Are Valve-Regulated Lead-Acid Batteries Reliable? An End-User Perspective

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Valve Regulated Lead-Acid (VRLA) batteries have been commercially available for more than 20 years and have been enthusiastically embraced by users of uninterruptible power supplies (UPS) because of the anticipated reduction in installation and operating costs, smaller footprint, lighter weight, and fewer environmental concerns. However, as with any evolving technology, both users and suppliers have encountered varying degrees of performance reliability. Manufacturers and end-users agree that the premature failures experience by field installations are mainly due to temperature and charging sensitivity, manufacturing quality control, and compatibility issues with appropriate applications. Proprietary concerns and incomplete data management systems have reduced publicly available performance and lifecycle data. This limits the ability to evaluate premature capacity loss that has been reported for VRLA batteries after as few as two years of service.

This project was funded by DOE Energy Storage Systems, International Lead Zinc Research Organization (ILZRO), and the Advanced Lead-Acid Battery Consortium (ALABC). The focus of this study is to characterize the relationship between VRLA technologies, service conditions and failure modes. These organizations are impartial regarding VRLA battery choice, and their sponsorship of this effort has created an unbiased forum for evaluating VRLA product characteristics, operating conditions, field performance and service life.

This study consists of three phases:

- Confidential survey of manufacturers of VRLA cells for stationary applications
- Confidential survey of VRLA end-users in stationary applications, primarily utility and telecommunications
- Analysis of the two surveys to identify combinations of design, manufacturing and operating procedures that may enhance VRLA performance and reliability

The two surveys revealed very candid descriptions of battery operation and maintenance and interesting linkages between service conditions and failure modes.

The manufacturer survey addressed differences in VRLA design and manufacturer commitment to quality control. Each manufacturer was asked to respond to questions describing their cells physical, electric, and performance characteristics (see Table 1).

Table 1. Survey Question Categories for VRLA Manufacturers

Physical Characteristics	**Electrical Characteristics**	**Performance Characteristics**
• Exterior dimensions • Electrolyte • Separator material • Case and post sealing methods • Plate geometry • Recommended operating temperature	• Cell Amp-hour capacity • Internal resistance • Monthly self-discharge • Specific energy	• Application • Recommended float voltage • Expected yearly premature failures • Cause of premature failures

The end-user survey revealed installation and operating procedures that may have contributed to the apparent success or failure of the VRLA cells. Each end user was asked to respond to questions describing where they purchased their cells, their VRLA installation, and operating and monitoring regimes (see Table 2).

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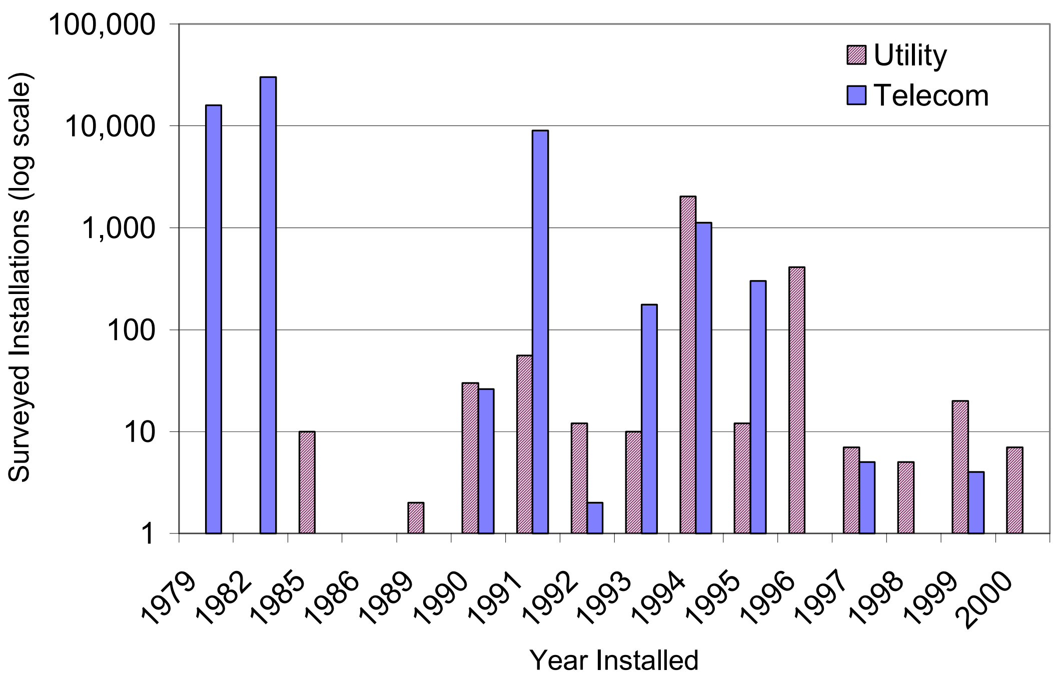
Table 2. Survey Question Categories for VRLA End Users

