

Best Practices to Maximize Lead-Acid Battery Life and Reliability

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Abstract

Lead-acid batteries have been around for over 150 years and are renowned for their proven lifespan. High-quality lead-acid batteries, in particular, are known for their lifespans of twenty years or more. However, achieving a battery's full potential requires careful attention at every post-selection stage.

This paper delves into critical steps and best practices for end-users to follow in order to maximize the life and reliability of lead-acid batteries in standby and stationary applications. It offers practical guidelines and real-world examples, highlighting common mistakes, challenges, and providing effective solutions. The insights presented aim to equip end-users with the knowledge to enhance battery performance, ensuring longevity and reliability in various applications.

Introduction

Lead-acid batteries have been a cornerstone in standby and stationary applications for many decades, renowned for their reliability and long lifespan. Despite advancements in battery technology, high-quality lead-acid batteries remain the preferred choice for various applications due to their cost-effectiveness, recyclability, proven reliability, performance, and longevity. However, to fully leverage their potential, users must adhere to a few best practices throughout the battery's lifecycle.

Although not the focus of this paper, it is important to recognize that one of the key factors in maximizing the life and reliability of the battery is selecting the correct battery for your application from a reliable supplier. For battery selection, these factors include vented lead acid (VLA) versus valve regulated lead-acid (VRLA), plate type and alloy, discharge rate and time, cycle-life, operating temperature, and desired lifetime. For supplier selection, consider experience, reputation, quality production processes, and compliance with standards and certifications such as ISO and IEC.

This paper aims to provide a guide for end-users, detailing some of the critical steps necessary to maximize the life and reliability of their lead-acid battery systems. From selection to the final stages of maintenance, each phase plays a crucial role in ensuring optimal performance. By understanding and implementing these practices, users can avoid common pitfalls and maximize the longevity of their battery systems.

We will explore various aspects such as ordering, factory testing, storage, installation, charging, and maintenance. Through practical guidelines and real-world examples, we will highlight common mistakes, challenges, and effective solutions. The goal is to equip end-users with the knowledge and tools needed to achieve the best possible outcomes for their lead-acid batteries, ensuring maximum life and reliability.

Battery Ordering and Project Coordination Issues

One of the biggest challenges users can face is battery deliveries arriving too far in advance of project dates or projects that are significantly delayed, especially seen during the COVID era. This can negatively impact your battery's overall life, reliability, and warranty. Lead-acid batteries are not stable shelf items and require additional maintenance and recharge cycles to keep them in optimal condition while maintaining their warranties and ensuring maximum life. This can lead to increased costs and resource allocation, which can be avoided with a few simple steps.

First and foremost, effective coordination among purchasing, engineering, operations, and vendors is essential to ensure batteries are delivered exactly when needed. Insufficient communication and collaboration between departments can exacerbate these issues. Regular communication and collaboration between all teams are crucial for aligning schedules and meeting project deadlines.

Mistimed orders can lead to premature deliveries, requiring extended storage and extra recharge cycles, which, if unmanaged, can reduce battery life or void the manufacturer's warranty. Late arrivals can disrupt planned outages, halting progress and causing delays in project completion, which can increase labor costs or affect overall project start-up/completion, potentially carrying significant financial penalties.

A lack of standardized procedures and guidelines for procurement can lead to inconsistencies and inefficiencies in the ordering process. Without clear protocols, teams may struggle to align their efforts, resulting in delays and errors. Inadequate training and knowledge of purchasing and project management staff can hinder effective procurement of batteries. It is crucial to ensure that staff are well-trained and knowledgeable about the batteries they are ordering. Too often, purchasing and project management teams have little understanding that batteries have a limited storage period, leading to requests for deliveries too far in advance. Poor vendor management can also lead to unreliable deliveries. Selecting reputable vendors/partners and maintaining strong relationships with them is vital for ensuring timely and quality deliveries.

Here are a couple of real-world examples of ordering issues and solutions:

- **Example 1:** A major utility's purchasing department consistently ordered batteries under the assumption that they are shelf-stable commodities. To avoid issues related to storage, recharging, and even warranty concerns, we developed a system of checks with the installation and engineering groups. This system ensures that orders and order dates are validated and adjusted as needed and are not based solely on the date put on the PO from purchasing.
- **Example 2:** After encountering issues with batteries needing to be scrapped and replaced after unregulated extended storage, a major building vendor expressed frustration with the fluctuating timelines associated with their capital projects. In response, we collaborated with them to develop a detailed project tracking system specifically for batteries. This system allows them to easily notify us of any changes needed in the battery delivery dates, ensuring on-time deliveries as required for their projects. This approach helps avoid costly errors associated with unplanned and unregulated battery storage while maintaining confidence in their fluctuating project schedules.

