



PB – 2000ITS

Operator's Manual Addendum

Battery Maintenance and Warranty Returns



2.4.1 Battery Back-Up Time Test

Purpose: Describes how to measure the back up capacity of batteries.

This test provides a measurement of back-up time during power outage by actually discharging the batteries. The back-up time is dependant on load, temperature and battery age. More back-up time is available with less load or higher temperature and less time with more load or lower temperature. The general industry recommended practice is to replace batteries if the capacity is below 80% of rating even if excess capacity is available because a capacity of 80% shows that the battery rate of consumption is increasing.



Tip: Batteries are rated at 25°C (77°F). Operation at cooler temperatures will decrease the operating time (less capacity). Operation at hotter temperatures will increase the operating time but decrease the overall battery life. The run time determined in the test below should be adjusted by the Time Correction Factor in IEEE 1888 if the initial battery temperature is significantly above or below 25°C (77°F). The formula to correct battery capacity at other than room temperature to capacity at 25°C is

$$C = T[\text{actual}]/(T[\text{rated}] \times \text{Time Correction Factor})$$

C is temperature-corrected battery capacity in % of rating when new
 T[actual] is the run time found in the test at other than room temperature
 T[rated] is the run time for the same discharge when new
 Time Correction Factor is a number from 0.684 for 5°C to 1.177 for 45 °C as found in IEEE 1188.

The graph below provides a simpler method to determine if actual run time is acceptable by showing what percent the rated or expected run time should be decreased or increased for battery temperature other than 25°C (77°F). This graph is generic as each battery design will have slightly different values. Also to be considered is that there is a 50% reduction in battery life for each 15°F the **average** operating temperature is above 77°F, meaning batteries that routinely operate in a hot environment will lose capacity faster.

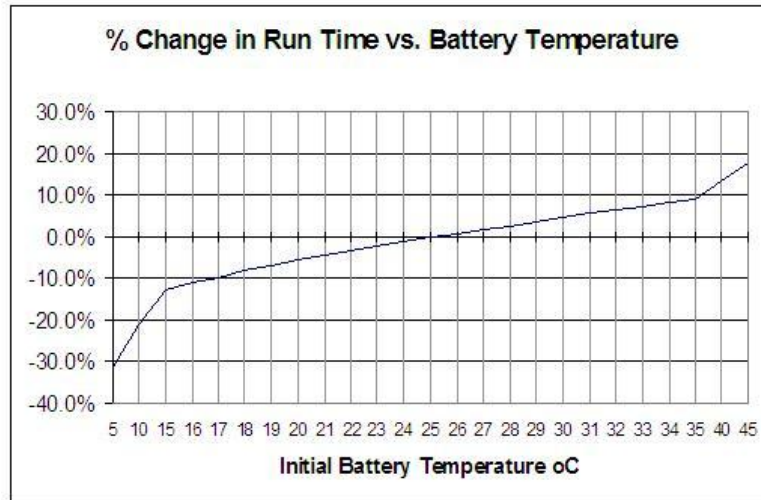


Figure 61
Battery Run Time Correction for Temperature



Tip: For traffic industry applications, it is recommended to test batteries at least yearly. For general industry standards for battery testing, refer to IEEE 1188 "Recommended Practice for Maintenance, Testing, and Replacement of VRLA Batteries for Stationary Applications." It is recommended that the battery test interval not be greater than 25% of the expected service life or 2 years, whichever is less. The expected service life may be significantly less than the warranty period if battery temperature or duty cycle are exceeded. If an acceptance test was not performed