Battery Identification	Installation Description	Operation/Monitoring
• Type of application • Seller/installer • Receipt of installation/operating instructions • Unusual failures • Root cause of failure	• Make/model of cells • Installation size (number of cells, modules, amp-hours) • Year installed • Indoor/outdoor and geographic location • Temperature control • Ambient temperature	• Float voltage • Year first cell replaced • Total cells replaced • Parameters monitored and frequency

A password-protected database has been created that identifies all known VRLA battery end users and descriptive and operating information on the installations represented by the respondents. Geographic location, installation size, conditioned space, float conditions, year installed and first cells replaced, cycle frequency, and parameter monitoring are addressed. A report on the results of the survey will be released in 2001 to ALABC and ILZRO members, Sandia, and manufacturer and end-user survey participants.

This paper focuses on the end-user survey results. As of August 1, 2000, 19 utilities and nine telecommunications firms completed surveys. These responses represent just under 60,000 installations with over one million cells. Utility and telecom installations are analyzed separately because of the fundamental differences in age, operation, and rate of failure. The telecom respondents represent a much older group of VRLA installations, with 81% installed before 1985. By contrast, all but 5% of the utility installations were installed since 1994 (see Figure 1).

Figure 1. Year Installed for Surveyed Utility and Telecom Installations



The age of the installation at first cell replacement provides insight into the rate of premature failure. None of the surveyed telecom and only four of the utility installations experienced first cell replacements within the first year, indicating few manufacturing flaws among the surveyed cells. Over 95% of the utility installations replaced the first cell within 1-3 years while only 3% of the installations experienced no cell replacements (see

Figure 2). By contrast, over 54% of the telecom installations never replaced cells, most of them over 15 years old. Only 17% of the telecom installations replaced cells within 1-3 years (see Figure 3).

