

Installation Manual and Operating Instructions

TRUE BLUE POWER

**TB20
SERIES**

ADVANCED
LITHIUM-ION BATTERY

Manual Number
9019286



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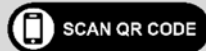
FOREWORD

This manual provides information intended for use by persons who, in accordance with current regulatory requirements, are qualified to install this equipment. If further information is required, please contact:

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We welcome your comments concerning this manual. Although every effort has been made to keep it free of errors, some may occur. When reporting a specific problem, please describe it briefly and include the manual part number, the paragraph/figure/table number and the page number. Send your comments to:

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REVISION HISTORY

| Rev | Date | Detail | Approved |
|------------|-------------|--|-----------------|
| A | 08/02/2019 | Initial release. | BAW |
| B | 10/01/2019 | Revised EQF, added DO-311A Compliance Qualification Form and provided additional limitation details (sec 2.5) | WVC |
| C | 05/21/2020 | Updated style and brand to meet Marketing and Engineering guidelines. Added downloadable event log feature and instructions to load/download custom configuration parameters. Updated DO-160 qual and installation instructions to include grounding recommendations. | DLR |
| D | 01/22/2021 | Revised mounting instructions and minor updates related to software version 1.0.2. | WVC |
| E | 01/06/2022 | Added recommended chargers; updates related to software version 1.0.3; updated EQF. | WVC |
| F | 06/23/2022 | Updated ARINC 352 status; revised EQF. | VAA |

SECTION 1 GENERAL DESCRIPTION

1.1 INTRODUCTION

The TB20 series Advanced Lithium-ion Battery, part numbers 6430020-(), are designed to deliver high current capability to start piston and light turbine aircraft engines and subsequently, provide power to the aircraft electrical bus in the event of generator function loss. The TB20 is a sophisticated energy storage and power system that utilizes state-of-the-art Nanophosphate[®] lithium-ion battery cell technology to optimize performance, safety, life and weight when compared to traditional or competing aircraft batteries. The design of the battery includes detailed focus on key electrical, mechanical, and software elements that combine to provide exceptional performance and safety that meets and exceeds the latest regulatory and industry standards. The TB20 is a complete battery solution providing significant value and benefit to an aircraft designer, owner and operator.

Key features of the TBX series (inclusive of the TB20, TB30, TB40 and TB60) include real-time state of charge and capacity reporting, programmable battery parameters configurable to individual installations, and maintenance-free operation with on-condition end of life. Multiple safety protections, continuous data monitoring, and an on-board status indicator also add value, reliability, and reduced cost of ownership for the life of the product.

The TBX series Advanced Lithium-ion Batteries require professional use and minimal service to deliver maximum performance and value as designed. This manual contains information related to the specifications, installation, operation, storage, scheduled service and other related topics associated with the proper care and use of this product.

1.2 PHYSICAL ATTRIBUTES

The TB20 is a single, integrated component contained in a metal enclosure with multiple interface connections. There is a primary 2-pin, industry standard mil-spec quick disconnect power receptacle, an 18-pin circular communications connector, and a threaded grounding location. A USB service port and an integrated push-button status indicator with LED indicators are available for ground operations as well. The lid of the enclosure includes two hold-down features on either side to support typical aircraft mounting. A handle integrated into the lid of the enclosure provides ease of lifting and carrying for installation, removal and transport. The 1.25 inch diameter vent port can be located on either the front or left side of the unit for an exhaust connection that directs any released emissions appropriately.

1.3 UNIT ARCHITECTURE

The unit is comprised of two primary building blocks:

- Battery cell modules with on-board monitoring, logic, and protections
- Battery Management System (BMS) with control and communication functions

Each battery module consists of thirty-two (32) cells arranged as eight (8) groups of four (4) parallel cells, connected in series. The cells are connected with welded bus bars which contain an individual fuse for each cell in the module. Each module contains multiple temperature monitors and an integrated heater that improves cold weather performance. Two modules connected in parallel through a network of bus bars provide combined power to the main connector and thus the aircraft.

The Battery Management System (BMS) is a microprocessor-based system that monitors individual signals provided by each module, manages battery operation and reports status information to the aircraft. It also manages heater functionality, stores operating parameters, contains an event log and provides interface capability.

Additional components in the unit include independent Resistance Temperature Detectors (RTDs) that produce analog electrical signals accessible through the 18-pin connector for redundant temperature monitoring.

1.4 TECHNICAL SPECIFICATIONS

| Electrical Attributes | |
|--------------------------------------|---|
| Power Input | 28.8 volts DC Nominal, 200A Max |
| Power Output | 26.4 volts DC Nominal, Continuous Current 525A; Power Peak Current (I _{PP}) 900A (at 18V CV discharge); Power Rated Current (I _{PR}) 700A (at 18V CV discharge) |
| Battery Capacity (Beginning of Life) | 20 amp hours (Ah) @ 23°C |

Table 1.1

| Physical Attributes | |
|--|---|
| Weight | 19.5 pounds (8.9 kg) |
| Dimensions at base (not including vent, lid and connectors) | 6.0 x 8.2 x 9.3 inches (see Figure 1.1) [153 x 208 x 236 mm] |
| Quick Disconnect Power Receptacle | 2-pin per MIL-PRF-18148/3 form factor (MS3509) |
| Communications Connector | 18-pin per MS3114E14-18P |
| USB Service Data Port | USB 2.0, Type-A port |
| Mounting | See Section 3.4.2 |

Table 1.2

| Qualifications | |
|-----------------------------|--|
| Certification | FAA TSO-C179b, Class A-4B |
| Performance Qualification | RTCA/DO-311A Minimum Operational Performance Standard for Rechargeable Lithium Batteries and Battery Systems (See Section 5.9) |
| Environmental Qualification | RTCA/DO-160G (See Section 5.10) |
| Software Qualification | RTCA/DO-178C, Design Assurance Level (DAL) A |

Table 1.3

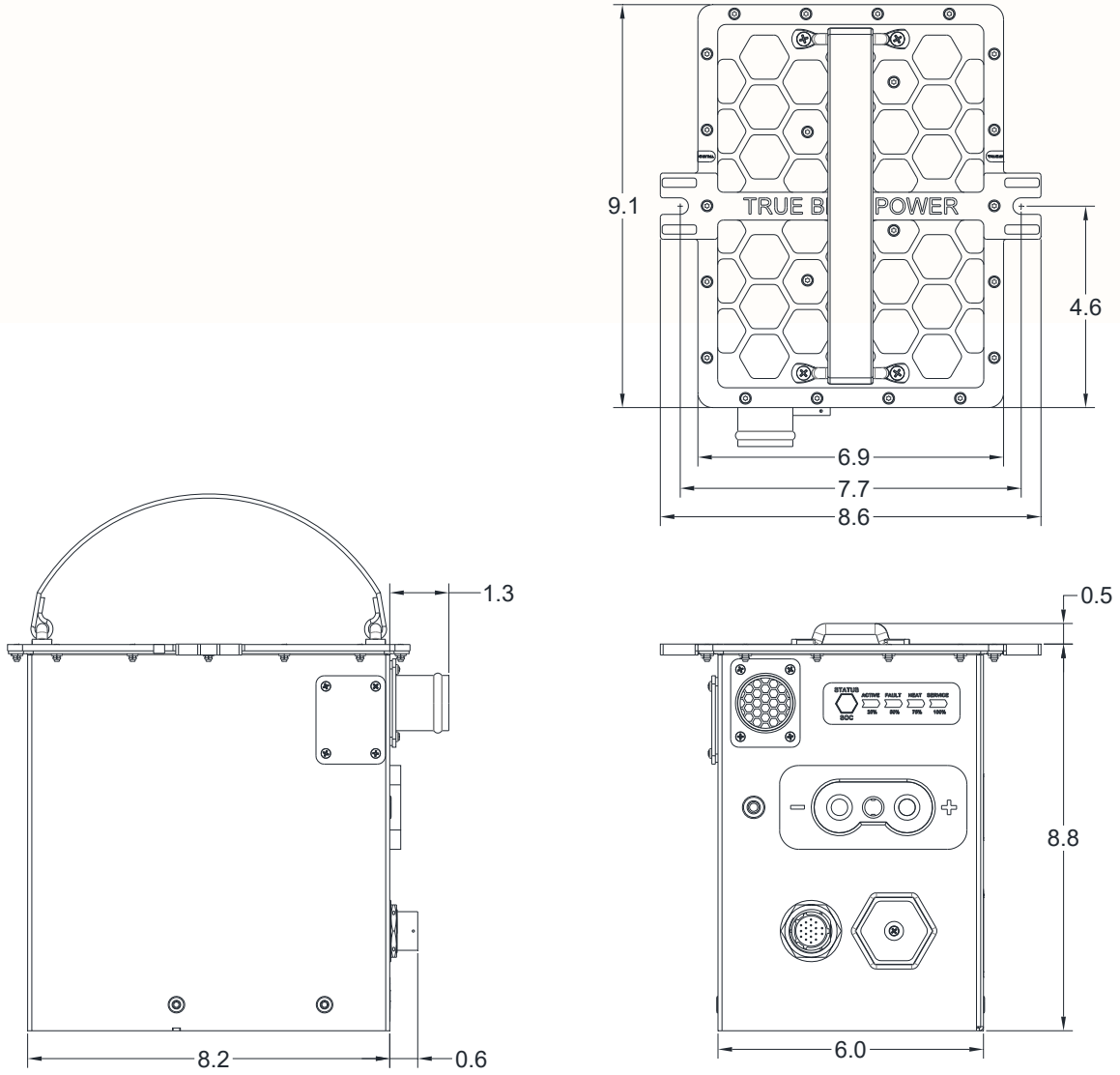


Figure 1.1
Outline Drawing

1.5 IMPORTANT SAFETY INFORMATION

Read this safety information BEFORE maintaining or servicing the battery.

1.5.1 Symbol Definition

This section describes the precautions necessary for safe operations. The following safety symbols have been placed throughout the guide.



Warnings identify conditions or practices that could result in personal injury.



Cautions identify conditions or practices that could result in damage to the equipment.

1.5.2 Handling Precautions



The battery pack's energy is high enough to sustain an ARC flash. Always wear safety glasses, fire retardant smocks, and use insulated tools when servicing the battery.

- Remove metal items such as rings, bracelets, and watches when working with battery packs. A battery could produce a short circuit current high enough to weld jewelry to metal and cause a severe burn.
- Always use appropriate Electrostatic Discharge (ESD) protection while working with the battery pack.
- All connections for battery pack testing must include appropriate short-circuit protection.
- The battery pack service area shall be properly ventilated and egress paths shall be unobstructed.
- Specialized breathing filters are not required under normal use.
- Always use electrically insulated tools.
- Never smoke or allow a spark or flame near the battery pack.
- Use caution to reduce the risk of dropping a metal tool on the battery. Dropping a tool could spark or short circuit the battery pack.
- Turn all accessories off before removing the ground terminal.
- Use appropriate lifting devices or equipment for handling batteries; use battery handles where provided.

1.5.3 Additional Precautions

The following design and operation factors are required for safe use.



- It is not acceptable to combine or use any battery cells or modules other than those approved by True Blue Power within this battery pack.
- There are no limitations in storing or using this battery in the vicinity of other battery chemistries. This battery does not emit or absorb any gas during storage, transportation or during normal operating conditions.
- Batteries must not be installed with the output terminals reversed. A reversed battery could be charged by other batteries in the circuit during discharge; or discharged by the charging system during charge.
- Battery terminals must be covered with non-conductive protective devices to avoid any possibility of shorting during handling, shipping or storage.

1.5.4 Shipping

True Blue Power lithium-ion cells and batteries are designed to comply with all applicable shipping regulations as prescribed by industry and regulatory standards. This includes compliance with the UN recommendations on the Transport of Dangerous Goods, IATA Dangerous Goods Regulations, applicable U.S. DOT regulations for the safe transport of lithium-ion batteries, and the International Maritime Dangerous Goods Code. In accordance with IATA and per UN 3480, PI 965, Section 1A and 1B, when shipped by air, the True Blue Power Advanced Lithium-ion Battery will be shipped with a state of charge (SOC) not to exceed 30% of rated capacity. This battery is classified as a Class 9 Dangerous Goods. If the battery requires shipment, please refer to Section 5.4.5 or contact the manufacturer for additional instructions on proper procedures.



NOTE: The unit is shipped with approximately 30% state-of-charge (SOC). Upon receipt the battery shall be fully charged using the procedures listed in this manual (prior to storage and again prior to installation/use).