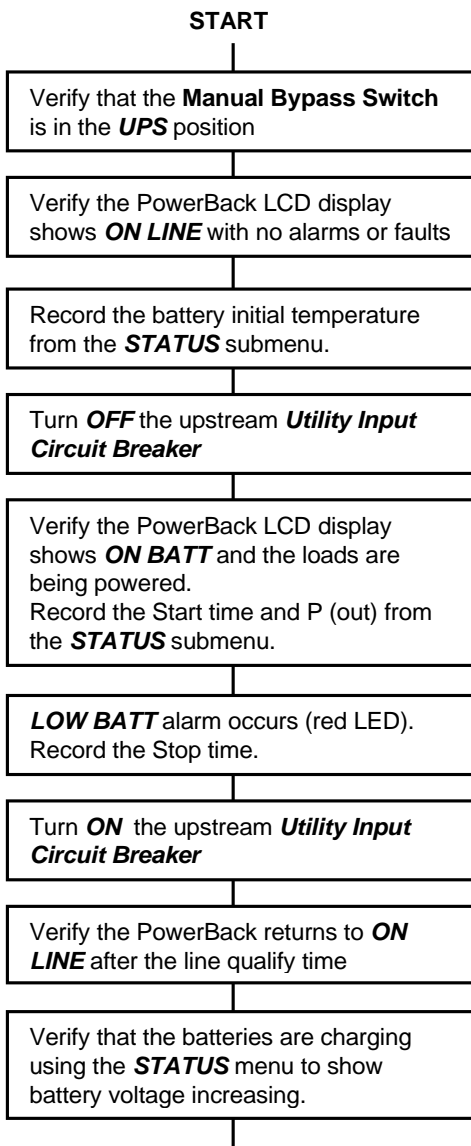
at initial installation, the first capacity test should be performed within one year of installation. If the run time test below will take too long for the installation (i.e., the UPS system is rated for many hours rather than just a few hours), a rate-adjusted test can be performed as described in IEEE-1188.



Tip: Make sure the batteries are fully charged before starting this test (STATUS submenu shows V (batt) of approximately 54 VDC or greater at 25°C (77°F)).



DANGER: If the actual intersection signals are used as the load for this test, and the load is left on the batteries beyond the low battery alarm (AC line power is not restored), the batteries will continue to discharge down to the Low Battery Shutdown, at which point power output to the intersection from the UPS is automatically shut off to avoid damaging the batteries. The intersection will go DARK.



EXAMPLE:

Start time is 1 PM when display shows **ON BATT**.

P (out) = 500 watts

Stop time is 4 PM when **LOW BATT** alarm occurs.

4 PM – 1 PM = 3 hours run time

Compare this run time to the time obtained when the batteries were tested within one year of installation, corrected for the actual battery temperature at test start. It will likely be less, but should not be significantly less than the previous test (more than 10% for the same P (out) value).

2.4.2 Battery Maintenance

Batteries are the weak link in any UPS system. They cannot be simply installed and forgotten about as many people think. The batteries typically provided with the PowerBack are Valve-Regulated Lead Acid/Absorbed Glass Mat (VRLA/AGM) and are often referred to as “maintenance-free”, *which only refers to the fact that these are sealed batteries that do not require water to ever be added.* With no free liquid in them, they are ideal for side-of-road use where they could potentially be hit and broken open in a vehicle accident. AGM batteries are also ideal for high-rate design often used in UPS systems that must provide power immediately on loss of AC.

But all batteries, regardless of type, require some amount of preventive maintenance to prolong the life of the batteries, insure their reliability and to provide documentation of correct operation for warranty claims if defects occur. Regardless of warranty, battery service life can be affected by many factors such as: operating temperature, charging temperature, number of discharges during the battery’s life, extent of discharge, and time left in discharged state. For example, if a battery has a 2-year warranty and is rated for 100 discharge cycles, but actually experiences 100 discharges in the *first* year of use, the 2-year warranty is no longer valid. The battery designer and manufacturer cannot control end user conditions that exceed the expectations for the battery selected. Customers may be asked to provide documentation of usage before warranty claims will be honored.

Industry-accepted guidelines for preventive maintenance for VRLA batteries can be found in IEEE Standard 1188 “Recommended Practice for Maintenance, Testing, and Replacement of VRLA Batteries for Stationary Applications.” IEEE suggests monthly, quarterly and yearly maintenance which may not be practical in traffic industry applications, therefore batteries should be inspected any time the traffic signal cabinet is visited for other maintenance. Typical preventive maintenance consists of inspections and tests which should be performed at least annually at a minimum. The “PowerBack & Battery Preventive Maintenance Checklist” on the following pages should be printed and completed to document performance of preventive maintenance.

Industry-wide, VRLA batteries experience a failure rate of less than 0.5% due to manufacturing defects. Any battery failures that exceed this rate may indicate a problem with the UPS controller, cabinet ventilation & environment, or AC and DC breakers. In traffic industry use, the expected service life of VRLA/AGM batteries is approximately 3 years. A high number of discharge cycles or high operating temperatures will reduce this lifespan. For a better understanding of VRLA/AGM batteries see section 2.4.3 of this manual immediately following the preventive maintenance checklist.