By addressing these challenges and fostering effective coordination and communication among all teams involved, you can mitigate potential issues and ensure a timely project completion while avoiding unnecessary costs.

Factory Testing

While all reliable manufacturers conduct quality control tests, additional specified Factory Acceptance Testing (FAT) is valuable for establishing baseline data consistent with field testing methods and usage. This step verifies critical metrics, such as battery capacity and corresponding ohmic values, providing specific baselines for ongoing performance evaluation. These tests confirm that the battery meets its published ratings and your requirements.

Conducting FAT following IEEE 450 and IEEE 1188 guidelines provides comprehensive insights into battery health and performance. These tests establish initial benchmarks for comparison during field testing and help users comply with industry requirements, such as NERC. Including these FAT requirements in your purchasing agreements and working with your vendors/partners to supply them is recommended.

A practical approach is to have your manufacturer or vendor duplicate the initial tests you will perform during site commissioning before shipment. This ensures consistency and reliability through the commissioning process. Requesting that the same ohmic meters be used during FAT and by your maintenance teams helps identify discrepancies and validate measurement accuracy, providing confidence in your initial baseline readings.

Consider your FAT requirements regarding duration and procedures. Tests aligned with your true application use are more beneficial than general QA tests that may be proposed by the vendor.

FAT should be conducted in a controlled environment to ensure precise testing conditions. Using calibrated and standardized equipment, such as ohmic meters, load banks, and temperature control systems, is crucial for maintaining data consistency between FAT and field testing.

Detailed test procedures, adhering to IEEE 450 and IEEE 1188 standards, including pre-test inspections, initial charge and discharge cycles, and specific tests for capacity, voltage, and internal resistance, should be meticulously followed and documented. We also recommend having a FAT cross-referenced with test cell numbering and cell or block serial numbers to allow for future correlation between the FAT testing and your system as installed.

Users should have the option to visit the test facility and witness FAT in person. Including this as a requirement in your requests provides additional assurance.

Examples of how FAT testing can be utilized:

- **Example 1:** One specific user was consistently having issues with their field crews providing questionable internal ohmic values with their meter of choice, which raised concerns internally about the reliability of their new battery systems. As a result, we worked with the customer to develop a custom FAT test plan where their batteries are now capacity tested per IEEE 450 standard while also providing internal ohmic values using their battery test equipment of choice. This approach provided them with a concrete set of baseline values for their batteries, correlated with the batteries' true capacity, allowing them to have correlating data for their field testing. This allowed them to have full confidence in their new batteries while also helping to eliminate some of the field errors previously seen.

- **Example 2:** In an effort to best match their switchgear use case scenario, following IEEE recommendations, one of our customers requests that we regularly perform a modified performance test. In this testing, the batteries and their connection scheme are tested at 80% of the 1-minute rate, followed by an 8-hour capacity test. Doing so confirms both the high-rate potential of the battery and its connection scheme, along with its full 8-hour support time, providing compliance documentation and allowing for full confidence in their new battery system.

By incorporating these FAT practices and requirements, users can ensure their lead-acid batteries are performing optimally and are in a ready-to-use state, maintaining and confirming a reliable baseline for ongoing performance evaluation. These initial baseline readings are critical to your overall maintenance program, key to trending and tracking data. More details on this will follow...

Battery Storage Considerations

Extended storage periods—which are more common now due to non-battery-related supply chain challenges—can degrade battery health. Lead-acid batteries require regular recharging and controlled temperatures to maintain optimal performance and lifespan. While storage requirements vary by alloy and technology, proactive planning and handling are necessary to prevent deterioration.

Since lead-acid batteries self-discharge over time, extended storage without recharging can lead to sulfation, which reduces battery capacity and lifespan. It is necessary to recharge batteries, as outlined by the manufacturer, during storage to maintain their health, reliability, overall lifespan, and warranty.

Generally, batteries should be stored in environments with stable temperatures, ideally between 4.4°C (40°F) and 25°C (77°F). Extreme hot temperatures can accelerate chemical reactions inside the battery, leading to degradation. Avoid locations with high humidity or fluctuating temperatures.

If your organization lacks the ability to recharge its battery inventory, it may be recommended to have an agreement with your manufacturer/vendor to return batteries for delayed projects for periodic recharging and storage to prevent early-stage degradation and to maintain your warranty. This involves setting up schedules for recharging and ensuring batteries are stored in optimal conditions.