Figure 2. Age of Utility Installations at First Cell Replacement

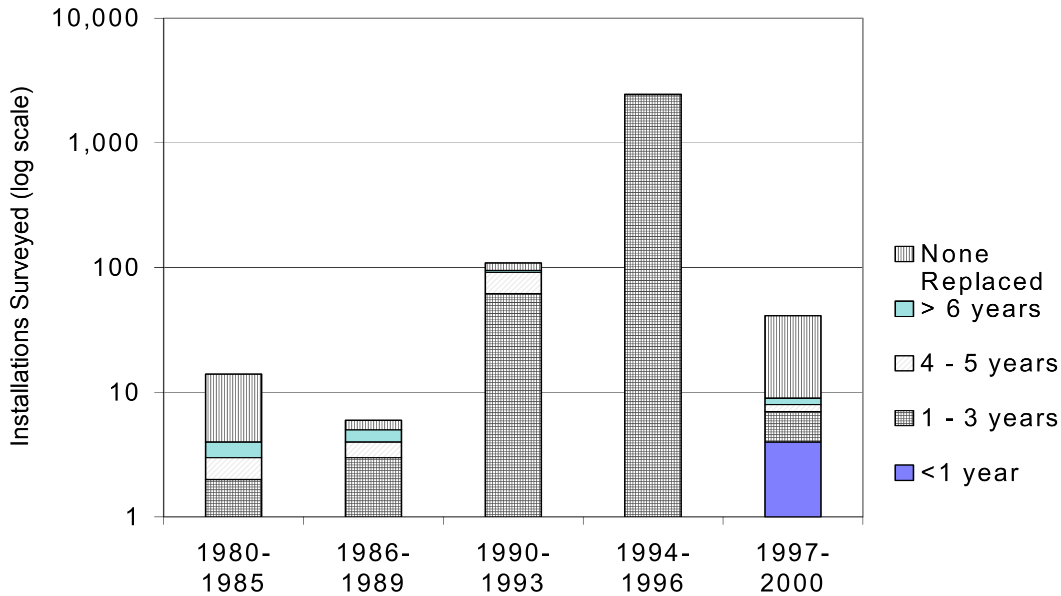
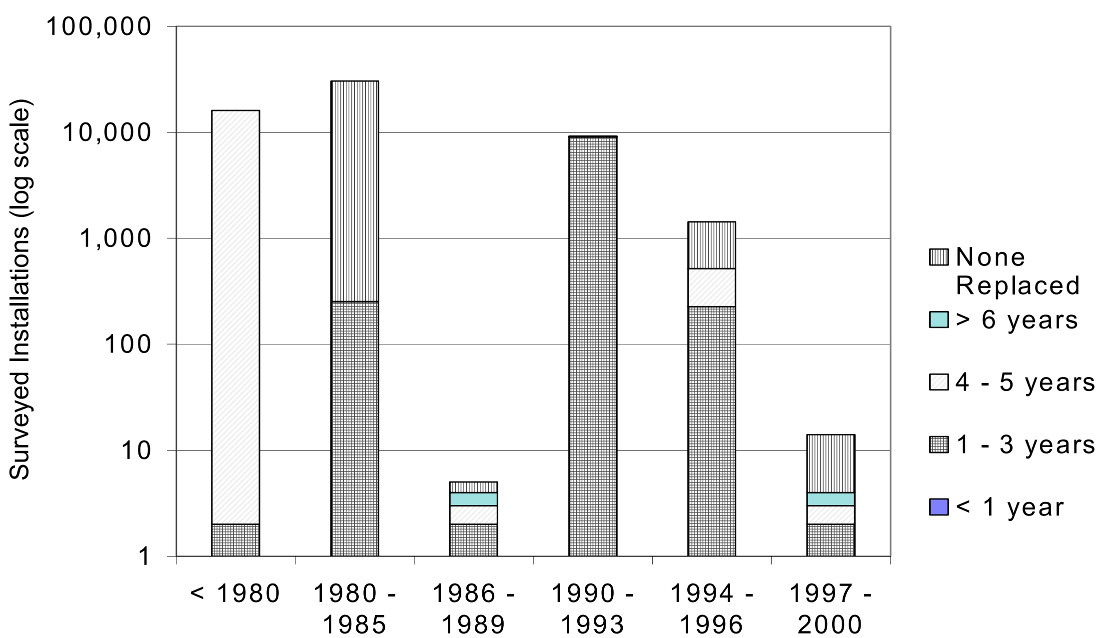
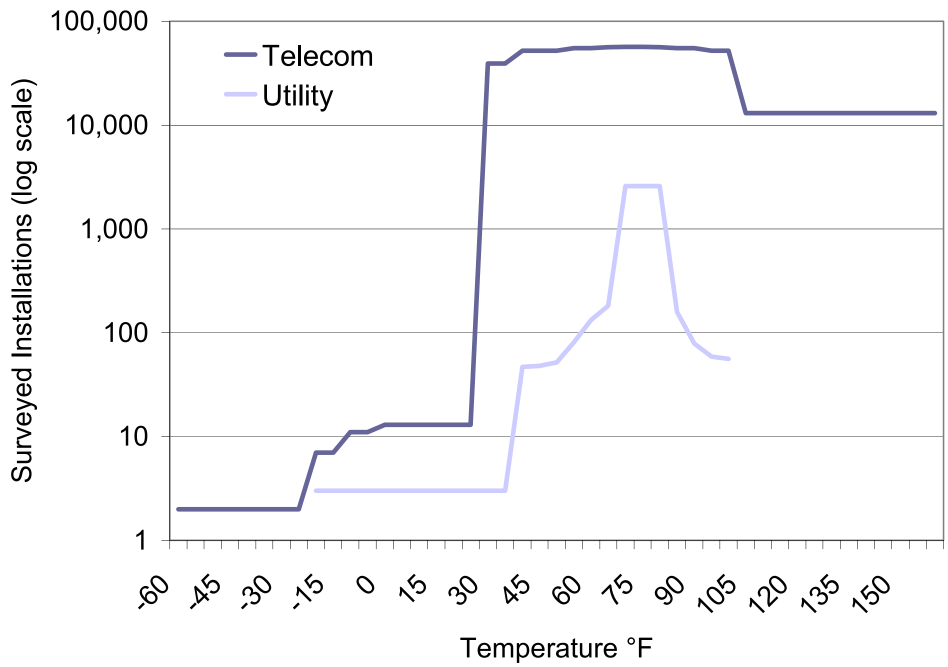


Figure 3: Age of Telecom Installations at First Cell Replacement



One of the primary causes of premature cell failure is temperature sensitivity. It is known that all electrical ratings and performance specifications are based on the specified standard temperature of 77°F and that the design life is cut approximately in half for every 15°F that the ambient operating temperature rises above that optimal temperature. As shown in Figure 4, the surveyed installations were subjected to temperatures ranging from –60°F to 160°F. Most of the telecom installations were operated in the range of 40-100°F whereas utility installations were operated in a narrower range of 75-95°F.

