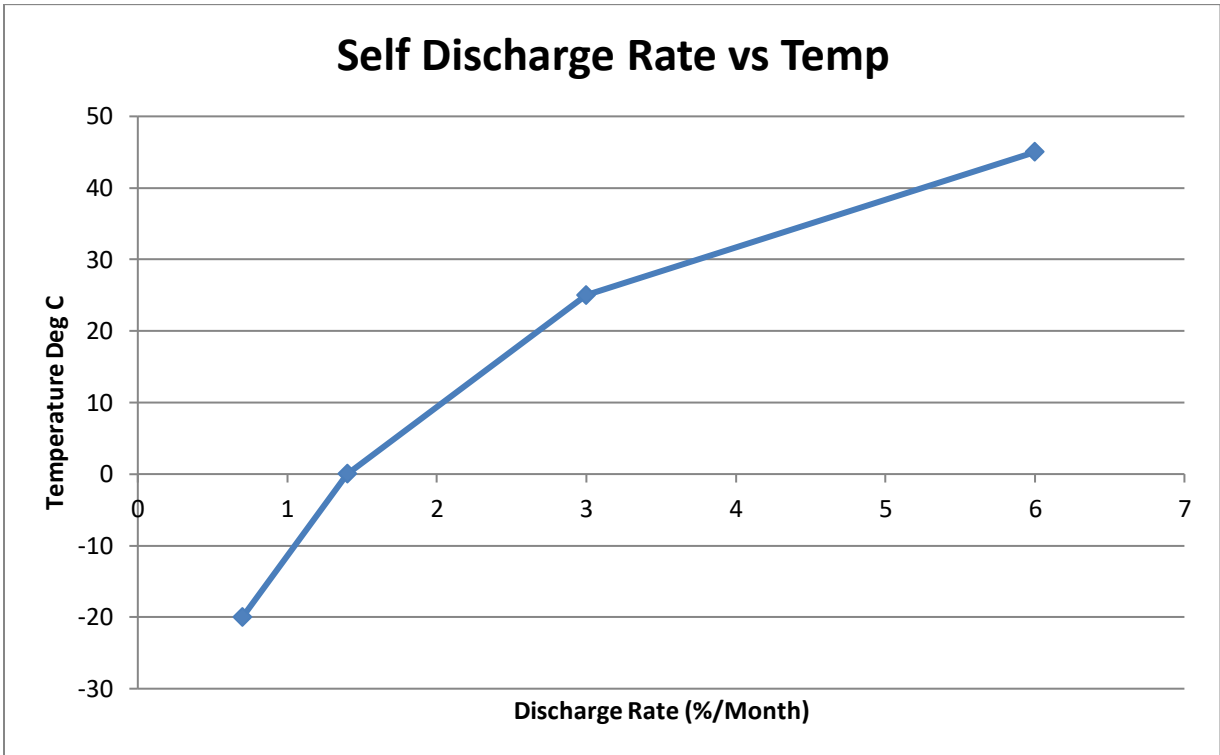
We use a similar Cold Cranking Amp test standard as the lead acid battery manufacturers (SAE test performed at 0°F, but 3 second discharge time vs 30 second). As such, our battery with a similar CCA rating as a lead acid battery should provide the same cranking performance at 0°F. But, below 0°F an equivalent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



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 -30°C as compared to 25 °C.

Self-discharge Rates

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



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 documentation listed in the Appendix of the Instructions for Continued Airworthiness (ICA) manual (180426).



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



The power terminals of the ETX-900-TSO are ALWAYS live. Do not short across the terminals. Use caution when handling the battery inside the aircraft around metallic structures.

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, such as upright or on its side.

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). 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. Mount the battery in the existing battery box with the approved spacer (see Appendix for specific instructions).
4. Connect the positive (red) cable first. Make sure the Phillips screw is securely fastened (45in-lbs), but do not over-tighten. Next, connect the negative (black) cable and tighten screw to 45in-lbs. Do not connect the battery in reverse polarity (positive to negative or negative to positive).

Re-install the battery holder or strap and tighten securely. Re-secure all the wires and cables with zip-ties or other fasteners. .



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. For specific installation instructions based on a specific model aircraft and or battery mounting location, see the Appendix. Plus, 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.
- Routing of vent tubes should include a 6” vertical section after exiting the battery and a downward slope so condensate drains to the outside of the aircraft.
- 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.

Fittings must be brass or stainless if installed within 2 feet from the battery (1/4” tube length of 2 feet). For fittings more than 2 feet from the battery they may be nylon. See figure in the specifications section above for tubing connections to the battery and clearances.



Installation of the battery in the cockpit requires the battery is properly vented over-board.