POWERBACK & BATTERY PREVENTIVE MAINTENANCE CHECKLIST

Date: _____ Name: _____ Agency: _____

Intersection: _____

PowerBack Part Number: _____ Serial # _____ DOM _____
(Above information is on label on left side of PowerBack)

Battery Manufacturer: _____ Model/Part No. _____ Date Code _____

- Download the PowerBack log file to verify the number of discharge cycles and battery temperature are not excessive. The log file may be required for warranty claims. Review the file for alarms and faults.
- Record the number of Inverter Events and Inverter Timer from the Status submenu:
 Inverter Events: _____ Inverter Timer: _____
- Verify the charger float voltage (batteries fully charged) corrected for battery temperature compensation setting (Status submenu, Battery Voltage & Battery Temperature; Settings submenu, Batt. Temp. Comp): 54.0 V at 25°C (subtract 0.072 V/°C, 0.096 V/°C, or 0.120 V/°C for -3 /-4 / or -5 mV/°C/Cell respectively) Actual: _____
- Measure voltage of each individual battery while on float charge. Individual battery voltages may vary by ±0.30 volts of the average battery float voltage above. Because float readings are affected by discharge and recharges, these readings should be taken when batteries have been on continuous, uninterrupted float for at least one month. A significantly different voltage on one battery may indicate a bad battery which degrades the entire battery string and string capacity since they are connected in series.
 Batt 1: _____ Batt 2: _____ Batt 3: _____ Batt 4: _____
- Verify the charger float current with batteries fully charged is approximately 50 mA per 100 Ah of battery capacity. If more than 3 times this value an internal problem such as a cell internal short may exist, or the charger float voltage is too high or the ambient temperature is too high.
- Verify individual battery temperatures are within approximately 3 °C (1.7 °F) of each other at the negative post.
 Batt 1: _____ Batt 2: _____ Batt 3: _____ Batt 4: _____
- Verify the battery temperature probe is firmly connected at the battery and the PowerBack (remove the probe at the PowerBack front panel, verify the PowerBack alarm LED flashes, reinstall the probe, verify the alarm LED goes out.) If indicated battery temperature is suspect compared to individual readings above or PowerBack “No Temp Probe” alarm is indicated even with probe plugged in, verify that temperature probe resistance is approximately 12,000 Ohms.
- Observe or Record the following values from Status submenu during On Line, Self Test (Control submenu, Self Test, then press Enter twice to access Status submenu) and On Batt (Manual Bypass Switch to Bypass). Expected values are in ().

	On Line	Self-Test	On Batt (Bypass)
PTS transfers (if buck/boost is disabled; NA if enabled as it is already transferred)	NA	(audible “clunk”)	(audible “clunk”)
V (in)	(~120)	(~120)	(0)
V (out)	(~120)	(~120)	(~120)
P (out)	(0)	<1500)	(0)
F (in)	(~60)	(~60)	(0)
V (batt)	(~54- 55.2)	(~50)*	(~54- 55.2)*
Batt. Temp.	(~25C)	(~25C)	(~25C)
Output LED	(steady on)	(steady on)	(flashing)
Alarm LED	(not on)	(not on)	(not on)
Current out - optional (clamp-on ammeter at AC Output terminal block)	NA	<12)	(0)

*Observe that battery voltage holds steady after initial drop. Any rapid continuing decrease indicates One or more weak batteries or a DC drain somewhere on the system.



**POWERBACK & BATTERY PREVENTIVE MAINTENANCE CHECKLIST
(Page 2)**

- Verify the power being drawn from the system during Self-Test above is the same as when the system was initially installed and does not exceed 1500 watts.
Original power at installation: _____ watts Power as of test date: _____ watts
- If the power being drawn as observed above has changed, note any new hardware that has been installed at the intersection that increases power requirements.