Examples of issues we have seen with battery storage and how they were resolved:

- **Example 1:** A utility user who was normally stocking inventory of batteries discovered that a significant portion of their inventory was faulty due to extended storage without recharge. This issue arose from a combination of knowledge lost through retirements and oversight during the COVID lockdown. Since having ready inventory was an important factor for them, we worked with the company to devise a purchase and ship-in-place scheme. This scheme allocated a small amount of inventory for immediate shipment as needed, allowing them to avoid the need to store and maintain a ready stock of batteries. This approach ensures their batteries are always in a ready-to-use, fully charged condition.

- **Example 2:** One of our electrical utility customers identified several battery strings that had been in storage. We worked with them to determine which strings needed to be scrapped, which ones were still usable, and which ones required specific charging and capacity testing to assess their viability. The strings that needed further evaluation and specific charging were returned for inspection. Some of these were found to be usable, while others were deemed unreliable. This process ensured that only reliable batteries were installed, saving the customer replacement costs by reusing evaluated batteries. Additional instructions were provided to help prevent similar issues in the future.

While some customers like to have limited inventory on hand for emergency purposes. It is important to have specific and detailed requirements for storage and recharge, including documentation. This is crucial for both end users who manage this in-house or contract out to third-party providers. Once damage has been done to a battery due to improper storage/handling, there is often no fixing the issue. You may still be able to use the battery, but it will likely affect the overall battery's reliability, life expectancy, and warranty.

Proper Installation

Now that we have covered some initial considerations, the next key element is ensuring proper battery installation. Properly trained installation teams are critical for the safe and reliable setup of new lead-acid battery systems. Following IEEE and manufacturer guidelines for batteries, racks, and spill containment ensures the proper and safe setup of your system, thereby ensuring the reliability and longevity of your battery systems.

Ensuring that installation teams are well trained is essential. It is recommended that all installation teams be trained and certified following IEEE 1657, which focuses on personnel qualification for the installation and maintenance of stationary batteries. Pre-installation training should cover all aspects of the setup, including handling batteries, assembling racks, and implementing spill containment measures. Teams should be familiar with IEEE standards such as IEEE 484 and IEEE 1184, which provide guidelines for the installation and commissioning of lead-acid batteries. Manufacturer guidelines must also be strictly followed to ensure compliance with safety protocols, optimal performance, and warranty validity.

Thorough documentation and checklists are vital tools for maintaining high installation standards. Documentation should include detailed procedures, safety protocols, and manufacturer specifications. A checklist or detailed work plan can help ensure that all steps are completed correctly and that nothing is overlooked during the installation process. This proactive approach minimizes the risk of errors and enhances the overall reliability of the battery system. This should also tie back to the FAT testing data, ensuring that your installers have access to and are reviewing your FAT test data as compared and correlated to your installation data.

After installation, it is crucial to conduct thorough visual and technical inspections of the battery system. Start with a visual review to identify any physical abnormalities. Ensure all components, including batteries, racks, and spill containment measures, are properly installed and secure. Verify that battery terminals are clean and free of corrosion, and that all cables are correctly connected.

Next, perform technical inspections using specialized tools such as voltmeters, ohmic meters, and hydrometers. Measure the battery voltage, connection resistance, and specific gravity of the electrolyte (for non-sealed batteries). Compare these readings with the baseline data obtained during FAT to ensure consistency and accuracy.

Finally, maintain detailed records of all post-installation checks. Document the results of both visual and technical inspections, noting any discrepancies or issues. This documentation is essential for future references and for ensuring compliance with industry standards and regulations.

If using a third-party contractor for installations, it is essential to ensure that your organization has detailed specifications and/or a scope of work to ensure that your vendors are properly trained, have properly documented safety protocols in place and are following IEEE, battery manufacturer, and your own internal guidelines. Failure to properly vet and oversee your contractors can result in subpar work, which can affect your system's overall life and reliability, along with possibly affecting your battery warranty.

A couple examples of where we have seen installation gone wrong and how this could have been prevented:

- **Example 1:** During a recent inquiry about broken batteries, it was found that a building vendor installed a new set of VLRA batteries on a 2-step/2-tier rack prior to transporting the building. Unfortunately, the installer did not properly secure the battery both through proper seismic rack installation and through secondary guards necessary when pre-installing a battery system in a building being moved. As a result, the entire battery system came loose and fell off the battery racking during transport, resulting in a total loss of the battery string to the tune of tens of thousands of dollars, along with requiring a significant cleanup effort. This could have been prevented by either installing the string after the building had been set on site (recommended) or through better installation training, safeguards and coordination with us to identify and address additional steps necessary if transporting the batteries in the rack was necessary.
- **Example 2:** BAE batteries were installed into a high-rate UPS application. The installation was performed by personnel without the proper training or equipment. No installation readings or proper documentation were taken or provided. IEEE 484 and manufacturer guidelines were not followed. The result was a fire that thankfully caused no personal injury but did cause significant damage. This highlights the importance of following both the manufacturers and IEEE guidelines, as failure to do so can, in the worst case, lead to severe consequences.

