Development of the “SLR-1000” Super Long Cycle Life Valve Regulated Lead Acid (VRLA) Battery

Abstract

GS Yuasa has developed the “SLR-1000” Super Long Cycle Life Valve Regulated Lead Acid Battery. The newly developed “SLR-1000” has excellent cycle life performance of over 5,000 cycles, more than twice as many as the existing “SLE-1000” battery, by using a newly designed positive grid and high density positive active material.

1. Introduction

Today, environmentally friendly, renewable energy is being introduced more and more into the electric power field. Solar power and wind power generation is becoming widespread. However, these renewable energy sources rely on climate and can be unreliable energy sources. Increased renewable energy generation linked to utility grids greatly affect electricity quality, therefore, stabilization of the electricity supply is essential in the market.

One of the measures being promoted is the use of storage batteries. Batteries store the excess power generated when demand is low and discharge when demand increases. Valve regulated lead-acid batteries designed for cycling are commonly used because of their reliable performance and easy maintenance.

The above events led GS Yuasa to drastically improve the cycle life performance from the existing long cycle life VRLA battery “SLE-1000” (1,000Ah/10HR). The newly developed super long cycle life VRLA battery is called “SLR-1000”.

ABOUT GS

GS BATTERY (U.S.A.) INC. is an American subsidiary of GS Yuasa Corporation Japan, the global leader in energy storage. Our batteries and energy storage systems are manufactured to the highest standards and deliver high quality, long life and superior performance in a wide variety of mission critical applications. GS Battery’s products deliver reliable battery power for Telecommunications, Renewable Energy, Uninterruptible Power Supply (UPS), Emergency Lighting, Power Sports, and Automotive industries.
2. Developing SLR-1000

2.1. Concept

(1) Nominal voltage: 2V. Rated capacity: 1,000Ah/10HR
(2) Designed cycle performance: 70% depth of discharge (DOD), 5,000 cycles at 25° C (Double cycle life of the SLE-1000)
(3) Operating condition: modular frame, horizontal installation
(4) To minimize installed space, utilize stacking module configuration. Maintain same dimension as the SLE-1000.

2.2 Developed Battery Overview

The following pictures are single battery view (Fig. 1), rack system view (Fig. 2), and single battery cell dimension (Fig. 3). 

**Table 1**

<table>
<thead>
<tr>
<th>Specification</th>
<th>SLR-1000</th>
<th>SLE-1000</th>
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<tbody>
<tr>
<td>Model Number</td>
<td>SLR-1000</td>
<td>SLE-1000</td>
</tr>
<tr>
<td>Nominal Voltage / V</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Rated Capacity (10 hR) / Ah</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>Expected Life / cycles (DOD 70%, 25° C)</td>
<td>5000</td>
<td>2000</td>
</tr>
<tr>
<td>Outer Dimensions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length / mm</td>
<td>287</td>
<td>287</td>
</tr>
<tr>
<td>Width / mm</td>
<td>165</td>
<td>165</td>
</tr>
<tr>
<td>Height / mm</td>
<td>493</td>
<td>493</td>
</tr>
<tr>
<td>Mass / approx. kg</td>
<td>67</td>
<td>64</td>
</tr>
</tbody>
</table>

Fig. 1 External appearance of newly developed “SLR-1000” valve regulated lead-acid battery

Fig. 2 External appearance of newly developed “SLR-1000” battery rack system
2.3 Plate Element Structure

(1) Diamond Style Grid

Common VRLA grids use a Calcium alloy. A Calcium alloy’s primary failure mode is grid corrosion and plate growth. When the plates grow, active material is shed from the grid which reduces battery capacity. Moreover, plate growth ruptures the grids causing end of life. This growth is a common failure mode in VRLA batteries. Minimizing grid growth was important in developing the SLR-1000 to improve cycle performance.

A larger cross-sectional area is a critical factor to minimize grid growth. Engineers simulated and CAE analyzed square-shaped grids for absorption of grid growth stress in order to retain grid integrity. As a result, making the grid 20% longer and optimizing the cross section achieved a 5,000 cycle performance.

Fig. 4 is the accelerated life test evaluation results of 3 battery types. Type A diamond style grid based on CAE analysis and study. Type B and C designs are different square shaped grids. The Type A diamond style grid performed significantly better and exceeded the target of 25 years in float service at 25° C.
Fig. 5 is the cross-sectional view of the newly developed positive grid after 1,500 cycles on DOD 70% cycle test.

Fig. 6 is the cross-section corrosion at 70% depth of discharge cycle life test. Compare with the existing, SLE-1000 battery. The trend for the SLR-1000 indicates that 5,000 cycles is possible in 70% depth of discharge life test.

Fig. 6 Expectation of positive grid corrosion at the end of cycle life test.
(2) Optimized Positive Plate Active Material

An increase in the density of the positive active material results in reduced initial capacity. However, the benefit is typically a longer cycle life time before the material becomes soft/sulfated and inactive. Also, lower coefficient of utilization of active material during discharging enhances cycle life performance. To achieve cycle life performance, the SLR-1000 adopted high density active material and lower utilization rate in design.