Upon receipt the battery shall be fully charged. Batteries that are stored thereafter shall be fully recharged at a minimum every six (6) months, following the procedure set forth in Section 5.4.2. For more detailed storage instructions refer to Section 5.6.

SECTION 2 PRE-INSTALLATION CONSIDERATIONS

2.1 COOLING

No internal or external cooling of the unit is required. The unit is designed to operate over a wide temperature range and includes internal thermal monitoring and protection circuits. See Section 4 for more details.

2.2 EQUIPMENT LOCATION

The True Blue Power Advanced Lithium-ion Battery is designed for mounting flexibility, allowing for installation with no requirement for temperature or pressure control. Although not required, optimum performance and life can be achieved by mounting the battery in a temperature controlled section of the aircraft. In addition to altitude and temperature tolerance, the unit is designed to withstand high levels of condensing humidity. However, installation locations where the unit could be subject to standing or direct water exposure should be avoided. The unit should be mounted in the upright position.

Failure mode, effects, and criticality analysis of the battery has shown that the potential for the release of toxic or flammable gases as a result of any potential condition is extremely improbable. However, for additional risk mitigation, the unit is designed with a vent which should be connected and diverted overboard in the event of such an occurrence. Details for vent installation are provided in Section 3. For additional precaution, installation near potential sources of ignition should be avoided.

Consideration should be given to how the status and reporting functions of the battery will be displayed within the aircraft. At a minimum, critical parameters determined at the time of certification should be available to the pilot and/or crew. Additionally, existing aircraft systems which are designed to work with traditional batteries may need alteration in order to accommodate the slight change in voltage output of this lithium-ion battery and the communication capabilities available.

2.3 ROUTING OF CABLES

The power terminal wires associated with the unit are heavy gauge wire and carry significant power. Be aware of routing cables near other electronics or with other wire bundles that may be susceptible to high energy flow.

Avoid sharp bends in both the power cables and the signal cabling and be cautious of routing near aircraft control cables. Also avoid proximity and contact with aircraft structures, avionics equipment, or other obstructions that could chafe wires during flight and cause undesirable effects. Cables should not run adjacent to heaters, engine exhausts, or other heat sources. The signal cable bundle wires are recommended to be no smaller than 24 gauge.

2.4 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 or class of aircraft, must determine that the aircraft installation conditions are within the TSO standards. TSO articles must receive additional installation approval prior to being operated on each aircraft. The article may be installed only according to 14 CFR Part 43 or the applicable airworthiness requirements.

The TBX series operates at temperatures up to 70°C. If, however, internal cell temperatures exceed 72°C, charging is disabled until cell temperatures fall below 62°C.

2.5 MODIFICATION

This product has a nameplate that identifies the manufacturer, part number, description, certification(s) and technical specifications of the unit. It also includes the “MOD” or modification number representing notable changes in the hardware design of the unit.

Modification (MOD) 0 is the initial release of the product and is identified on the nameplate by the lack of marking on the MOD numbers 1 through 9 (i.e. 1-9 are visible). All subsequent modifications are identified on the nameplate by the marking/blacking out of that particular MOD number (i.e. for MOD 1, the number 1 is not visible and 2-9 are visible - see Figure 2.1 for examples). MODs do not have to be sequentially inclusive and may be applied independent of each other.

For additional details regarding specific changes associated with each MOD status refer to the product published Service Bulletins at www.truebluepowerusa.com.

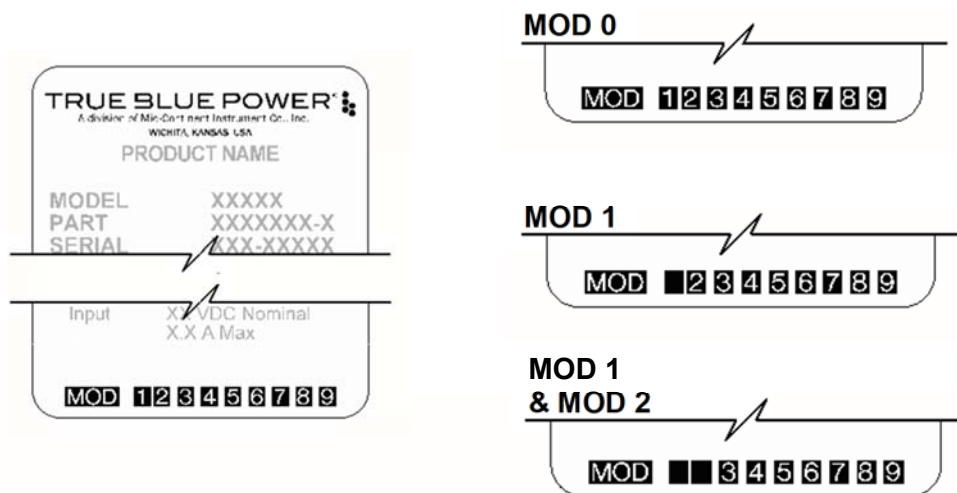


Figure 2.1
Nameplate and MOD Status Example

SECTION 3 INSTALLATION

3.1 GENERAL

This section contains mounting, electrical connections and other information required for installation. These instructions represent a typical installation and are not specific to any aircraft.

3.2 PRE-INSTALLATION INSPECTION

Unpacking: Carefully remove the battery from the shipping container. The shipping container and packing are designed specifically for the transit of lithium batteries and approved by international transportation agencies. These materials should be retained for use should the unit require future shipment.

Inspect for Damage: Inspect the shipping container and unit for any signs of damage sustained in transit. If necessary, return the unit to the factory using the original shipping container and packing materials. File any claim for damages with the carrier.



Note: The unit is shipped at approximately 30% state of charge (SOC). Upon receipt, the battery shall be fully charged using the procedures listed in this manual (prior to storage and again prior to installation/use).

3.3 PARTS

3.3.1 Included Parts

- | | |
|--------------------------------------|----------------------|
| A. TB20 Advanced Lithium-ion Battery | MCIA P/N 6430020-() |
| B. Installation and operation manual | MCIA P/N 9019286 |

3.3.2 Available Parts

- | | |
|----------------------------------|-----------------------|
| A. Connector Kit | MCIA P/N 9018042-1 |
| i. Power Connector Kit | |
| ii. Communications connector kit | |
| B. Vent Kit | MCIA P/N 9019322-1 |
| i. High temp vent hose (48") | |
| ii. Vent clamps (x2) | |
| C. Mounting Kit | MCIA P/N 9019576-1 |
| i. Corner Brackets (x4) | |
| ii. Silicone Pad | |
| D. MX Charger | MCIA P/N 282-101 |
| E. PRO Charger | MCIA P/N ACM-1260-101 |

3.3.3 Installer Supplied Parts

- A. Wires
- B. Appropriate hold-down hardware

3.4 INSTALLATION



DO NOT SHORT TERMINALS AT ANY TIME!

Extreme care and caution should be applied when handling and connecting to the unit. Danger of short circuit and subsequent arc flash, electrical burns or equipment damage can occur if not handled properly.

Install the battery in the aircraft in accordance with the aircraft manufacturer's instructions and the following sections. If connecting batteries in parallel contact manufacturer for guidelines on parallel operation.

3.4.1 Harness Preparation

Prepare aircraft wiring with mating connectors in accordance with the proper Wire Size and Type (Table 3.1), Connection Features (Figure 3.1) and Pin Identification Diagrams (Figures 3.3 and 3.4).

Proper grounding requires connecting the ground lug on the chassis to the aircraft frame. In addition, connect the ground lug to the 18-pin data communication connector backshell along with the cable shield and any signal shields.

Use of PTFE, ETFE, TFE, Teflon or Tefzel insulated wire is recommended for aircraft use. Recommended wire sizes and types are identified in Table 3.1 below. *Note: Wire gauge size for power connections is dependent on the particular aircraft installation, taking into consideration cable length, load profile, etc.

| Wire Size and Type | | | |
|--------------------|-----------------|---------------|------|
| Wire Gauge | Wire Type | Connector | Pins |
| 000 AWG * | Stranded Copper | Power | +/- |
| 18-24 AWG | Stranded Copper | Comm (18-pin) | A-U |

Table 3.1
Wire Size and Type

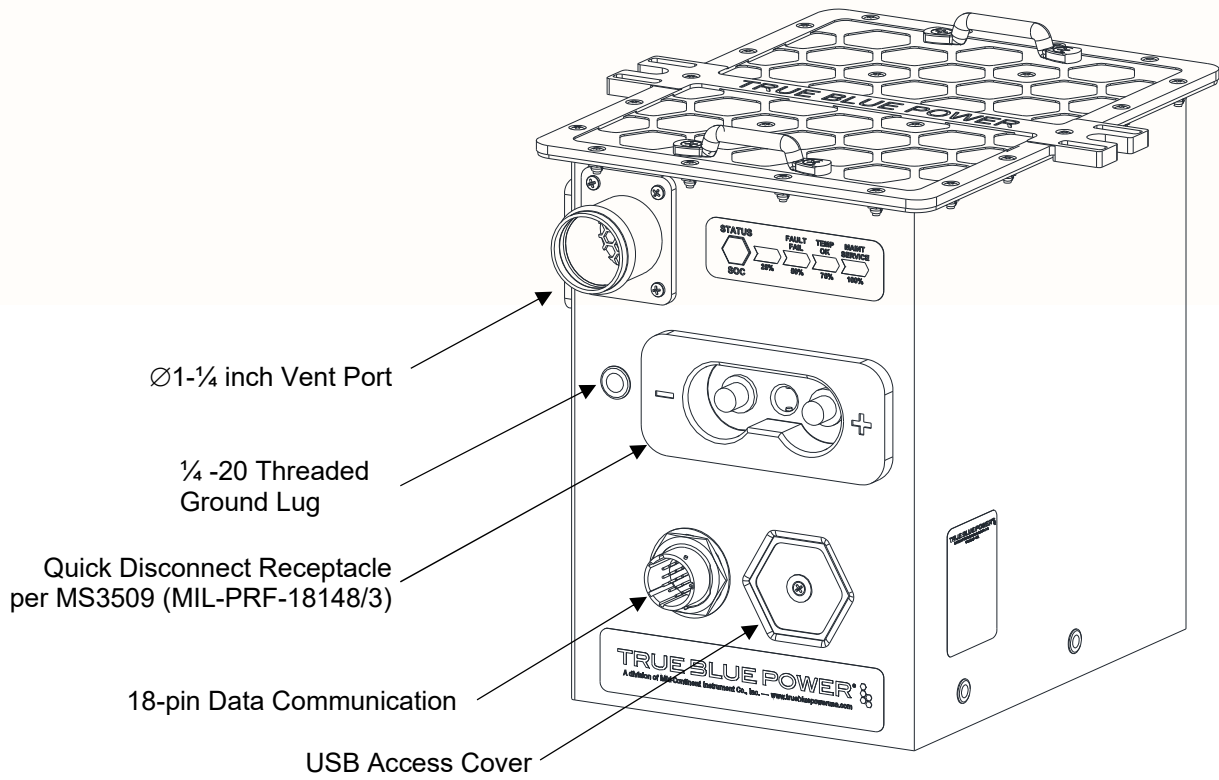


Figure 3.1
Connection Features

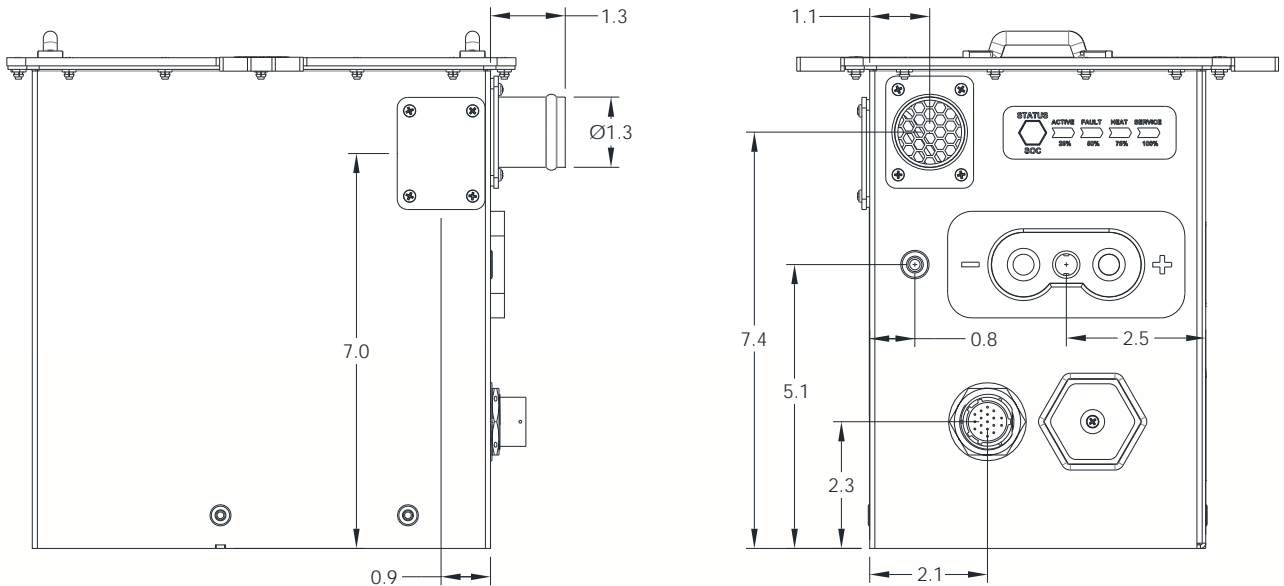
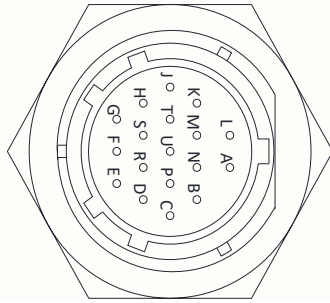