- Verify no alarms or faults are indicated before or during above self-test. Record any indicated alarms or faults: _____
- Perform a run-time test (see 2.4.1 of this manual) and correct for actual battery temperature at start of test if ambient temperatures have been less than 77°F.
- Verify the cabinet fan is operating correctly. Heat is the main problem for batteries. Even though batteries will operate (discharge) at 165°F, their life is severely shortened. The PowerBack charger shuts off at 122°F to protect batteries.
- Verify batteries have at least ½ inch of space between them and between batteries and cabinet wall to provide adequate heat dissipation. VRLA batteries on float charge convert almost all energy into heat. If this heat is not removed, the battery temperature increases and more current will be required to maintain float voltage, resulting in still more heat. If not prevented this "thermal runaway" can result in AGM battery melting. The PowerBack charger shuts off at 50°C as a safety measure and to prevent battery damage from overheating.
- Verify battery terminals and connections are tight, clean and free of corrosion. The battery cable connector on the front of the PowerBack must be firmly seated. There should be a "double click" when properly connected.
- Verify battery cases are clean to allow maximum heat dissipation and in particular are free of excessive dirt or moisture between terminals that could allow "tracking" of current. DO NOT use hydro-carbon (oil-based) or strong alkaline cleaning solutions as they can cause battery case to crack or craze.
- Batteries are not bulging excessively. **A certain amount of bulge is normal.** To prevent the permanent loss of gases so that recombination has time to take place, each battery can hold up to about 1.5 psi without venting. Batteries with very large cells will bulge somewhat as this normal pressure builds. This is especially true in higher temperatures, because the polypropylene case is pliable. If a battery bulges severely on charge, it is not normal. It is an indication of a blocked valve or an overcharge situation. Such a battery should be removed from service.
- Batteries are not "sucked-in" excessively indicating deeply discharged batteries. **A slightly sucked-in appearance can be normal.** The valve on a sealed battery only lets gas out, never in, so a partial vacuum can form under various circumstances. Battery temperature and ambient pressure play a role, but predominantly the recombination and discharge reactions are responsible. After charging ends, the recombination reaction continues until most of the oxygen in the battery headspace is consumed. The total volume of the battery components decreases slightly during a discharge. Batteries with large cells may display this appearance even when fully charged. A sucked-in battery should be charged. If it remains sucked-in after charging, or if only a single battery in a string displays or lacks this appearance a load test would be prudent.

COMMENTS: _____

CORRECTIVE ACTIONS TAKEN: _____

2.4.3 Understanding VRLA/AGM Batteries

2.4.3.1 Introduction

Batteries are not as simple as many people think them to be. Before declaring a battery *defective* under warranty, the following should be understood (**see details in sections below**):

1. **Effect of design on service life:** high rate vs. long duration vs. general purpose design have different plate thickness and specific gravity which determines how long a battery will last
2. **Effect of Battery selection and installation on service life:** load profile, margin and installation effects on operating temperature
3. **Effect of operating conditions on service life:** temperature, number of cycles, and maintenance practices
4. **Relationship between warranty and service life:** marketing vs. reality, warranty covers premature loss of capacity due to defects, not conditions beyond the control of the designer or manufacturer.

Misconceptions about lead-acid battery life:

1. Battery design life is equal to warranty life.
2. Battery warranty life is equal to service life.
3. Battery selection and installation have little impact on service life.
4. Installation, operating and maintenance practices have little impact on service life.

Definitions:

Design Life = Expected (calculated) life of a battery based on the design at assumed manufacturer-established ideal operating conditions.

Service Life = Actual life of a battery based on the actual installation, operating conditions, and maintenance practices.

Warranty Life = The life of a battery over which the manufacturer amortizes the cost, often unrelated to the design and has no relationship whatsoever to the service life of the battery. For some manufacturers this is nothing more than a marketing tool or an insurance policy.

2.4.3.2 Effect of Design on Service Life

There are three basic battery types based on purpose and they have different service lives:

- High Rate (often called UPS)
- Long Duration (often called Telecom)
- General Purpose

The aging mechanism of a lead-acid battery is positive plate growth. As the grid grows, active material can shed and electrical contact between the grid and the active material is lost resulting in a loss of capacity.

Factors that influence the rate of positive plate growth:

- Physical strength of the grid
- Acid concentration
- Operating temperature

The battery designer cannot control operating practices, and design life is based on operating the battery within the parameters established by the designer.

The amount of current a battery can produce depends on the amount of active material in contact with the electrolyte and the acid concentration in the electrolyte.

In a high rate design, the goal is to have the maximum amount of active material in contact with the electrolyte at all times. This is done by reducing the thickness of the plates, thus allowing more plates in the same volume, increasing the surface area in contact with the electrolyte. It is also not uncommon for manufacturers to increase the specific gravity to 1.250 or 1.300 to improve the high rate.