Since it is in all parties' interest, it is recommended to coordinate training with your battery manufacturer/vendor for your internal teams and vendors to ensure proper installation practices are followed. We recommend utilizing personnel who are knowledgeable, experienced, and have real-world hands-on knowledge when it comes to battery installation.

By adhering to these best practices and guidelines, users can ensure safe and reliable installation of their lead-acid battery systems, minimizing risks and maximizing performance.

Charging Your Batteries

Correct charging practices are essential to maximize battery life. Charge voltage must be carefully matched to battery specifications, particularly when batteries or chargers are replaced independently. Improper voltage settings can significantly reduce reliability and lifespan, along with voiding your battery warranty.

Best Practices for Charging

To ensure optimal performance and longevity of lead-acid batteries, it is crucial to follow the manufacturer's guidelines. Here are some key considerations:

- **Use the Correct Charger:** Always use a charger specifically designed or compatible with lead-acid batteries. Chargers should match the battery's voltage and capacity specifications. For standby applications, we recommend chargers designed to meet IEEE 2405 requirements.
- **Monitor Charging Process:** Regularly monitor the charging process to prevent overcharging or undercharging. Overcharging can lead to excessive gassing and water loss, while undercharging can cause sulfation. Both conditions shorten battery life and void warranties. Utilize chargers with over and under voltage alarms to quickly address issues before battery damage occurs.
- **Temperature Compensation:** Adjust the charging voltage based on ambient temperature if recommended by the battery manufacturer. The general rule of thumb is for every degree above 25°C (77°F), reduce the voltage by 3mV, and for every degree below 25°C, increase the voltage by 3mV. However, the users should follow what is recommended by the manufacturer. Failure to compensate for temperature can affect battery life due to overcharging or undercharging caused by physical changes in the battery especially associated with long duration temperature extremes.
- **Avoid Fast Charging:** Fast charging methods can cause overheating and reduce battery lifespan. Use controlled charging methods as advised by the manufacturer.
- **Equalization Charging:** Periodically perform equalization charging to balance voltages, mix the specific gravity of the electrolyte, and desulfate the battery plates. This should only be done as recommended by the manufacturer, as over-equalization can also shorten battery life.

Some examples of where we have seen charging oversights lead to premature battery failures:

- **Example 1:** A set of 125V 50Ah batteries were installed, but the charger voltage was set far too low. After several years, the customer noticed visible issues and contacted us. Upon review, it was determined that the charger voltage was so low that it did not overcome the batteries' self-discharge, causing them to slowly discharge to the point of failure. A simple step of reviewing the maintenance readings and correcting the voltage would have prevented this. Instead, the 20-year VLA battery needed to be replaced after only a few years in service.
- **Example 2:** At a large Data Center, as part of a general site review after nearly a decade of service and ahead of some capacity testing, we were asked to review and make recommendations on some observed site condition issues. As part of this review, we were provided the maintenance records of the battery strings in question. During the review process, it was noted that a large number of the 540VDC battery strings were charging well above the BAE recommended values and had been that way for over six years. As a result, the battery strings were starting to show signs of accelerated positive grid corrosion and post growth. With some corrective actions, the high-rate system tested adequately, but in subsequent years, they were replaced earlier than normally seen due to the accelerated aging effects of overcharging. Again, a simple review and correction of charging voltage on the UPS would have provided for a longer battery life.

By following these best practices and ensuring that charge voltage settings are carefully matched to battery specifications, users can maximize the reliability and lifespan of their lead-acid batteries.

Maintaining Your Batteries

Regular, standards-compliant maintenance is vital for battery reliability and warranty protection. Consistent review of measurements by qualified personnel ensures early detection and resolution of issues, such as adjusting low charge voltage settings promptly to mitigate long-term damage.