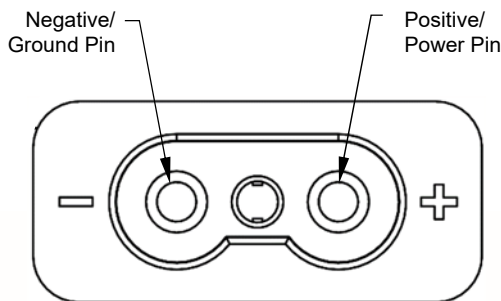
Figure 3.2
Connection Locations



**Figure 3.3
Communication Connector**

| Communication Connector (18-pin) | |
|----------------------------------|-----------------------|
| Pin | Description |
| A | Analog SOC |
| B | Battery Disable Input |
| C | Heater Disable Input |
| D | RTD-1A |
| E | RTD-1B |
| F | RTD-2A |
| G | RTD-2B |
| H | ARINC 429 (A) |
| J | Service Discrete |
| K | Fault Discrete |
| L | Heating Discrete |
| M | Min Capacity Discrete |
| N | Analog Ground |
| P | Spare / BMS Ref * |
| R | Spare |
| S | ARINC Shield |
| T | Engine Start Discrete |
| U | ARINC 429 (B) |

**Table 3.2
Communication Connector Pinout**



**Figure 3.4
Power Connector**

| Power Receptacle (2-pin) | |
|--------------------------|-----------------|
| Pin | Description |
| + | 28VDC power in |
| - | Aircraft Ground |

* Note: Communication Connector pin P is a BMS ground reference. This does not apply to any of the TBX battery models with p/n ending in -1.

3.4.2 Securing the Unit

The battery is designed to be secured in the aircraft using hold-down rods. The hold-down features are integrated into the lid of the battery. The hold-down consists of a slot for the hold-down rod, open to the outboard sides, and two perpendicular slots on each side to keep the rod vertical using an alignment washer. The battery is then secured with the appropriate nut or hardware designed to mate with the rod. Tighten the nut or equivalent to approximately 20 in-lbs (2.5 Nm). It is recommended to constrain the battery bottom with angle brackets or similarly constructed features in the aircraft.

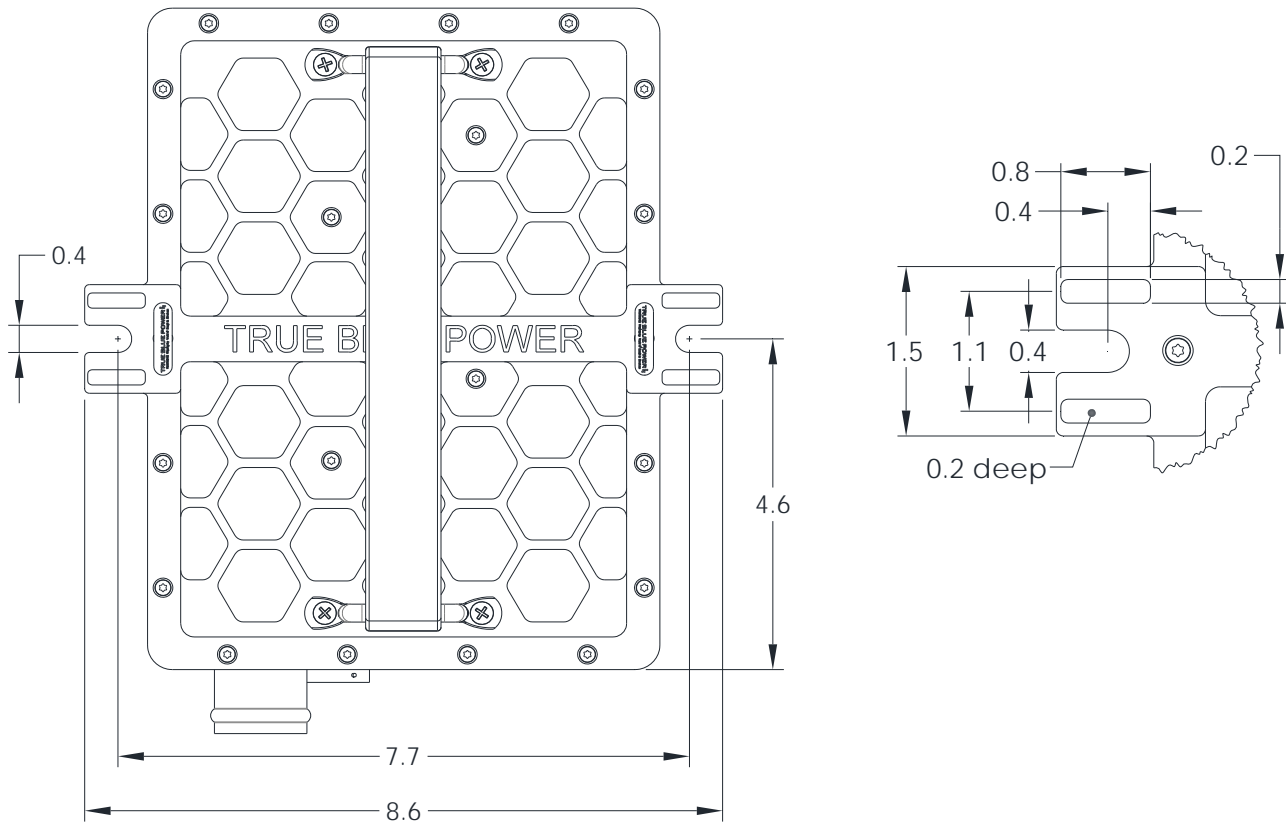


Figure 3.5
Hold-Down Mounting Features

TB20 installations require usage of the mounting kit (see Section 3.3.2), which includes corner braces and a silicone pad to limit overall motion of the battery. Alternative/similar mounting hardware can be used at the discretion of the installer.

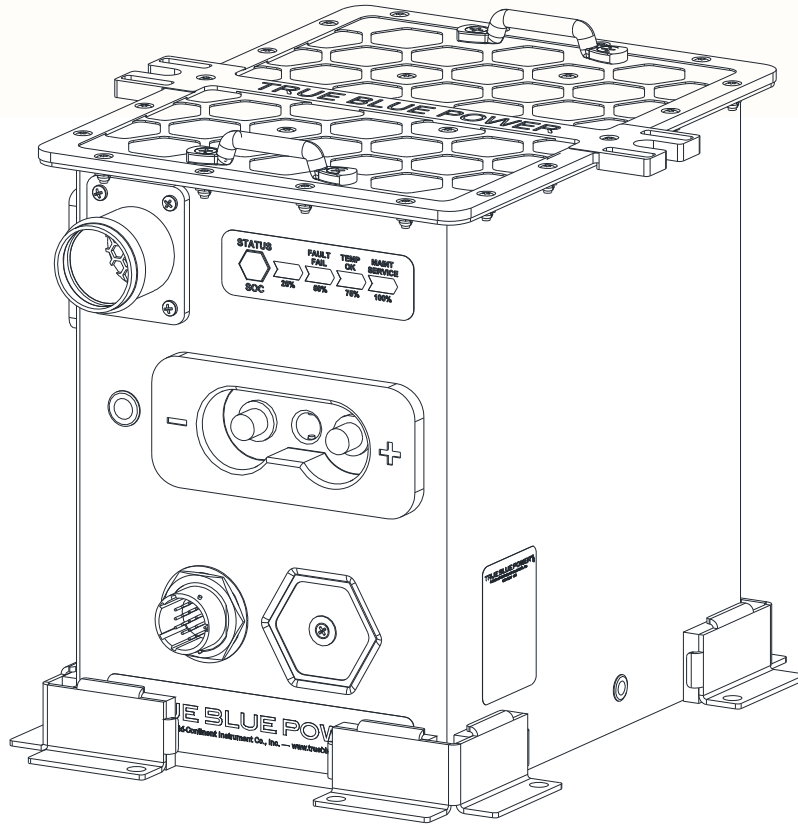


Figure 3.6
Mounting Kit

3.4.3 Vent Installation

It is recommended that the battery be operated with the vent tube in place when installed in the aircraft. The vent port is 1.25 inches in diameter and has a protrusion just inboard around the outside diameter to help prevent any disengagement of the attached vent tube.

There are two possible locations for the vent port to be configured. The default position is on the front face of the unit in the upper left corner. The alternate location is on the left side of the unit in the upper right corner. See Figure 3.2 for the vent location dimensions. Both locations are eligible for certified installation. If the alternate location is desired, simply remove the four screws and vent port from its original location, remove the four screws and blank plate from the alternate location, switch the positions and reinstall. Visually verify that the silicone gasket between the port or plate and the case fully covers the holes in the case and has not squeezed completely out from under either part. Screw torque applied should be approximately 5.5 in-lbs. See Figure 3.6 for a diagram of the vent and blank plate assembly.

A Vent Kit is available that includes a high temperature vent hose and hose attachment hardware (see Section 3.3.2). Contact True Blue Power for potential alternatives. The vent tube should be properly and securely attached to an aircraft exit point which would allow any gaseous emissions to be vented overboard. The battery produces no emissions during normal operation. Emissions will only be present in the event of a battery failure. Be sure to locate the vent where emitted gases would not be directed toward any of the aircraft's air intake points.

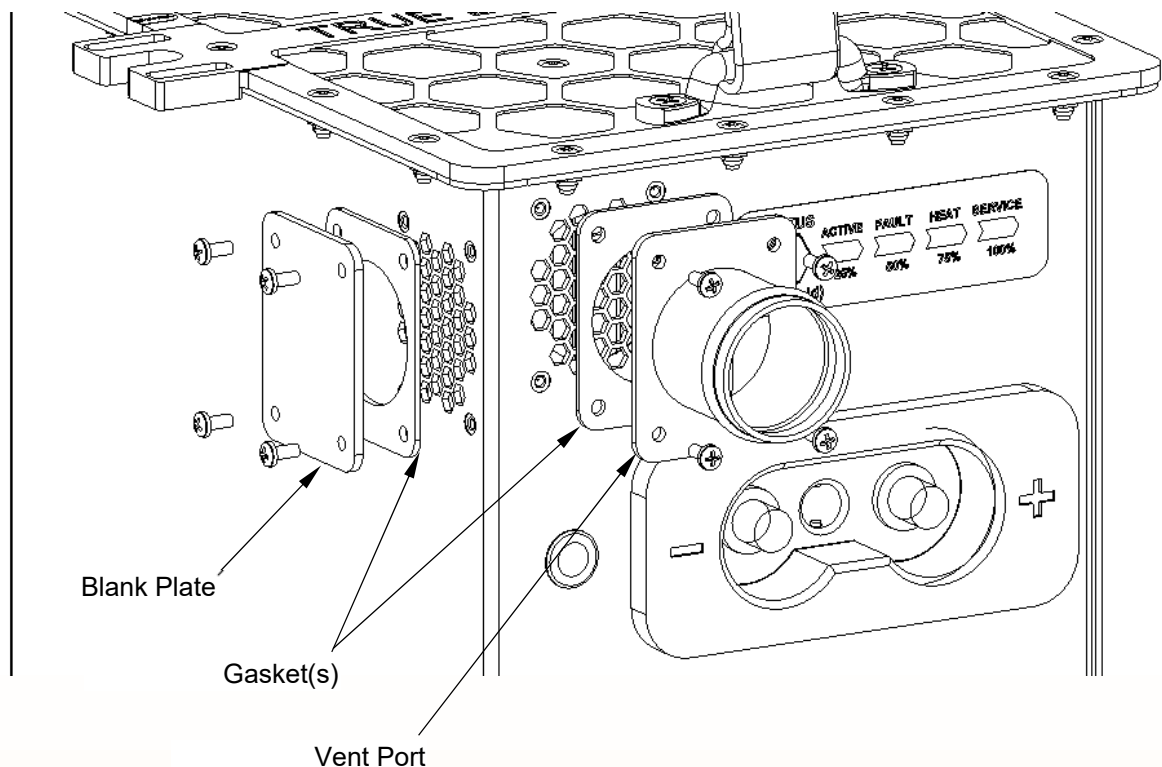


Figure 3.6
Vent Location Option

3.4.4 Custom Programmable Parameters

The True Blue Power Advanced Lithium-ion Battery is designed with software control that provides the ability to configure it with custom parameters that are specific to the aircraft. This can only be done while the battery is not in flight and is in Control Mode (see 4.3.2).