In a long duration battery *the opposite is true*. Thick grids are used and specific gravity is typically 1.215. This results in a battery with a low 1 minute current but excellent long term power production capabilities.

A general purpose battery falls in between these two extremes. Plates are thicker than high rate designs, but less thick than long duration designs. Specific gravity is typically 1.215 to 1.250. This results in a battery with moderate high rate capabilities and good long term power production capabilities.

High rate designs with thin grids have the least amount of strength, while long duration designs have the highest grid strength. Thick grids have the strength to resist the growth caused by corrosion. Thin grids do not. Higher specific gravity gains short term capabilities but sacrifices life due to the increase in corrosion rate. So as you go from high rate to general purpose batteries you gain 25% to 30% life expectancy.

Not all batteries are designed to deliver the same service life, even if they have the same warranty life.

2.4.3.3 Effect of Selection and Installation on Service Life

Lead-calcium batteries are excellent for float operation, but they have a relatively short cycle life (typically 80 to 100 cycles).

2.4.3.3.1 Battery selection depends on load profile. The load profile that a battery must supply is the usually the deciding factor. A high rate design has a shorter expected service life than a general purpose or long duration. In some cases, high rate designs are selected for applications that can be served by a general purpose design, such as when a high initial rate is required and the physical space for the battery is relatively small. It is not uncommon to find a high rate battery installed with a relatively long load profile of several hours. The other advantage is that the high rate battery will have a lower cost than the general purpose battery. However use of high rate batteries for frequent long duration service is not recommended.

2.4.3.3.2 Lack of aging margin in battery sizing is becoming more common as an issue. Unless the purchase specification explicitly details aging factors, competitive pressures force vendors to leave them out. This keeps the initial cost down but results in a battery without any aging margin that will have to be replaced when capacity falls below 100%. Specifications should always require at least 20% aging margin, and warranties likewise do not apply unless the battery falls to less than 80% capacity during the specified time period.

2.4.3.3.3 Battery installation effects on operating temperature.

In the US, batteries are rated at 25°C or 77°F. Operation at cooler temperatures will decrease the operating time. Operation at higher temperatures will decrease the overall service life of the battery.

Operating temperature is one of the most misunderstood battery parameters. In reality, the operating temperature is *the internal cell temperature*. While ambient temperature influences battery temperature, it is not the only determinant. Battery temperature in a well ventilated space normally runs 1 to 2°F above ambient temperature. In a space with localized temperature gradients caused by such things as direct sunlight or a heat source, the battery can be exposed to *very large extremes in cell temperature resulting in uneven aging of the cells*.

For Valve Regulated Lead-Acid (VRLA) batteries, air flow is of great importance. In VRLA designs, the recombination reaction at the negative plate produces heat that must be dissipated to the environment. If adequate air flow around the cells is not provided, or if the air flow is restricted, localized hot spots can develop within the battery. *At the least, these hot cells will age at a more rapid rate.* At the worst, they can pull the battery into thermal runaway and in the worst case scenario result in a fire.

2.4.3.4 Effect of Operating Conditions on Service Life

2.4.3.4.1 It's a fundamental fact: heat is bad for batteries and has the greatest effect on battery life. IEEE 450 contains a graph that shows for every 15°F rise above 77°F *continuous average operating temperature*, a flooded battery loses half of its available life. This holds true for VRLA high rate designs also, except the life is much

shorter to start with. For a 10 year expected service life, the life drops to 5 years at 92°F and 2.5 years at 107°F. *Unfortunately, battery manufacturers have not developed a way to accurately predict the effects of the more normal frequent hot and cold cycles.*

2.4.3.4.2 Temperature gradients can cause a battery string to have a shorter life. Temperature can be unequal across the battery string to the point that batteries in a string age at significantly different rates. Because heat rises, typical causes are racks with more than 2 tiers and uneven temperature gradients from bottom to top. *The aged batteries in the string become the limiting factor in ability of the string to produce energy, resulting in reduced run times.*

2.4.3.4.3 Number of discharge cycles effects battery life and is not well understood. It is easier to quantify the effect of temperature on battery life than it is to quantify the effect of discharge cycles. The impact of cycles on battery life is highly dependent on the frequency of the discharges, the depth of the discharge, and how quickly the battery is recharged following the discharge. Most lead-calcium batteries are rated for 80 to 100 cycles (a cycle is defined as a discharge of greater than 80% of available battery capacity followed by a recharge.) While a battery can withstand a higher number of shallow discharges, they still accelerate the aging of the battery and result in loss of service life. While a lead-calcium battery may be initially selected for a particular location, if the site is subjected to frequent power disturbances (hence battery discharge / recharge cycles), then the battery should be replaced with a battery more suited to cycling operation such as a lead-antimony or lead-selenium design.