(3) Nano-Carbon Negative Paste

To reduce sulfation on the negative grid, a higher ratio of carbon in the negative active material paste was utilized. This gave the negative plate more charging reaction which provided greater cycle life performance. Too much carbon causes less purity and less strength of the lead active material and capacity loss. We examined a number of different chemistries and found the right mixture for the active material. The result of different ratios of carbon mixed paste is shown in Fig. 7.

The negative plate active material also improved charge acceptance to enhance PSOC (Partial State of Charge) performance.

![Fig. 7 Different ratio of carbon mixed paste plate cycle life test result.](image)
(4) High Density Glass Fiber Separator

In order to retain high compression, a high density glass fiber mat separator is needed for longer cycle life to prevent positive active material from dropping off. The SLR-1000 separator has approximately 10% higher glass density compared to the separator in the SLE-1000 model Fig. 08. This new high density mat maintains greater compression for better cycle life performance.

2.4 Battery Container and Lid

Cycling batteries are sometimes used in areas with unreliable electricity generation and a variety of harsh environments. A polypropylene resin container was chosen because of its ability to prevent water loss and its resistance to variations in temperature.

Fig. 8 High density glass fiber separator.

Fig. 9 SLR-1000 battery image cut view
2.5 Installation and Setting

An important factor to improve cycle life operation is a consistent concentration of electrolyte around the battery elements. To prevent electrolyte stratification, batteries are kept horizontal by placing them horizontally in a rack module. Modules can be stacked to create a multi-cell string. **Fig. 10** is the SLR-1000 48V module system design which passed earthquake-resistance strength evaluation.

**Fig. 10** External dimensions of newly developed “SLR-1000” assembled battery cabinet system.
3. Performance of SLR-1000

3.1 Discharge performance

Fig. 11 shows discharge data at 25°C. Standard specification maximum discharge is 1CA discharge (100 Amp).

Fig. 11 Discharge characteristics for newly developed “SLR-1000” and existing “SLR-1000” battery at 25°C.
3.2 Cycle Life Performance

Fig. 12 demonstrates the SLR-1000’s battery capacity under DOD 70% cycle test. The graph shows that the SLR-1000 retained its capacity without any active material deterioration after 2,500 cycles. From this data, the SLR-1000 is expected to achieve more than 5,000 cycles.

Fig. 12 Cycle life test for newly developed “SLR-1000”
3.3 Safety

Table 2 provides the results of the JIS C 8704-2-1:2006, JIS C 8704-2-2:2006, and GS Yuasa internal standard reliability tests performed on the SLR-1000. The results confirmed that the SLR-1000 battery does not deform, leak, or suffer damage during testing and has high reliability. The SLR-1000 is listed as a UL recognized component (File No. MH12970) and compliant to the UN2800 transportation regulation.

<table>
<thead>
<tr>
<th>Test item</th>
<th>Standard</th>
<th>Condition</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shock test</td>
<td>JIS*</td>
<td>A fully charged battery is dropped in the upright position from height of 10 cm onto a hard board having a thickness of 10 mm or more. Test is repeated 3 times.</td>
<td>No breakage and leakage.</td>
</tr>
<tr>
<td>Large current discharge test</td>
<td>JIS*</td>
<td>A fully charged battery is discharged at 6 CA for 5 seconds.</td>
<td>No case deformation and breakage.</td>
</tr>
<tr>
<td>Vibration test</td>
<td>JIS**</td>
<td>A vibration 16.7 Hz frequency and peak to peak amplitude 4 mm is applied to the X-, Y- and Z-axis directions of a fully charged battery for 60 minutes respectively.</td>
<td>No case deformation, breakage and leakage.</td>
</tr>
<tr>
<td>Electrolyte leakage test</td>
<td>GY***</td>
<td>A fully charged battery is charged at 0.2 CA for 5 hours.</td>
<td>No case deformation, breakage and leakage.</td>
</tr>
<tr>
<td>Short circuit test</td>
<td>GY***</td>
<td>A fully charged battery terminals are connected with a bar of 50 m-ohms or less resistance.</td>
<td>No burn and burst. No leakage.</td>
</tr>
<tr>
<td>Heat–cycle test</td>
<td>GY***</td>
<td>A batteries are charged on the conditions from -15 degrees C to 65 degrees C.</td>
<td>No case deformation, breakage and leakage.</td>
</tr>
</tbody>
</table>

* JIS C 8704-2-1:2006 and JIS C8704-2-2:2006
** JIS C 8702-1:2009
*** Company standard
Conclusion

The goal to achieve 5,000 cycles was accomplished. The cycle life of the SLR-1000 has almost doubled the SLE-1000 and more than tripled the market’s standard products’ performance by combining proper design and testing. These features are perfect for on demand electricity consumption and energy storage use. Cyclic-use lead acid batteries have been used for generated power stabilization for a long time. This long cycle life high performance battery is one of the best solutions for the renewable energy market.