Fault Monitoring Installation

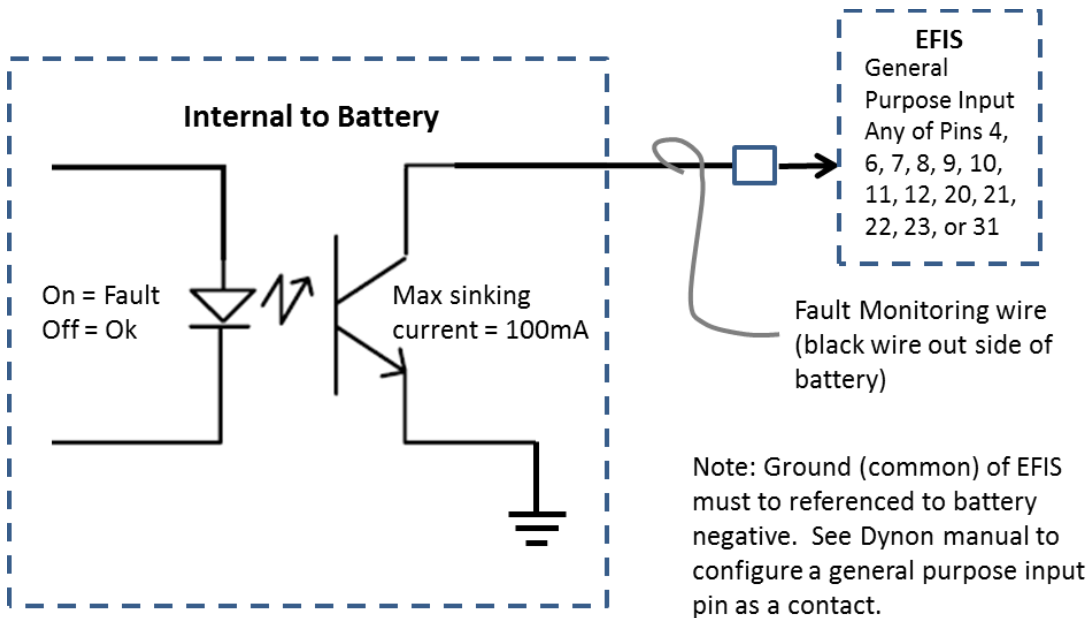
The ETX Hundred Series batteries have a discrete output that can be connected to many aircraft Electronic Flight Instrument System (EFIS) electronics or to a remote mounted LED. The diagrams below detail the required connections for both type installations. For specific installation instructions based on a specific model aircraft and or battery mounting location, see the Appendix or refer to the instruction given in the STC.

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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 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).

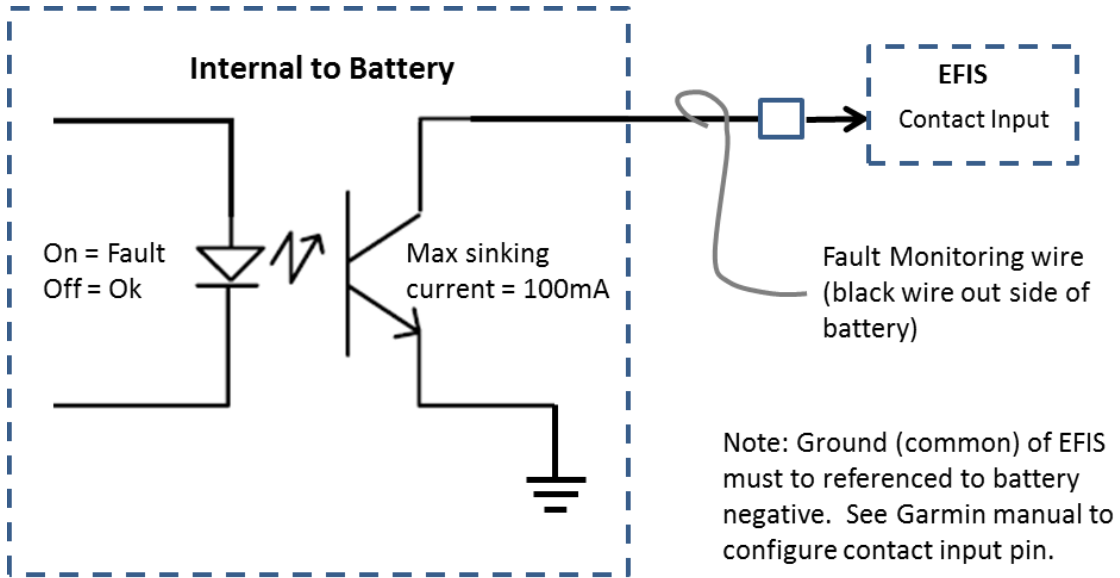
Fault Monitoring Connection to Dynon Avionics