2.4.3.4.4 Maintenance practices affect battery life. A continuous over-charge of .01 volts per cell has a similar impact as operating the battery at 80°F. For a typical 48 volt battery string with 24 cells, this results in a 0.24 volt increase in overall string voltage. In the opposite case, failure to maintain individual battery voltages above critical voltage can cause batteries to self-discharge and sulfate. In extreme cases, this can lead to the plates expanding until the case ruptures, creating an open circuit in the battery string. Even if the case does not rupture, a failed battery creates a high resistance condition that significantly reduces the battery string's ability to produce power. High resistance terminal connections can also fail and cause battery fires.

2.4.3.4.5 Air quality is a potential issue. The build up of dust on the battery cover in the presence of humidity can result in tracking. An even worse impact is if the battery is exposed to an environment where the dust is conductive. Tracking creates external shorts and can cause individual batteries in a string to fail. Ability to use horizontal arrangement of posts in VRLA designs (batteries on their side) does not make them immune to tracking because the vent is normally located with the posts and can release small amounts of acid, which does not dry and attracts moisture and dust.

2.4.3.5 Relationship Between Warranty and Service Life

FACT: Conditions beyond the control of the manufacturer affect the service life of a battery.

EXAMPLE: In the United States, many industrial *flooded* lead-acid batteries are sold with a twenty-year warranty whether or not there is a reasonable expectation that the battery will last twenty years. This is because industrial consumers have come to expect the twenty-year warranty. In Europe, the opposite is true. Almost no batteries are sold with twenty-year warranties. The difference is that some U.S. manufacturers use longer battery warranties as a marketing tool to increase sales. It has little to do with the actual design life of the battery.

2.4.3.5.1 Long warranties for high rate products or VRLA designs are not reasonable compared to the actual service life. Manufacturers must charge extra money for the longer warranty, knowing they will be giving some of it back. This is like an insurance policy. A reasonable warranty provides the necessary coverage against manufacturing defects as intended without excessive coverage and its associated cost based on battery capacity over time with all its variables.

2.4.3.5.2 Warranty claims must be reasonable and documented. The warranty is specific about the operating conditions and maintenance requirements. When the end user fails to meet these requirements, they must shoulder the burden for short battery life. End users should keep the necessary records to support warranty claims. With the price of lead doubling in 6 months, battery suppliers are not going to accept warranty returns without proof of proper operation, and that may mean more frequent PM checks or diligently recording UPS system log files every month to prove the number of cycles or temperature has not been excessive.

2.4.3.5.3 Battery selection, installation, operating conditions, and maintenance affect the service life of the battery. If battery strings in one or more locations fail while others from the same purchase and supplier do not,

there is usually a reason other than defective batteries. End users must be able to tell the difference between what is a warranty claim due to manufacturing defects or errors and what is shortened service life based on operating conditions and maintenance practices.

2.4.3.5.4 Provide capacity margin for aging. Batteries begin consuming themselves as soon as they enter service. A design that has no margin sacrifices battery life to keep the initial cost down. This may result in a 10-year battery having only a 3 to 5 year service life before capacity falls below the value needed for the battery to perform its design function. *This is not a warranty issue.* This is a failure on the part of the purchaser to understand that the lowest price up front can have a significant impact on the overall life cycle maintenance cost of the installation. Aging margin of 20 to 25% capacity should be included on top of the needed operating capacity.

2.4.5 PowerBack Return Instructions

BATTERY WARRANTY RETURNS

Before contacting Quixote Traffic Corporation to request a Return Material Authorization (RMA) for batteries supplied as part of the PowerBack[®] UPS system, verify the batteries were supplied by Quixote Traffic and not by the local distributor.

An RMA for batteries will require that the preventive maintenance checklist in section 2.4.2 of this manual be completed and faxed to Quixote Traffic before an RMA will be issued, including the signature of the person that performed the checks and the date they were performed at the top of the checklist.