Figure 4. Operating Temperatures of Surveyed VRLA Installations



Limits on operating ranges were assessed. An operating range of 50°F was considered to be less demanding on the installations than operating ranges exceeding 50°F. As seen in Figure 5, 92% of all telecom installations and 1% of all utility installations surveyed were exposed to an operating temperature ranges in excess of 50°F. Of those telecom installations, 43% experienced first cell failures within five years (18% within the first three years) and 57% did not have to replace a single VRLA battery. Similar to telecom installations, 56% of the utility installations experiencing an operating temperature range in excess of 50°F did not make any cell replacements. Of the installations operating within a narrow temperature range, 78% of telecom installations experienced their first cell failures within five years and 97% of the utility installations within three years. These results do not support other studies claiming that wider operating temperature ranges (in excess of 50°F) result in shortened life.

Overcharging cells can lead to cell dry out. This is another cause for concern when discussing premature failures in VRLA cells. To prevent cell dry out the recommended float voltage for the majority of VRLA cells surveyed is 2.26 volts per cell (vpc). If the cells are exposed ambient temperatures above 77°F, the float voltage should be decreased below 77°F to ensure optimal life. Most manufacturers provide this information in their installation and operating instructions, which 71% of the end-user participants reported receiving. The vast majority of installations surveyed (99%) reported floating their cells between 2.25 – 2.26 vpc. Of the installations receiving operating instructions, 99% exposed their installations to ambient temperatures greater than 95°F without lowering the current during float (see Figure 6). Thirty-seven percent of these installations experienced cell failures with five years of service.

Additional findings are being analyzed and will be released in the final report.

Figure 5. Operating Temperature Ranges and First Cell Replacement

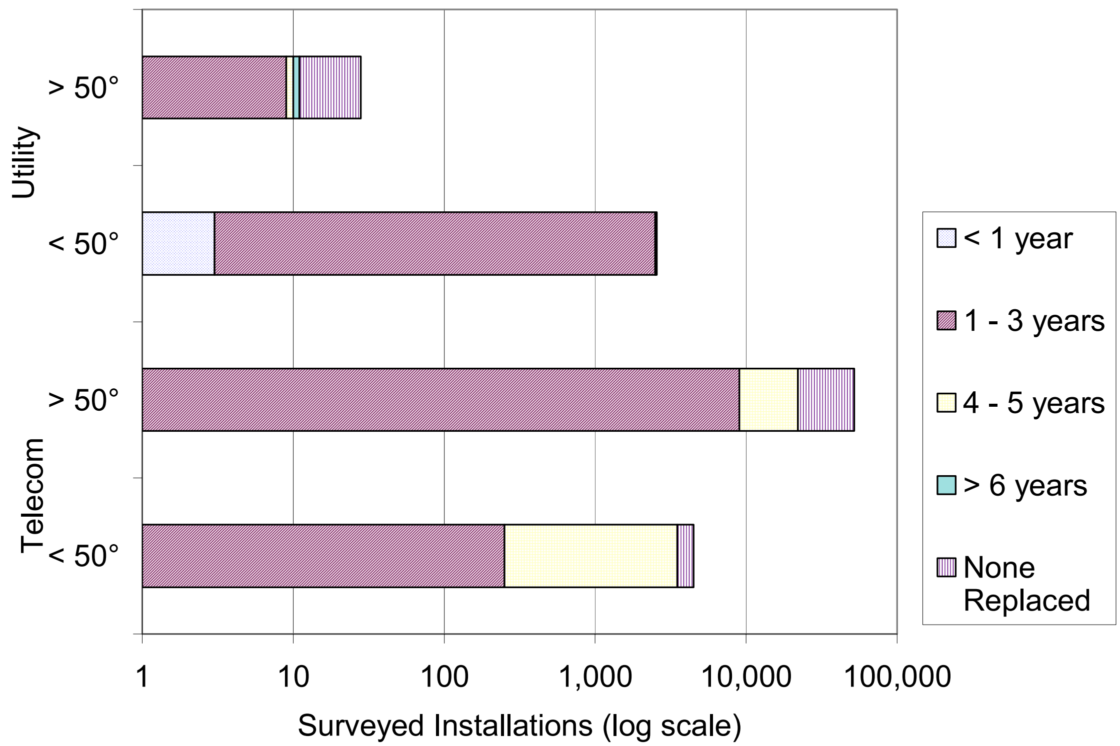


Figure 6. Float Voltage by Maximum Ambient Temperature