Custom configuration parameters are loaded onto the unit using a standard USB 2.0 compatible flash drive (see Section 5.3.2). A fixed file format and file name with valid data parameters is required to be loaded onto the battery. Invalid file formats or data will be rejected and not allowed to load. Contact True Blue Power to coordinate parameter and file creation for your application.

The following parameters are available for configurable customization:

- Charge Current Limit

Setting the charge current limit restricts the maximum current that the battery is allowed to consume from the aircraft electrical bus. Because of the very low internal impedance of the battery, it can provide extremely fast charging and discharging at high current. For some aircraft that have limited electrical power available, or to manage power consumption at a known amount, a current limit may be desired.

The Charge Current Limit can also be disabled (by setting Charge Current Limit to 0), allowing the battery to charge as quickly as possible and take up to its maximum charge current. The Charge Current Limit parameter is not required; it is set to 0 (disabled) as the initial factory default.

- End of Life

Setting an End of Life capacity provides an ARINC and discrete signal to indicate when the battery is approaching, or at End of Life and in need of replacement. This is based on a comparison of the programmed value with the battery's real-time capacity measurement. End of Life capacity is determined in accordance with the specific aircraft requirements at time of the battery installation certification. This is typically the minimum capacity required to provide power to critical aircraft systems for a particular period of time in the case of primary power generation loss. The End of Life capacity parameter and indication is not required; it is set to 0Ah (disabled) as the initial factory default.

- Minimum Capacity

Setting a Minimum Capacity value provides an ARINC and discrete signal that validates the state of charge against the aircraft's specific required minimum for emergency operations. This is typically used to verify that the battery has been charged sufficiently prior to dispatch to support an emergency mission profile. A Minimum Capacity parameter and indication is not required to be programmed; it is set to 0% (disabled) as the initial factory default.

- Engine Start

Setting the Engine Start parameters provides ARINC and discrete signal that indicates that the required amount of energy and peak current, given the existing environmental conditions and state of the battery, is available to complete a full engine start. This indication is useful to avoid a potential 'hot start' with a turbine engine due to the battery depleting before completing the start sequence. Coordinate with the manufacturer to determine the proper Engine Start parameter values based on specific engine start characteristics.

- The first Engine Start parameter is Start Energy required. An Engine Start parameter of 0Wh bypasses evaluating the energy for an engine start.
- The second Engine Start parameter is Engine Start Peak Current required. An Engine Start Peak Current parameter of 0A bypasses evaluating the maximum current required for an engine start.

The Engine Start parameters are not required to be programmed; they are both set to 0 (disabled) as the initial factory default.

3.4.5 Event Log

The True Blue Power Advanced Lithium-ion Battery is designed with software features providing downloadable event logging capability which captures fault and failure events as well as high current discharges typically occurring during engine starts. The event log can capture approximately 74,000 time stamped events available for downloading to a USB 2.0 compatible flash drive. If the number of events exceeds the maximum number of events, then older events are overwritten. Downloading events can only be done while the battery is not in flight and is in Control Mode (see Section 4.3.2).

To download the event log onto a USB flash drive, follow instructions in Section 5.3.4. Contact True Blue Power for further details with respect to the event log.

SECTION 4 OPERATION

4.1 DESCRIPTION

The True Blue Power TB20 Advanced Lithium-ion Battery is designed to supply power for starting an aircraft engine and providing emergency backup power to aircraft systems in the event of primary power generation loss. It utilizes rechargeable Nanophosphate lithium-ion cells in a parallel and series configuration to provide the specified voltage, power and total energy capacity. The unit supplies power through a connector with positive and negative power terminals and provides battery status and communication through an 18-pin circular connector.

4.2 CONSTRUCTION AND THEORY OF OPERATION

4.2.1 Cells

The TB20 Advanced Lithium-ion Battery contains 64 individual cylindrical lithium-ion cells. Lithium-ion battery cells have a very high energy density, producing more power than comparable battery types in a significantly lighter package. The cell's high-performance Nanophosphate chemistry is a proprietary form of lithium iron phosphate (LiFePO₄). The lithium iron phosphate chemistry provides safety enhancements over alternative lithium technologies by producing a cell that is more abuse tolerant to external conditions like over-charge or short circuit. It has a very low self-discharge rate, high cycle life, and is more stable with significantly less-energetic failure modes. The Nanophosphate advantage enhances typical lithium iron phosphate chemistries by providing exceptional power and energy. The combination of these characteristics make it an excellent choice for use in aircraft applications where high power, less weight, and enhanced safety are of utmost importance.

4.2.2 Battery Modules

The TB20 is comprised of two identical battery modules. In each module, four individual cells are connected in parallel to form a battery string; and eight strings are connected in series to produce a module of 32 total cells. At a full, rested charge, each cell (and string of cells) supplies approximately 3.3 VDC. The individual cells provide up to 120A of current and 2.5Ah of energy, or capacity. When connected as described above, each module is rated to provide 10Ah of energy at 26.4VDC. When two modules are connected in parallel, the battery provides a voltage of 26.4VDC, a total capacity of 20Ah, and a peak current of 960A. Each module contains two circuit boards, the Control and Switch boards. Monitoring wires are used to report cell voltages to the Control board for balancing, protections, status and health. Additionally, each module has multiple temperature sensors, bus bars with individual cell fuses, cell heaters and mechanical construction designed to secure the cells for an aircraft environment. The individual cell fuses allow for the potential of a single cell failure to occur without a significant safety concern or complete loss of function.

4.2.2.1 Switch Board

The Switch board incorporates high-power transistors used to enable and disable charging or discharging of the unit. This allows for the unit to take action based on its own monitoring and protections to prevent damage to the product. The Switch board also contains the current limiting functionality. This important feature allows the battery to control the amount of current it will accept from aircraft. Although the very low internal impedance of lithium-ion cells produces benefits of fast charging and high power, it also can accept as much or more than many aircraft power generation systems can supply. The current limiting feature prevents the unit from utilizing the full available power of the aircraft so that other key systems can remain active. The Switch board also includes the unit's ability to measure current flow of the battery as a protective input.

4.2.2.2 Control Board

The Control board contains the logic to collect cell parameters and report to the Battery Management System (BMS). It also receives decisions back from the BMS and sends information to the Switch board to enable, limit, or disable charging and discharging.

4.2.3 Battery Management System (BMS)

The BMS board is independent of the modules and manages the power control and external data interface of the battery. Using cell and battery conditions passed to it by the Control boards, the BMS microcontroller and software provide instructions back to the Control boards, and through it, the Switch boards, to control the battery. The software logic monitors the battery functions and provides protections for conditions such as short circuit, over-temperature, over-discharge and others. It also controls the internal heaters. The BMS generates battery status and data that is provided to the aircraft through the 18-pin communication connector for cockpit monitoring. Data is provided in serial (ARINC 429), discrete, and analog formats. The BMS provides the logic that operates the built-in/on-board visual status indicator on the outside of the case as well.

The software is qualified to RTCA/DO-178C, Design Assurance Level A (DAL A). The battery contains no airborne electronic hardware, known as AEH or complex hardware.

4.2.4 Resistance Temperature Detectors

There are two Resistance Temperature Detectors (RTDs) in the unit that supply direct analog resistance through four pins on the 18-pin connector for independent temperature monitoring. Each RTD uses two pins of the connector (see Figure 3.2 and Table 3.2) and are characterized with a resistive output. See Section 4.4.1 for details.

4.2.5 Case and Hardware

The mechanical construction plays a key role in the design to specifically support optimal functionality, mitigate and contain any potential failure, and withstand the expected aircraft environment. Material selections, component design, assembly processes and test all contribute to the performance and safety of the product.

Nickel bus bars are used to connect the individual cells within the modules. Larger bus bars then connect each module to the main connector to deliver the battery power. Temperature and electrical insulating materials are used to support the cells within the modules and to isolate all internal surfaces from the metal case. Each module uses an internal aluminum heat sink that connects to the machined lid for thermal management, particularly during charge current limiting and high discharges. A threaded connection is provided for convenience to ground the battery to the airframe. A nylon handle is used for ease of transport and handling.

The case is constructed to address the unique needs of lithium technology. In particular, it is designed to contain and direct emitted gases overboard, maintain a safe external temperature and pressure, constrain any debris or flame and ultimately to prevent any effect on its surroundings in the aircraft, even during a worst-case failure scenario.

4.2.6 Visual Status Indicator

The battery has a built-in/on-board status indicator incorporated into the front face of the battery. This can be used to quickly and visually determine the battery's status and state of charge either on the aircraft or off, during storage or service. The status indicator will identify any of the following states: ACTIVE, FAULT, HEAT, and/or SERVICE. It can also be used to assess the state of charge. More details can be found in Sections 4.3 and 4.4.

4.2.7 Data Exchange Access

The front face of the battery has a sealed hexagonal access cover below the main power connector, secured with a single screw. When removing the cover, it reveals access to a USB Type-A port, a recessed service button, and a service light. These can be used in Control Mode to update the battery software, configure its customizable parameters, validate the custom parameters and download the event log. More details can be found in Section 5.3.

4.3 OPERATIONAL MODES

The battery has three basic modes of operation: Sleep Mode, Control Mode, and Active Mode. These modes, and associated functionality, are explained below.

4.3.1 Sleep Mode

Sleep Mode is used to disable the power output of the battery and reduce internal energy consumption to preserve resting state of charge. When the battery is in Sleep Mode, the battery is not charging or discharging, the internal battery heaters are inactive, all active communications are disabled, and internal energy consumption is reduced by 90% with respect to Active Mode.

In Sleep Mode, up to 30mA of power is available that enables low power devices to operate without causing the battery to transition to Active Mode. The battery is also capable of monitoring the terminals for an external load or charge and the external control discrete inputs (battery disable and heater disable) while in Sleep Mode.

The battery will enter Sleep Mode when the Battery Disable control discrete is engaged (closed), when the battery is inactive or when the STATUS/SOC button is held for 3 seconds. The battery is inactive when all of the following conditions are true:

- Internal battery voltage is less than 27.5VDC (unless STATUS/SOC button is held for 3 seconds while in Active Mode)
- Five minutes after:
 - No charge or discharge (<200mA)
 - No protections actively being applied
 - Pre-heat cycle is off

4.3.2 Control Mode

Control Mode is reserved exclusively for the following interactions with the battery:

- Battery Software Update
- Installing Custom Programmable Parameters
- Downloading Custom Programmable Parameters
- Downloading Event Log

Control Mode is not available or accessible in flight. In order to enter Control Mode, the battery must not be charging or discharging, the service button must be pressed, and a valid USB flash drive must be present in the USB port.

Additional information regarding the customization of the configuration parameters can be found within Section 3.4.4. Information regarding software updates, custom programmable parameters and event log can be found in Section 5.3.

4.3.3 Active Mode

In Active Mode, the battery is fully functional and available to provide power barring no protections are being enforced and the battery is operating properly. In Active Mode, the battery continuously monitors all cells and battery conditions to manage operation and mitigate exceedances as needed through its various protection methods. Data and status is available through the communication connector and the heater is available in cold conditions while in Active Mode. Each major function available during Active Mode is described in further detail below.

The following figure and table summarizes the transitional conditions between the Sleep Mode, Active Mode, and Control Mode.