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

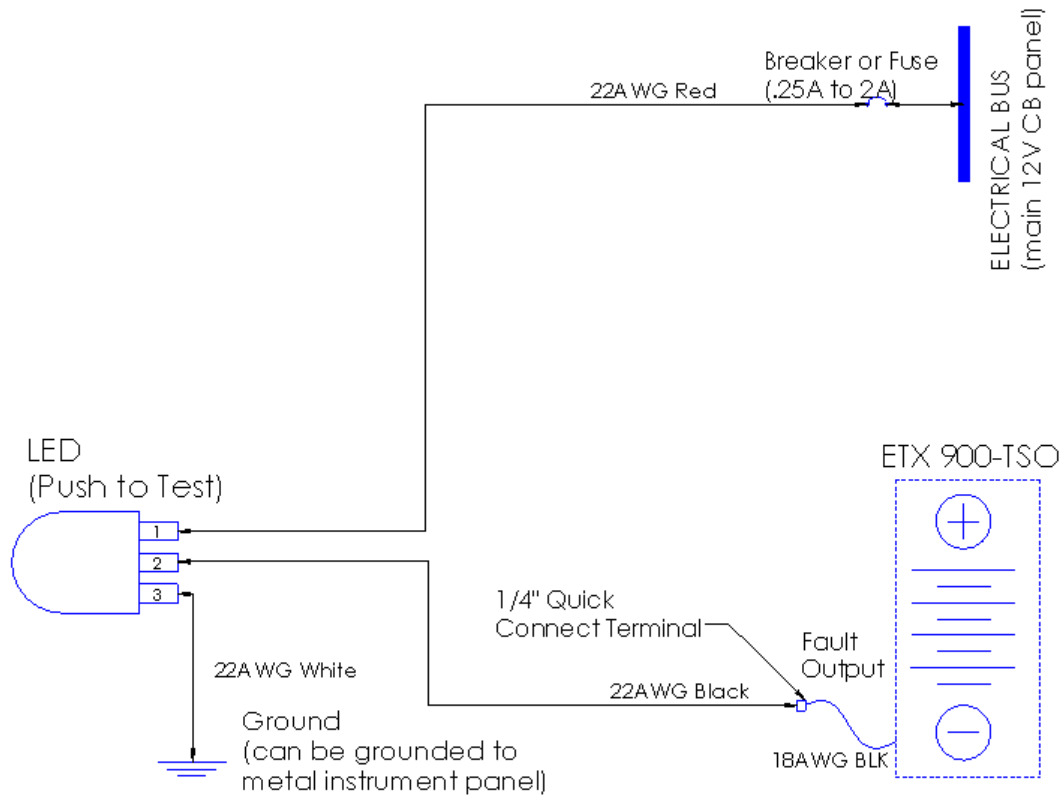
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Configure the digital input (contact input) as “active low”, “user defined alert” type.

Fault Monitoring Connection to 12V LED (Part # 11MM12)

Connect the LED’s red wire to a spare or existing fuse or breaker off the electrical bus. Use any .25 Amp to 2 Amp fuse or breaker. Connect the LED’s white wire to aircraft ground. The black wire is to be connected to the battery’s fault output (black wire), using a male 1/4” quick connect terminal.



Return to Service Checks (Tests)

Follow these steps to check the battery operation prior to returning to or putting in service:

1. Apply power to the aircraft via master switch, observe proper voltage, typically 13.2 to 14.2 V.
2. Verify the battery fault LED is off.
3. Press the LED “push-to-test lens” and observe the LED illuminates.

Aircraft Voltage Monitoring Equipment (if applicable)

The table below shows the recommended user alerts based on voltages when in flight. This pertains to existing aircraft equipment, and is not applicable if existing low or high voltage alerts do not exist or are not adjustable.

The low charge level is very different from a lead acid battery, for a lithium battery is completely drained at approximately 11.5V, and the normal resting voltage is 13.3V.

Note: this table pertains to existing voltage level warning equipment and is NOT associated with the Fault monitoring LED.

| Voltage | User Alert |
|---------|---------------------------|
| >15V | High voltage warning |
| <13.5V | Alternator off-line alert |
| <12.8V | Low charge level warning |

Accessory Parts

- Additional ¼” Tubing: 5239K13_G12 (12 feet length)
- 35 Ah Battery Spacer: 190531
- LED Kit: 11MM12

Replaceable Parts

There are no replaceable parts.

Installer Supplied Parts

- Vent port
- Hold down hardware

Operating Instruction

See the ICA for operating instruction, or for a specific aircraft, refer to the instruction given in the STC like an Aircraft Flight Manual Supplement (AFMS).



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. For more details, see the Instructions for Continued Airworthiness (ICA) manual (180426).