Best Practices for Maintenance

To ensure optimal performance and longevity of lead-acid batteries, follow these best practices:

- **Regular Inspections:** Conduct regular inspections to check for signs of wear, corrosion, and other potential issues. This includes visual inspections and technical checks using specialized tools such as voltmeters, ohmic meters, and hydrometers. Regular inspections should at minimum satisfy the requirements outlined by your battery manufacturer to maintain your battery warranty.
- **Standards Compliance:** Adhere to industry standards such as IEEE and NERC PRC-005, which outline minimum maintenance activities and maximum time intervals for battery maintenance. Compliance with these standards helps ensure reliability and protects warranties.
- **Qualified Personnel:** Ensure maintenance is performed by qualified personnel trained to detect and address issues early. This includes reviewing measurements and adjusting settings as needed while in the field.
- **Use Monitoring Systems:** Implement real-time monitoring systems to continuously track battery performance and alert personnel to potential issues. This proactive approach helps prevent failures, extends battery life, and minimizes overall maintenance costs.
- **Review and Trend Data:** Ensure that knowledgeable personnel review, trend, and track the maintenance data collected. Battery maintenance is rarely a “pass” or “fail” situation; it involves detecting potential issues and taking corrective actions as necessary. This can be done in conjunction with your battery manufacturer/vendor or handled internally by your battery SMEs.

A couple examples of some common maintenance oversights that we have seen over the years:

- **Example 1:** A relatively common issue we have seen over the past few years, as NERC guidelines have driven the more accepted use of Ohmic values, is a general lack of consistency in measuring these values. This issue is not limited to one customer but is a general problem observed in the industry. We have noticed that a lack of consistency and training leads to differences in ohmic readings, both internal and connection, resulting in questionable readings. This inconsistency makes tracking and trending, which are key to ohmic evaluation, very difficult. It can lead to false battery failure questions, unnecessary replacements, or worse, unexpected failures due to issues hidden by faulty data. To help our users prevent this, we have provided training seminars centered on best practices for maintaining BAE batteries, with a strong focus on correctly taking and recording ohmic values.
- **Example 2:** A user in the upper Midwest noticed significant deviations within the battery string voltages of multiple of their sites and contacted us, suspecting a battery problem. However, after an intensive review of these sites, it was discovered that this issue occurred only during the winter months at sites heated by resistance-style heaters. Once battery temperature readings were obtained, it was found that on the 2-tier battery racks, there was over a 20-degree temperature gradient between the batteries on top and bottom tiers. Prior to this, no cell temperatures were being taken and recorded, so this issue was previously overlooked. Once room circulation fans were added to the battery areas, the voltage issue was no longer present.

As with installation, it is recommended to coordinate training with your battery manufacturer for your internal teams and vendors to ensure proper maintenance practices are followed.

By adhering to these best practices and ensuring consistent review of measurements by qualified personnel, users can maximize the reliability and lifespan of their lead-acid batteries.

Conclusion

Maximizing the life and reliability of lead-acid batteries in standby and stationary applications requires meticulous attention to detail at every stage of the battery's lifecycle. In addition to selecting the correct product from a reliable supplier, ensuring proper installation, charging, and maintenance practices is crucial for achieving the full potential of these batteries.

Battery Ordering and Project Coordination: Effective coordination among purchasing, engineering, and operations teams, as well as suppliers, is vital to avoid premature deliveries and extended storage periods, which can degrade battery health. Proactive internal training along with planning and communication with suppliers can prevent early-stage degradation and maintain warranty validity.

Factory Acceptance Testing (FAT): Conducting FAT tests following IEEE guidelines provides confirmation that the battery will perform as needed and provide valuable baseline data for ongoing performance evaluation. Ensuring consistency between FAT and field-testing methods helps verify critical metrics and maintain battery health and overall peace of mind.

Storage: Proper storage practices, including regular recharging and controlled temperatures, are necessary to prevent deterioration during extended storage periods. Coordinating with suppliers for periodic recharging or ideally avoiding storage can help maintain battery health.

Installation and Post-Installation Checks: Properly trained installation teams and adherence to IEEE and manufacturer guidelines ensure safe and accurate setup. Thorough documentation, checklists, and post-installation checks help identify and resolve issues early, ensuring system reliability.

Charging: Correct charging practices, including using the right charger, monitoring the charging process, and adjusting for temperature compensation, are essential to maximizing battery life. Avoiding fast charging and performing equalization charging as recommended by the manufacturer can prevent premature degradation.

Maintenance: Regular, standards-compliant maintenance by qualified personnel is vital for early detection and resolution of issues. Consistent review of measurements, proactive monitoring and taking corrective actions help prevent failures, extend battery lifespan, and maintain warranty validity.

High-quality lead-acid batteries will remain the preferred choice for many users. By following these best practices and guidelines, users can ensure the optimal performance, reliability, and longevity of their lead-acid battery systems. Implementing these strategies not only protects the investment in battery systems but also contributes to the compliance and reliability of standby and stationary applications.