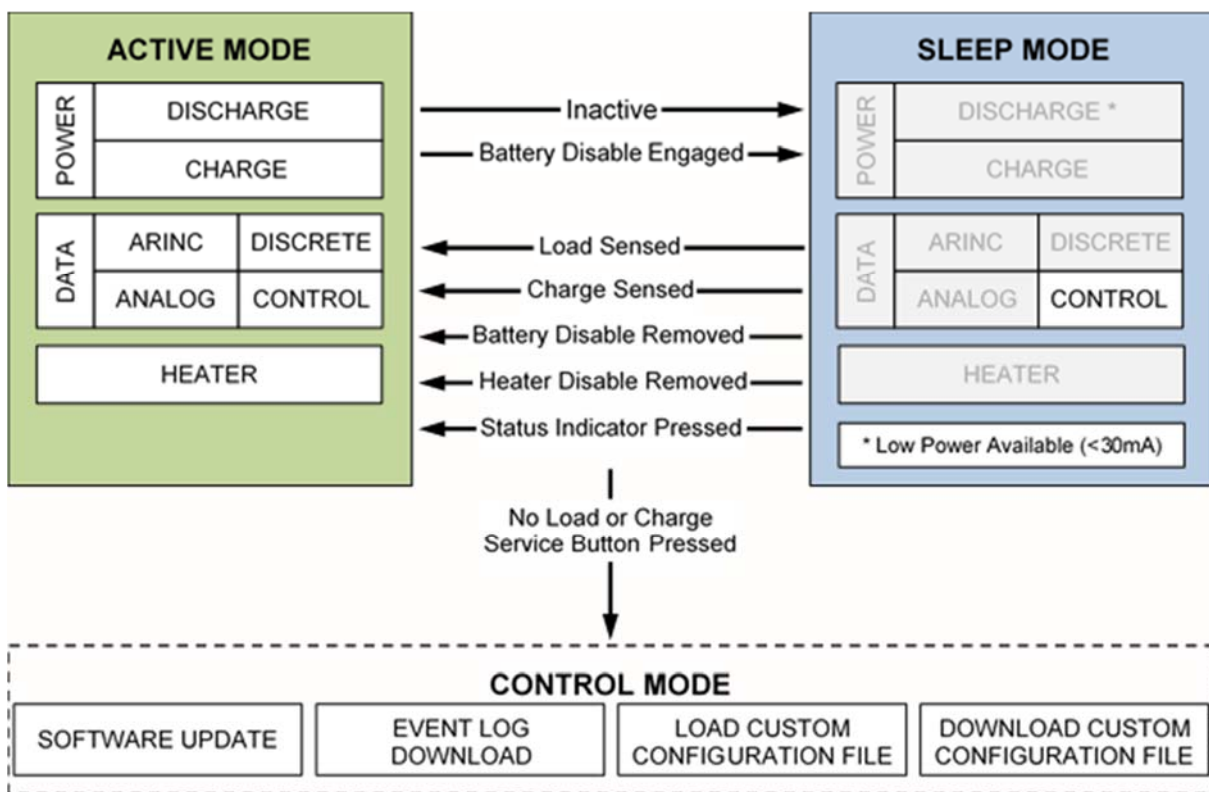


Figure 4.1
Operational Modes State Diagram

4.3.3.1 Engine Start

The TB20 battery can provide a peak current of 960A for the purpose of aircraft engine starting. It will provide a maximum of 560A for up to 15 seconds and below 52.5A continuously. The low internal impedance of the Nanophosphate lithium-ion chemistry allows extremely high current delivery while maintaining higher voltage than traditional battery types. This equates to a higher total power delivery, producing quicker, stronger starts, lower engine temperatures, more start attempts when needed, and a higher remaining battery capacity following engine start. The higher voltage also means better power to supporting systems during an engine start.

4.3.3.2 Providing Aircraft Power

When the aircraft's power generation systems are offline or fail, the unit will provide immediate power to the equipment/loads on the associated power bus. As the unit's capacity is used, the voltage will begin to drop until the unit is fully depleted. A fully charged unit will initially provide approximately 28 volts. Depending on the load, the battery will provide an average of approximately 25.5 volts for the duration of discharge. See Section 4.5 for more details on available capacity.

In order to avoid depleting the unit's power and ensure availability for the next flight, be sure to turn off all aircraft systems, lights and accessories after a flight. If the unit is depleted, see Section 5.4.2 for charging instructions.

4.3.3.3 Maintaining Charge

After engine start, the unit recharges and maintains charge by accepting power from the aircraft power generation system. The battery can be customized to set the charge current limit such that the battery will only draw a pre-determined maximum amount of current from the aircraft bus. The time required to replenish the capacity of the battery is a function of the depth of initial discharge and the value of the current limit. See Section 3.4.4 for more details on the configurable current limit feature.

At maximum charge current, a fully depleted battery can be recharged to 95% SOC in less than 15 minutes. In typical applications, the unit is likely to be fully recharged from the aircraft power generation system within several minutes following an engine start.

4.3.3.4 Heating

The battery is designed to support an engine start from as low as -5°C (23°F), depending upon the engine start profile, without pre-heat required. Below this temperature, the performance of the unit begins to decrease in current and energy delivery as the electrolyte in the cells begins to thicken and the internal impedance increases to retard ion flow. To address this, each module contains an individual heater which is powered by the cells themselves, even at very low temperatures.

The heaters are available at all times when the battery is both in Active Mode and when the Battery and Heater Disable signals are off/inactive. The heaters will only provide heat when active and when the battery temperature is sensed below 0°C. The heaters will stop heating when the internal battery temperature is above 5°C. The heaters will automatically turn on and off as needed until the battery enters Sleep Mode or the Heater Disable signal is engaged. When the heaters are active, they consume approximately 300W each for a total of 600W on a TB20 battery.

4.3.3.5 Pre-Heat Cycle

The battery has the ability to pre-heat itself at temperatures down to -40°C (-40°F) utilizing the internal, self-powered heaters, bringing the battery up to full operational capability. Pre-heat time will vary depending on temperature but can be fully warmed in 15 minutes or less after turning the heaters on.

(See Section 4.5 for more details on pre-heat times and energy use.)

The battery transitions to Active Mode and the ACTIVE green LED on the Status Indicator blinks once every three seconds when in the Pre-Heat Cycle.

The Pre-Heat Cycle can be initiated in one of two ways:

(Battery Disable signal, if installed, must not be engaged/closed)

- From Sleep Mode press the STATUS/SOC button.
- Toggle the Heater Disable signal from open > closed > open.

The Pre-Heat Cycle will continue to maintain the battery temperature for one hour and then enter Sleep or Active Mode (per Sections 4.3.1 and 4.3.3), unless one of the following occurs:

- Press and hold the STATUS/SOC button for 3 seconds. Battery will immediately transition to Sleep Mode if the battery is not charging or discharging.
- Close/ground the Heater Disable signal (if installed). If the Pre-Heat Cycle has been active for less than 5 minutes, the HEAT yellow LED will be on until the battery enters Sleep Mode (Section 4.3.1). If the Pre-Heat Cycle has been active for more than 5 minutes, it will immediately transition to Sleep Mode.
- Close/ground the Battery Disable signal (if installed). Battery will immediately transition to Sleep Mode.

4.3.3.6 Battery Protections

The TB20 Advanced Lithium-ion Battery has built-in protections for conditions that may exceed specified operating limits:

| Protection | Parameter(s) | Action | Recovery |
|--------------------------------|--|---------------------------------|--|
| Under Voltage (low current) | If discharge current < 80A and battery voltage < 16VDC or cell string voltage < 1.8VDC | Discharging disabled | Battery Voltage > 20VDC and Cell string voltage > 2.5VDC (Charging will be limited to 4A/Module until Module Voltage > 20VDC or Module Cell String Voltage > 2.5VDC) |
| Under Voltage (high current) | If discharge current > 80A and battery voltage < 12VDC or cell string voltage < 1.0VDC | Discharging disabled | Battery Voltage > 20VDC and Cell string voltage > 2.5VDC (Charging will be limited to 4A/Module until Module Voltage > 20VDC or Module Cell String Voltage > 2.5VDC) |
| Over Discharge | Any module cell string voltage < 1.2VDC and current < 100mA for 10 seconds | Module is disabled | Factory Service |
| Over Voltage | Module voltage > 30.6VDC or Any cell string voltage > 3.8 VDC | Charging disabled | Module voltage < 29.2 VDC and All cell string voltages < 3.6 VDC |
| Over Current | Battery discharges > 560A for more than 15 seconds | Discharging Disabled | External Load removed or charging current detected |
| Short Circuit | Battery detects current > 1000A for > 100ms | Discharging Disabled | External Load removed or charging current detected |
| Over Temperature (Discharging) | Any cell temperature > 95°C or Discharge control circuitry > 130°C | Discharging Disabled | All cell temperatures < 80°C and Discharge control circuitry < 90°C |
| Over Temperature (Charging) | Any cell temperature > 72°C or Charge control circuitry > 130°C | Charging disabled | All cell temperatures < 62°C and Charge control circuitry < 90°C |
| Cell Over Temperature Fail | Any cell temperature > 110°C | Module is disabled | Factory Service |
| Module Charge Required | One or more modules have charged/discharged 50Ah or more without being fully recharged | Battery SOC may not be accurate | Fully Charge Battery |

**Table 4.1
Battery Protections**

4.4 BATTERY COMMUNICATION

When in Active Mode, the Advanced Lithium-ion Battery presents multiple status indications and data to the aircraft for display and monitoring on appropriate systems. These are supplied as either serial, discrete, or analog signals. The various outputs and their definition are supplied in Sections 4.4.1 through 4.4.3. Locations and descriptions of each pin of the 18-pin communications connector are listed in Figure 3.3 and Table 3.2.

The battery also provides an on-board status indicator that can be used on- or off-aircraft to determine current health and state of charge; see Section 4.4.4.

4.4.1 Analog Communication Signals

The battery provides two pieces of data via analog outputs. These are temperature data from the dual, independent RTDs and analog state of charge.

Each RTD has a resistance of 100 ohms at 0°C. Resistance (ohms) for all temperatures (T, in degrees Celsius) can be calculated using the following formula(s):

(per specification) Resistance = $100 \times [1 + (0.00390833 \times T) + (0.00000057753 \times T^2)]$

(linear approximation) Resistance = $(0.3781 \times T) + 100.24$

(temp from resistance) Temperature = $(R - 100.24) / 0.3781$

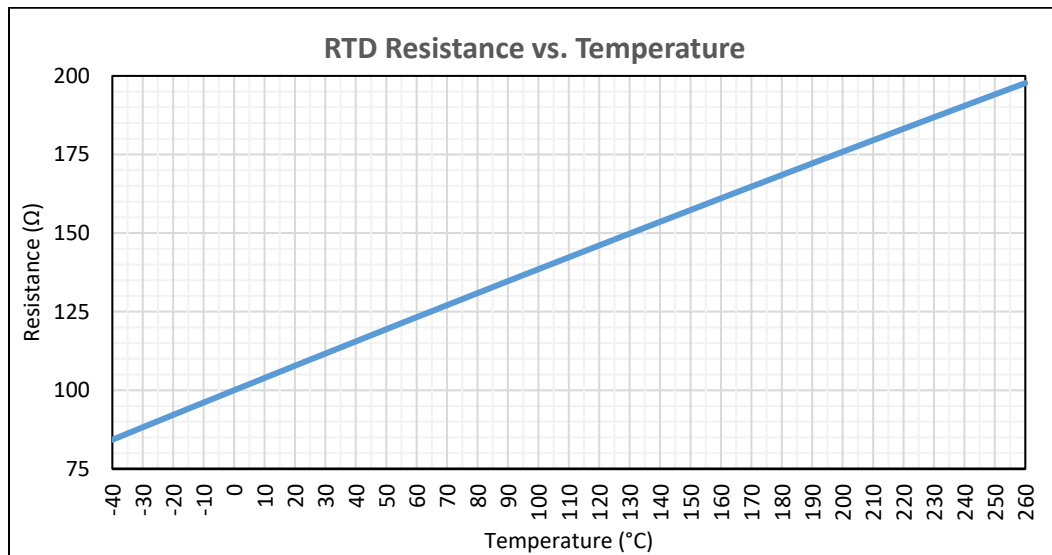


Figure 4.2
RTD Resistance vs. Temperature

The battery also provides the state of charge as an analog output. The state of charge of the battery is represented from 0 to 100% as 0 to 5VDC. This signal can be used to drive either a digital or mechanical indication of the state of charge in lieu of the serial communication signals if preferred. The voltage reference is between Pin A ('Analog SOC') and Pin N ('Analog Ground').