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 aircraft 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 and maximum charge rate is specified on the top label of the battery. 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 | 5 amp (TM291 Charger) | 3 hour |
| | 10 amp (TM275) | 1.5 hour |
| | | |

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 switch” off. In those cases, we recommend disconnecting a battery cable from the battery during long term storage (greater than 6 months).

Only an approved battery charger shall be used; Optimate TM291 (5 amp) or TM275 (9.5amp).

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 return to > 9volts (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 1-10 amps for 20-30 minutes), and then re-check the voltage. If the voltage is 12.8V or greater and holding a charge, the battery should be ok and can be fully charged. If the battery voltage does not return to >9 volt after removing any and all load. Then (step 1) connect the Optimate battery cables to the battery (red clamp to positive and black clamp to negative),

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next (step 2) plug the charger power cord into AC outlet. The charger should startup and go into the “Save” charging mode. If not contact EarthX technical support.

If using a Ground Power Unit (GPU), the current rating or current setting SHALL NOT be more than the max charge rate stated on the battery label or in this manual. It is recommended that a warning label is placed next to the GPU plug stating the max current allowed.



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.

Storage

If the Aircraft is to be put in storage for an extended period of time (> 6 months), disconnect the battery cable to eliminate drain from the Aircraft’s electrical system. A fully charged battery can be put in storage for up to a year without charging, but should be charged and inspected annually.

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!

Part Number Revision

| Part Number | Revision | Configuration (Release Date) |
|---|----------|--|
| EXT900-TSO* BMS Part # Rev: BMS_DR** | A | 0 (Initial) BMS_DR Rev G 4/22/2019 BMS_DR Rev H 7/5/2019 |
| | | |
| | | |
| | | |

* 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 dealer 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 non-transferable and for the original purchaser. Batteries determined to meet the conditions of this warranty will be replaced free of charge one time. For warranty replacement consideration, fill out the online warranty submission form located on the EarthX website. 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 www.earthxbatteries.com for details.

Troubleshooting

The table below is a summary of the battery's three fault modes of operation; solid, slow cycling or fast cycling 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 (alternator) not charging the battery. | Charge the battery. Verify aircraft charging system is functioning. |
| Slow Flashing (5s on/5s off) (> 1 hour time period) | 12.8-14.6V | Weak or failing cell | Charge the battery with an approved charger and observe fault LED. If LED persists, charge the battery a second time with approved charger. If the LED fault persists, the battery should be |

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| | | | |
|---|-----------------------|---|---|
| | | | replaced. |
| Slow Flashing (5s on/5s off) | Greater than 15.2V | Over-charging (due to faulty charging system regulator) | Verify aircraft charging system is functioning. |
| Slow Flashing (5s on/5s off) (< 60 min. time period) | 13.2V – 14.6V | Cell to cell charge levels are not equal. The battery’s BMS cell balancing circuitry needs time to re-balance the cell charge level. | Charge the battery with an approved charger and observe fault LED. If LED persists, charge the battery a second time with approved charger. If the LED fault persists, the battery should be replaced. |
| Solid Light | Any voltage | BMS electronics issue | Isolate the battery from the aircraft (disconnect positive or negative cable). Disconnect the battery’s fault wire from the aircraft’s LED or EFIS. If the fault LED on the battery is not extinguished, the battery should be replaced. |
| Solid Light that turns off after 3 minutes | Any voltage | Short Circuit protection was activated | Verify normal voltage (13.2 to 14.5 volt) at the battery terminals. Battery can be returned to service. |
| Short Flashing (2s on/2s off) | Any voltage | Battery temperature very high (> 85°C / 185°F) due to environment or excessive discharge. | If due to excessive discharge amperage, let the battery cool down prior to cranking or charging. If environmental temperature is too high, engineer means to cool battery when in service. |

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 www.earthxbatteries.com 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

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. |
| IWD | Installation and Wiring Diagram |
| OEM | Original Equipment Manufacturer |
| STC | Supplemental Type Certificate |
| IEC | International Electro-Technical Commission on safety standards. |

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. | | |

ETX TSO LITHIUM BATTERIES

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 | Equipment identified as Category X, no auxiliary cooling Equipment tested to Cat. B3 Equipment tested to Cat. A3, 50,000ft Equipment tested to Cat. A3, -15,000ft |
| High Temperature | 4.5.2&4.5.3 | |
| Loss of Cooling | | |
| Altitude | 4.6.1 | |
| Decompression | 4.6.2 | |
| Overpressure | 4.6.3 | |
| 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 |

ETX TSO LITHIUM BATTERIES

| | | |
|---|----|---|
| 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 |
| <p>Remarks</p> <ul style="list-style-type: none"> - 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. | | |