4.4.2 Discrete Communication Signals

Discrete signals are available to provide both basic battery status and simplified indication of battery readiness specific to the aircraft's requirements. In some cases, where serial data cannot be integrated with the aircraft's avionics or other messaging systems, the discrete battery status signals can be used to meet minimum regulatory annunciation requirements for lithium batteries.

Each discrete output is normally open and provides an active low/ground when the condition is true as described below. The circuit consists of a MOSFET connected to the battery negative (ground) with a series resistance of 60Ω. Each pin is current limited to 50mA.

| Discrete Communication Signals | |
|--------------------------------|---|
| Heating | Active when the Heater is providing heat. |
| Fault | Active when the battery has an internal fault. Internal faults may be temporary and may result in partial or fully degraded functionality. Faults may clear with time or upon next usage. Verify battery health and availability by cross-checking other parameters (voltage, state of charge, etc.). |
| Service | Active when the battery has a permanent fault. Service faults may result in partial or fully degraded function. Verify battery health and availability by cross-checking other parameters (voltage, capacity, state of charge, etc.). Battery should be submitted for service in accordance with the aircraft's flight manual supplement. |
| Min Capacity | Active when the battery has determined that its state of charge is BELOW the value programmed according to the aircraft's customizable configuration parameters. |
| Engine Start | Active when the battery has determined that its available energy is NOT sufficient to fully complete an engine start. The requirements to complete an engine start must be programmed according to the aircraft's customizable configuration parameters. |

Table 4.2
Discrete Output Definitions

There are two discrete inputs as described below. Both are normally open and are required to be grounded to activate their function.

- Battery Disable: This input, when grounded, manually and fully disables the battery, including power and communication.
- Heater Disable: This input, when grounded, manually disables the heaters from operating.

4.4.3 Serial Communication Signals

The battery generates a sophisticated array of situational status and data available for real-time reporting and awareness. This is provided to the aircraft in the form of serial data using the ARINC 429 protocol. Below is the definition of the data the battery provides. Contact the manufacturer to receive additional details associated with the format of the data provided for each label.

| ARINC 429 Parameter Descriptions | | |
|----------------------------------|--------------------------|---|
| Label | Parameter Name | Definition |
| 271 | Battery Discrete Outputs | Provides equivalent serial representation of the previously defined Discrete Communication Signals described in 4.4.2. |
| 340 | DC Current | Amperage being supplied (discharge (+)) or accepted (charging (-)). |
| 341 | DC Voltage | Voltage at the battery terminals. |
| 342 | Battery Temp | Internal temperature of the battery (°C). |
| 343 | Deliverable Energy | Amount of energy the battery can currently deliver at a 1C rate. Deliverable Energy is defined as State of Charge (%) x Current Maximum Capacity. <ul style="list-style-type: none"> Example: A TB20 has aged and its current maximum capacity is 18Ah, instead of its original beginning-of-life 20Ah. If its current State of Charge is 80%, then: Deliverable Energy = 80% x 18Ah = 14.4Ah. |
| 344 | Capacity | Current maximum capacity of the battery. This is the real-time tracking of the battery's capacity that decreases over time with age and use. |
| 345 | State of Charge | Total amount of charge the battery has, in relation to its capacity (%). |
| 346 | Life Remaining | Percent of capacity left before the battery's capacity reaches the programmed End of Life. <ul style="list-style-type: none"> Example: A TB20 has been programmed for End of Life of 15Ah for a given aircraft. The current capacity, due to aging, is now 18Ah, then: Life Remaining = $(18Ah - 15Ah) / (20Ah - 15Ah) = 3/5 = 60\%$. |
| 350 | Software Version | Loaded software version presented as X.Y.Z (Example: 1.0.1). |
| 351 | Operational Status | Provides three discrete states: Charging, Charge Limiting, Discharging. |
| 352 | Fault Status | Provides discrete indication of any active faults (see next page). |
| 377 | Equipment ID | ARINC defined equipment identifier: 0B3. |

Table 4.3
ARINC 429 Label Definition

| ARINC 429 Label Format Definition | | | | | | | | |
|-----------------------------------|--------------------------|-----------|--------|-------|----------|------------|------------------------|------|
| Label | Parameter Name | Data Type | Range | Units | Sig Bits | Resolution | Transmit Interval (ms) | |
| | | | | | | | Min | Max |
| 271 | Battery Discrete Outputs | DISCRETE | - | - | - | - | 250 | 500 |
| 340 | DC Current | BNR | ± 4096 | A | 15 | 0.125 | 250 | 500 |
| 341 | DC Voltage | BNR | 64 | V | 15 | 0.001953 | 250 | 500 |
| 342 | Battery Temperature | BNR | ± 512 | C | 12 | 0.125 | 1000 | 2000 |
| 343 | Deliverable Energy | BNR | 512 | Ah | 13 | 0.0625 | 1000 | 2000 |
| 344 | Capacity | BNR | 512 | Ah | 13 | 0.0625 | 1000 | 2000 |
| 345 | State of Charge | BNR | 128 | % | 11 | 0.0625 | 1000 | 2000 |
| 346 | Estimated Life Remaining | BNR | 128 | % | 11 | 0.0625 | 1000 | 2000 |
| 350 | Software Version | DISCRETE | X.Y.Z | - | - | - | 1000 | 2000 |
| 351 | Operational Status | DISCRETE | - | - | - | - | 500 | 1000 |
| 352 | Fault Status | DISCRETE | - | - | - | - | 500 | 1000 |
| 377 | Equipment ID | DISCRETE | - | - | - | - | 1000 | 2000 |

Table 4.4
ARINC 429 Label Format

Fault Status Indications for ARINC Label 352:

- Invalid Configuration
- Stack Over Voltage
- Cell Over Voltage
- Charge Cell Over-temp (Disable Charging)
- Over Current
- Short Circuit
- Cell Under Voltage
- Stack Under Voltage
- Discharge Cell Over-temp (Disable Discharging)
- FET Over-temp
- Continuous BIT Fault
- Continuous BIT Failure
- End of Life
- Over-Discharge
- Heater Fault
- Heater Fail
- Module Charge Required
- Cell Imbalance Fail
- Cell Over Temperature Fail

4.4.4 On-board Status Indicator

The on-board Status Indicator can provide active or on-demand health status and state of charge. It can also be used to manually transition the battery from Sleep Mode to Active Mode by pressing the STATUS button. This can be used to check status, state of charge, or to initiate the heaters to pre-heat the battery (if the battery is cold).

When the battery is in Active Mode, status is continuously displayed. Status is listed as one or more of four states as listed below. For each state, a lighted chevron will appear under the associated label on the Status Indicator. Note that the gray chevrons in Figure 4.3 are not visible (black) on the Status Indicator until a lighted annunciator segment is active.

- **Active** Solid Green indicator: Battery is Active.
 Flashing Green indicator: Battery is in Pre-Heat Cycle.
- **Fault** Solid Yellow indicator: Battery has an internal fault. A fault is also communicated through both the discrete fault signal and via ARINC. See Section 4.4.3 for further description.
- **Heat** Flashing White indicator: Battery heaters are currently heating.
 Solid Yellow indicator: Heater is disabled.
- **Service** Solid Red indicator: Battery has a permanent fault. A service fault is also communicated through both the discrete service signal and via ARINC. See Section 4.4.3 for further description

The Status Indicator can also provide on-demand state of charge. By temporarily pressing the STATUS/SOC button, the chevrons will quickly cycle in blue, indicating a change to state of charge indication. The Status Indicator will display nine different state of charge ranges for approximately six seconds as described below in Table 4.5. See 4.4.4.1 for additional functions of the STATUS/SOC button.

| State of Charge | Indicator 1 "25%" | Indicator 2 "50%" | Indicator 3 "75%" | Indicator 4 "100%" |
|-----------------|----------------------|----------------------|----------------------|-----------------------|
| 0 - 10 % | Flash Yellow | Off | Off | Off |
| 10 - 15 % | Dim Green | Off | Off | Off |
| 15 - 25 % | Solid Green | Off | Off | Off |
| 25 - 40 % | Solid Green | Dim Green | Off | Off |
| 40 - 50 % | Solid Green | Solid Green | Off | Off |
| 50 - 65 % | Solid Green | Solid Green | Dim Green | Off |
| 65 - 75 % | Solid Green | Solid Green | Solid Green | Off |
| 75 - 90 % | Solid Green | Solid Green | Solid Green | Dim Green |
| 90 - 100 % | Solid Green | Solid Green | Solid Green | Solid Green |

Table 4.5
State of Charge Indication

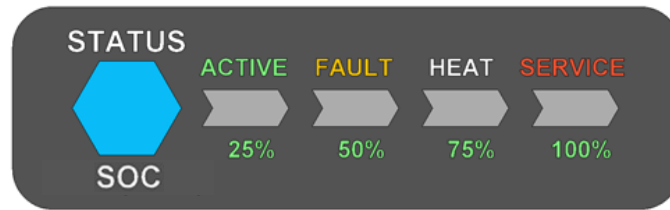


Figure 4.3
On-Board Status Indicator

4.4.4.1 STATUS/SOC Button

Pressing the STATUS/SOC Button serves several purposes.

- From Active or Sleep Mode:
 - Cycles the chevrons in blue, followed by the state of charge (SOC) indication, followed by continuous display of the Status indication.
 - Initiates a self-test of all battery discrete outputs which are set to active for 10 seconds.
 - If the battery has reached the end of discharge and under-voltage protection is activated, pushing the status button will clear the under-voltage fault (if battery voltages meet under voltage recovery limits as indicated in Table 4.1) and allow further discharge.
- From Sleep Mode (in addition to above):
 - Places the battery into Pre-Heat Cycle.
- From Active Mode, when pressing and holding for three seconds:
 - Transitions to Sleep Mode
 - If the battery is charging or discharging, it will blink the ACTIVE green LED and then remain Active (not enter Sleep Mode).

4.5 PERFORMANCE

4.5.1 Capacity

Capacity is the measurement of the energy stored in the battery and most often is used to determine the length of time a particular electrical load can be operated. A standard measure of rechargeable battery capacity is the current-over-time performance (measured in amp-hours) called the “C” rate.

The C-rate is a function of the size of the load in relation to the capability of the battery. A 1C rate corresponds to a constant current load (in amps) which the battery can supply for one hour. The TB20 has a 1C rating of 20Ah and thus can supply 20 amps for one hour. Note that many typical lead-acid batteries, and some lithium systems as well, are defined at a 1/20th (0.05) or 1/5th (0.2) C-rate. This is defined as the constant load that can be applied over 20 or 5 hours, respectively. For example, a lead-acid battery rated at 20Ah at a 0.2 C-rate can deliver 4A for 5 hours (4A x 5 hours = 20Ah). However, that same system typically does not perform linearly at higher C-rates. For instance, the same 20Ah lead-acid battery rated at 0.2C may typically only support a 20A load for 45 minutes, not a full hour, resulting in a true 1C capacity of only 15Ah. The capacity for these types of batteries is generally defined by a logarithmic function of load versus time. So, when doubling the load, a lead-acid battery will last less than half the time.

One of the significant advantages of lithium-ion technology is its constant capacity versus load. As the load on the TB20 increases, its capacity maintains its rating proportionately. As an example, if the standard 1C load of 20A is doubled to the 2C load of 40A, the discharge duration is proportionally cut in half to 30 minutes. Doubling the load again to 80A would deplete the battery in 15 minutes.

4.5.2 Temperature Performance

The TB20 incorporates cell technology that performs well over temperature extremes. It can support an engine start from as low as -5°C (23°F), depending upon the engine start profile. Cold temperature performance is extended to as low as -40°C (-40°F) when using the internally powered heater and allowing the appropriate pre-heat time. This feature prevents the necessity to remove the unit from the aircraft when stored at extremely low temperatures overnight or for longer periods of time. The battery also exhibits excellent high temperature performance, rated for operation as high as 70°C (158°F). The data below demonstrates expected pre-heat duration based on the battery starting at several different cold temperatures.

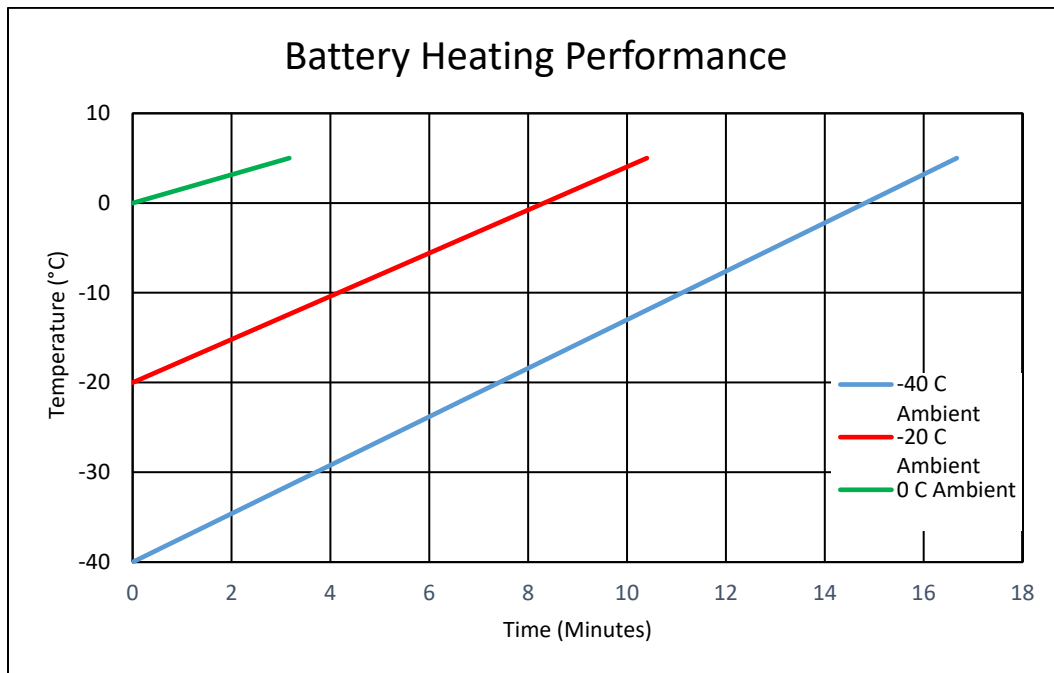


Figure 4.4
Battery Heating Performance

SECTION 5 CONFORMANCE

5.1 DISPATCH VERIFICATION AND IN-FLIGHT MONITORING

The main ship battery typically serves two primary purposes: engine start and emergency backup power.

- **Engine Start:** In order to attempt an engine start, the user should verify that the FAULT signal is not active. It is also recommended that the battery be fully pre-heated (HEATING signal not active) for an engine start. If used, the pre-programmed Engine Start indicator can also be used to verify that the battery is ready to start an engine.
- **Dispatch for Emergency Backup Power:** If the aircraft has a minimum backup power requirement for loss of aircraft electrical generation in emergency operation, the user may need to verify battery capacity prior to flight. This can be done in various ways, possibly including an SOC verification or verifying the Minimum Capacity indicator. Check with the aircraft operating requirements for specific procedures. Once battery capacity is verified as sufficient, the battery is ready for dispatch.

During flight, the battery is capable of providing a number of status indications and health monitoring information to the cockpit or crew through its communication outputs (see Section 4.4).

- **In-Flight Monitoring:** Typically, all annunciations from the unit should be inactive during flight. However, the HEATING signal may be observed depending on the temperature of the unit and does not represent a hazard or loss of function. An indication of the FAULT signal or independent monitoring of the RTD sensors could require action or degraded function. Consult your aircraft flight manual for details.

5.2 INSTRUCTIONS FOR CONTINUED AIRWORTHINESS

No periodic scheduled maintenance is necessary for continued airworthiness of the TBX series Advanced Lithium-ion Batteries. If the battery is stored for more than six (6) months, refer to Section 5.4.2 for charging instructions. If the unit fails to perform to specifications, the unit must be removed and serviced by True Blue Power or their authorized designee.

True Blue Power will have, on occasion, the need to update the software of the TBX series Advanced Lithium-ion Batteries to improve and/or enhance functionality or performance.

With the TBX Battery's easy field-upgrade option, the unit does not have to be returned to the factory, and in most cases, may not have to be removed from its installation.

Software updates are typically communicated to the public via Service Bulletins issued by True Blue Power and can be found on the product website www.truebluepowerusa.com. Refer to Section 5.3 for updating the TBX series Advanced Lithium-ion Battery software.

5.3 CONTROL MODE

For control mode operations (e.g. software updates, custom programmable parameters and event log) refer below to Figure 5.1 and Table 5.1. If the Service Button is pressed and a valid flash drive is not inserted within one minute the battery will reboot into flight mode.

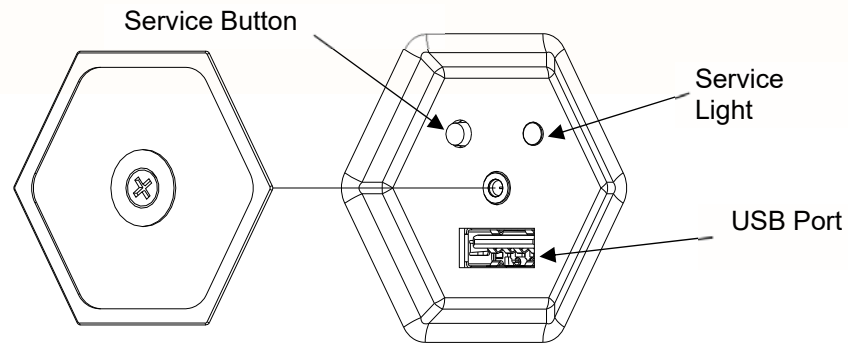


Figure 5.1
USB Service Port

| Update Status | Light Status |
|-----------------------|--------------|
| Idle | Flash White |
| Opening USB Storage | Flash Blue |
| Operation In Progress | Flash Yellow |
| Operation Successful | Solid Green |
| Operation Error | Solid Red |

Table 5.1
Service Light Status

5.3.1 Software Update

- A. Download the approved software update file from <https://www.truebluepowerusa.com/software-updates/http://www.truebluepowerusa.com/products/aviation/advanced-lithium-ion-batteries/tb20/> to the root directory of a standard FAT formatted USB 2.0 compatible flash drive, ensuring the filename is exactly update.muf. – It is recommended that this is the only file (update.muf) loaded onto the flash drive.
- B. Remove the USB access cover.
- C. Insert the configured USB flash drive into the USB Type-A port on the battery.
- D. With the battery idle (no charge or discharge current, no active protections), transition to control mode by pressing and holding the blue service button (located above and to the left of the USB port) until the service light (located above and to the right of the USB port) changes from solid white to blinking white (approximately 3 seconds) and releasing before the flashing white stops (5 seconds).

- E. While the battery is reading from or writing to the USB flash drive the service light will blink yellow when installing the software update.
- F. Once the software update is completed the service light will be solid green (if software update completed successfully) or be solid red (if software update did not complete successfully).
- G. Remove the USB flash drive and the battery will reboot into flight mode with updated software.
- H. Replace the USB access cover securely.

5.3.2 Load Custom Programmable Parameters

- A. Download the installer configuration file to the root directory of a standard FAT formatted USB 2.0 compatible flash drive, ensuring the filename is exactly *installer.cfg*. Contact True Blue Power to coordinate parameter and file creation for your application.
- B. Remove the USB access cover.
- C. Insert the configured USB flash drive into the USB Type-A port on the battery.
- D. With the battery idle (no charge or discharge current, no active protections), transition to control mode by pressing and holding the blue service button (located above and to the left of the USB port) until the service light (located above and to the right of the USB port) changes from solid white to blinking white (approximately 3 seconds) and releasing before the flashing white stops (5 seconds).
- E. While the battery is reading from or writing to the USB flash drive the service light will blink yellow when installing the custom programmable parameters.
- F. Once the custom programmable parameters update is completed the service light will be solid green (if custom programmable parameters update completed successfully) or be solid red (if custom programmable parameters update did not complete successfully).
- G. Remove the USB flash drive and the battery will reboot into flight mode with updated custom programmable parameters.
- H. Replace the USB access cover securely.

5.3.3 Verify Custom Programmable Parameters and Software Version

- A. To verify custom programmable parameters or the currently loaded software version, place an empty text file named *getcfg.cmd* onto the root directory of a standard FAT formatted USB 2.0 compatible flash drive. Contact True Blue Power if you have questions regarding creation of the *getcfg.cmd* file.
- B. Remove the USB access cover.
- C. Insert the configured USB flash drive into the USB Type-A port on the battery.

- D. With the battery idle (no charge or discharge current, no active protections), transition to control mode by pressing and holding the blue service button (located above and to the left of the USB port) until the service light (located above and to the right of the USB port) changes from solid white to blinking white (approximately 3 seconds) and releasing before the flashing white stops (5 seconds).
- E. While the battery is reading from or writing to the USB flash drive the service light will blink yellow when the battery is downloading the custom programmable parameters onto the USB flash drive.
- F. Once the custom programmable parameter update is completed the service light will be solid green (if custom programmable parameters download completed successfully) or be solid red (if custom programmable parameters download did not complete successfully).
- G. The USB flash drive will now have a file named *installer.txt* that can be viewed with any text editor. In addition to validating the custom programmable parameters, the *installer.txt* file also provides a timestamp when the *installer.txt* file was created and also displays the battery software version. Note: If the USB flash drive contains both the *installer.cfg* and *getcfg.cmd* files in the root directory, the custom programmable parameters will be installed first and then the *getcfg.cmd* file will generate the *installer.txt* file in this sequence.
- H. Remove the USB flash drive and the battery will reboot into flight mode.
- I. Replace the USB access cover securely.

5.3.4 Download Event Log

- A. To download the battery event log place an empty text file named *getlog.cmd* onto the root directory of a standard FAT formatted USB 2.0 compatible flash drive. It is recommended that this is the only file (*getlog.cmd*) loaded onto the flash drive. Contact True Blue Power if you have questions regarding creation of the *getlog.cmd* file.
- B. Remove the USB access cover.
- C. Insert the configured USB flash drive into the USB Type-A port on the battery.
- D. With the battery idle (no charge or discharge current, no active protections), transition to control mode by pressing and holding the blue service button (located above and to the left of the USB port) until the service light (located above and to the right of the USB port) changes from solid white to blinking white (approximately 3 seconds) and releasing before the flashing white stops (5 seconds).
- E. While the battery is reading from or writing to the USB flash drive the service light will blink yellow when the battery is downloading the event log onto the USB flash drive. A full event log (approximately 74,000 entries; 8MB maximum) may take up to 8 minutes to download to the USB flash drive.
- F. Once the event log is downloaded the service light will be solid green (if event log download completed successfully) or be solid red (if event log download did not complete successfully).

- G. The USB flash drive will now have a file named *eventlog.csv* that can be imported into a spreadsheet for viewing and further analysis.
- H. Remove the USB flash drive and the battery will reboot into flight mode.
- I. Replace the USB access cover securely.

5.4 OPTIONAL SERVICE

The True Blue Power Advanced Lithium-ion Battery is a maintenance-free product. No scheduled maintenance is required once installed. The procedures described in this section are included for verification of battery performance only on an as-needed, or on-condition, basis. Note, however, that the battery **MUST** be recharged every six (6) months when not in use.



EXTREME care and caution should be applied when handling the unit. Danger of short circuit, electrical burns or equipment damage can occur if not handled properly. Be EXTREMELY cautious to avoid shorting terminals, dropping metal objects, hardware or tools on top of or down into the battery. REMOVE ALL JEWELRY before working with the battery.

5.4.1 Visual Inspection

- A. Verify that proper communication is available to the cockpit to validate the battery is transmitting data appropriately. To perform this, turn on the avionics master and deactivate the battery disable (if installed). Verify battery operating parameters are displayed appropriately according to the aircraft installation (voltage, SOC, capacity, CAS messages, etc.).
- B. Visually inspect the power terminals and Communication connector to make sure they are secure. Inspect the vent connection and make sure the vent hose/tube is secure. Verify that none of the connections are loose and there are no signs of damage, wear or corrosion.
- C. Remove the unit from the aircraft. Visually inspect the exterior of the battery casing for signs of damage or wear. Verify that the lid is secure and not loose. Verify that no damage has occurred which would prevent the battery from maintaining its air-tight seal. Inspect the battery area of the aircraft for any signs of improper installation or unusual wear.
- D. Some wear is expected due to normal use (for instance: scratches on the bottom of the battery or near the hold-down points). However, if there are any anomalous or concerning visual indicators, the unit should be evaluated and tested for repair or replacement by an authorized repair facility.

5.4.2 Charging

Recommended Chargers / Operation:

1. True Blue Charger Pro TT28-12 – refer to User Manual
2. True Blue Charger Mx TT28-2 – refer to User Manual
3. Benchtop Power Supply: 0-30VDC Range

In order to charge the unit off-aircraft, follow the steps listed below:

1. Set the power supply to a constant voltage of 28.8VDC
2. Limit the maximum current of the power supply to 20A (or less)
3. Charge the battery until the charge current tapers to less than 1.0A.

5.4.3 Capacity Check

Most aircraft are certified to use the battery's reserve energy to maintain critical systems in the event of a main power generation loss for a minimum period of time. The required minimum capacity will vary by application. Verify requirements associated with your aircraft.

The battery is designed to dynamically compute its capacity at all times throughout its life. As the battery ages, the accuracy of its reported capacity can change due to a variety of factors associated with its use, environmental conditions, and the characteristics of the cells. Using the procedures in this section, the battery's reported capacity can be recalibrated or verified. This procedure is recommended for improved performance and accuracy, but does not represent required maintenance nor is required for continued airworthiness by the manufacturer. However, consult your aircraft's maintenance procedures for specific requirements.

5.4.3.1 Self-Learning Capacity Calibration

Using the procedure below, the battery can re-calibrate its capacity measurement to improve its accuracy for ongoing use.

- A. Ensure that the unit is charged per Section 5.4.2.
- B. Apply a constant current load of 20A to discharge the battery pack. (Capacity check should be conducted at 23°C ±3°C (68-79°F) for best results.)
- C. When the battery is nearly depleted, it will turn off its power output and stop discharging.
- D. Charge the battery again per Section 5.4.2. The battery's reported capacity will be reset to the actual measured value.

5.4.3.2 Manual Capacity Check

If there is any reason to suspect the accuracy of the reported capacity, a manually measured capacity check can be performed.

- A. Ensure that the unit is charged per Section 5.4.2.
- B. Apply a constant current load of 20A to discharge the battery pack. (Capacity check should be conducted at 23°C ±3°C (68-79°F) for best results.)
- C. Monitor the time (in minutes and seconds) from initially applying the constant current load in Step B until the unit the battery is nearly depleted and turns off the power output/stops discharging.
- D. Calculate the capacity in amp-hours (Ah):
 - Discharge time (in hours) = discharge minutes / 60
 - Capacity (Ah) = (amps) x (hours) = (20 amps) x (Discharge time)

5.4.4 Return to Service

- A. Recharge the unit per Section 5.4.2.
- B. Measure and verify that the voltage on the unit's power terminals is greater than 27.6 VDC. A unit should never be returned to service if the voltage is less than this value after charging.
- C. Re-install the unit in the aircraft, including securing it via proper hold-downs, mating the electrical connections, and verifying proper vent attachment.
- D. Record service action in aircraft log book.

5.4.5 Return to Service

In accordance with IATA and per UN 3480, PI 965, Sections 1A and 1B, when shipped by air the True blue Power Advanced Lithium-ion Battery must be shipped with a state of charge (SOC) not to exceed 30% of rated capacity.

- A. To prepare the battery for shipment, refer to the Advanced Lithium-ion Battery Support Guide (located at www.truebluepowerusa.com), which includes a Shipping Preparation Guide.

5.5 COMPONENT SERVICE

The cells, electronics, and other components that comprise the TB20 Advanced Lithium-ion Battery are not user serviceable or replaceable items. Therefore, data is not available from the manufacturer to conduct field service. If the product requires service, please contact the manufacturer.

5.6 STORAGE INFORMATION

In normal use, the battery utilizes the aircraft power to maintain the proper charge voltage and sustain the battery cells at peak capacity. Although the cells have an extremely low relative self-discharge rate, all batteries will slowly self-discharge if left unused for long periods. In addition, self-discharge rates are directly related to the storage temperature. Higher storage temperatures will result in faster self-discharge rates.

Rechargeable lithium-ion batteries must be stored in a dry, well-ventilated area. They must not be kept in the same area as highly flammable materials. The unit can be stored in the same area as other battery chemistries. The battery does not emit or absorb any gas during storage, transportation, or during normal operating conditions.



NOTE: The unit is shipped with approximately 30% state-of-charge (SOC). Upon receipt the battery shall be fully charged using the procedures listed in this manual (prior to storage and again prior to installation/use).



STORED BATTERIES MUST BE FULLY RECHARGED AT A MINIMUM EVERY 6 MONTHS.

SHELF-LIFE: Batteries stored for an extended period of time must be occasionally recharged. Follow the procedure set forth in Section 5.4.2 for charging. If the storage time is unknown, a battery should be recharged prior to reaching 10% state of charge according to the indicator on the front of the battery.



If a battery is allowed to self-discharge after it has been depleted (i.e if it is not recharged within 7 days), the cells can be damaged. If the battery becomes over-discharged due to this condition, it will protect itself by preventing subsequent charging. The battery must then be returned to the factory for assessment.

STORAGE TEMPERATURE: Exposure to temperatures above 30°C (86°F) for sustained periods of time are possible, but may increase the self-discharge rate or result in some permanent loss of capacity. Storage temperatures above 50°C (122°F) are to be avoided.

5.7 END OF LIFE

Estimated life for the True Blue Power Advanced Lithium-ion Battery is expected to exceed six (6) years. The unit has reliably demonstrated over 20,000+ simulated engine starts and subsequent charge cycles. The cells themselves are designed for a useful life of up to ten (10) calendar years.

The following conditions will help maintain or extend the life and performance of your product:

- Avoid significant exposure to high temperatures (above 30°C/86°F) during operation or storage
- Avoid long periods (greater than 7 days) after a full discharge
- Avoid long periods of storage (greater than 6 months) without recharge

End of life is represented by the inability of the unit to meet the minimum capacity requirement of the aircraft either as programmed and self-determined by the battery, or upon verification of manual capacity check and verified against aircraft requirements. In the event that the unit exhibits failure, insufficient capacity or expired life, contact True Blue Power for repair, exchange or replacement. Visit www.truebluepowerusa.com for more information.

5.8 DISPOSAL



NOTE: All lithium-ion batteries are classified by the United States government as non-hazardous waste and are safe for disposal as normal municipal waste. However, these batteries do contain recyclable materials and recycling options available in your local area should be considered when disposing of this product. Dispose of in accordance with local and federal laws and regulations.
Do not incinerate.

5.9 DO-311A COMPLIANCE QUALIFICATION FORM

MODEL NUMBER: TB20 **PART NUMBER:** 6430020-()
DESCRIPTION: Advanced Li-Ion Main Ship Battery **CERTIFICATION:** FAA TSO-179b
MANUFACTURER: True Blue Power, a division of Mid-Continent Instrument Co., Inc.
ADDRESS: 9400 E. 34th St. North, Wichita, KS 67226, USA
SPECIFICATION: Test Specification (TS) 713 Test Data Sheet (TDS) 713
STANDARD: RTCA DO-311, Rev A, dated 12/19/2017

| SECTION | SUB | TITLE | RESULT | SUMMARY | |
|---------|---------|--|--------------------------------|---|---|
| 1 | 1.4 | Battery Categories | Comply | Energy Category 4: >200Wh Venting Category B: designed vent Architecture Category: Standalone | |
| 2 | 2.1 | General Requirements | Comply | RTCA/DO-178C, DAL A Rated Capacity: 20Ah | |
| | 2.2 | Equipment Requirements | Comply | Met by passing tests in 2.4.4 | |
| | 2.3 | Environmental Conditions | Pass | Required sections of RTCA/DO-160 complete; see EQF | |
| | 2.4.4 | 2.4.4.1 | Physical Examination | Pass | See IM for physical specifications |
| | | 2.4.4.2 | Acceptance Test Procedure | Pass | ATP per MPS identified above |
| | | 2.4.4.3 | Insulation Resistance | Pass | Contacts/case electrically connected |
| | | 2.4.4.4 | Handle Strength | Pass | Each handle capable of 2X unit weight |
| | | 2.4.4.5 | Capacity Test | Pass | 20Ah minimum |
| | | 2.4.4.6 | Capacity Test at Low/High Temp | Pass | 16.5Ah @ -40°C; 19.5Ah @ 70°C |
| | | 2.4.4.7 | Constant Voltage Discharge | Pass | I _{PP} = 900A, I _{PR} = 700A @ 18V |
| | | 2.4.4.8 | Charge Acceptance | Pass | 18Ah @ -40°C; 19Ah @ 23°C |
| | | 2.4.4.9 | Charge Retention | Pass | 90% @ 23°C; 80% @ 50°C |
| | | 2.4.4.10 | Cycle Test | Pass | Retained 99% capacity @ 100 cycles |
| | | 2.4.4.11 | Rapid Discharge Test | Pass | I _{MAX} = 160A @ 70°C |
| | | 2.4.4.12 | Short Circuit with Protection | Pass | Max current = 2980A; S/C cutoff @ 124ms |
| | | 2.4.4.13 | Overdischarge Test | Pass | Protective circuitry prevented charging after overdischarge |
| | | 2.4.4.14 | Overcharge Test | Pass | Overcharge protection activated at 31.5V |
| 2.4.5 | 2.4.5.1 | Short Circuit Test of a Cell | Pass | No release of fragments, flames or emissions | |
| | 2.4.5.2 | Short Circuit Test of a Battery without Protection | Pass | No release of fragments, flames or emissions | |
| | 2.4.5.3 | Overdischarge without Protection | Pass | Emission of gas, smoke and electrolyte exited vent port | |
| | 2.4.5.4 | Single Cell Thermal Runaway Containment Test | N/A | | |
| | 2.4.5.5 | Battery Thermal Runaway Containment Test | Pass | All cells achieved thermal runaway; Maximum case temp = 122°C | |
| | 2.4.5.6 | Explosion Containment | Pass | No ruptures in case; no emissions observed | |
| | 2.4.5.7 | Drop Impact | N/A | | |

REMARKS:

- Compliance includes all of Section 1 and Section 2, unless noted.
- Sub-paragraphs without specific criteria of note are not listed.

5.10 DO-160 ENVIRONMENTAL QUALIFICATION FORM

MODEL NUMBER: TB20 **PART NUMBER:** 6430020-()
DESCRIPTION: Advanced Li-Ion Main Ship Battery **CERTIFICATION:** FAA TSO-179b
MANUFACTURER: True Blue Power, a division of Mid-Continent Instrument Co., Inc.
ADDRESS: 9400 E. 34th St. North, Wichita, KS 67226, USA.
SPECIFICATION: Test Specification (TS) 713 Test Data Sheet (TDS) 713
STANDARD: RTCA DO-160, Rev G, dated 12/08/2010

| CONDITIONS | SECTION | DESCRIPTION OF TEST |
|--|---------|--|
| Temperature and Altitude | 4 | Category C4 |
| Temperature Variation | 5 | Category S2 |
| Humidity | 6 | Category B |
| Operational Shock and Crash Safety | 7 | Category B |
| Vibration | 8 | Fixed Wing: Category R; Curves C & C1 Rotorcraft: Category U; Curve G |
| Explosion | 9 | Category H |
| Waterproofness | 10 | Category W |
| Fluids | 11 | Category F |
| Sand and Dust | 12 | Category S |
| Fungus | 13 | Category F |
| Salt Fog | 14 | Category S |
| Magnetic Effect | 15 | Category A |
| Power Input | 16 | Category B(RX) |
| Voltage Spike | 17 | Category A |
| Audio Frequency Conducted Susceptibility | 18 | Category Z |
| Induced Signal Susceptibility | 19 | Category ZC |
| Radio Frequency Susceptibility | 20 | Category Y (conducted) Category G (radiated) |
| Emission of Radio Freq Energy | 21 | Category ML |
| Lightning Induced Transient Susceptibility | 22 | Category B3 (pin injection) Category K3L3 (cable bundle) |
| Lightning Direct Effects | 23 | Category X |
| Icing | 24 | Category X |
| ESD | 25 | Category A |
| Fire, Flammability | 26 | Category X |

REMARKS:
Section 4: Category C4 with excursions as declared by the manufacturer:

- 4.5.1: Ground Survival Low Temp -55°C
- 4.5.1: Short-Time Operating Low Temp -40°C
- 4.6.1: Altitude +55,000 feet
- 4.5.3: Ground Survival High Temp +85°C
- 4.5.4: Short-Time & Operating High Temp +70°C
- 4.6.2: Decompression +8,000 feet

Section 13: Category F met by analysis.