FLOODED LEAD ACID BATTERY TEST REPORT

(THIS TEST RESULT COVERS ALL BATTERY MODELS IN TROJAN BATTERY'S PREMIUM LINE)

Product group:	Flooded/wet lead acid cells with flat plates
Type designation:	L16RE-B, 6V, 330Ah (10-hr rate) battery
Endurance in cycles according to	IEC 61427:2005-05
Test, Chapter:	IEC 61427:2005-05: Secondary cells and batteries for PV energy systems – General requirements and methods of test Chapter 8.4: Cycle endurance test in photovoltaic application (extreme conditions)
Test laboratory:	Trojan Battery Company
Test temperature:	40° C ± 3° C
Test started:	July 2008
Test ended:	October 2009

Test Description

In photovoltaic (PV) applications the battery will be exposed to a large number of shallow cycles but at different states of charge. The cycle endurance test is an accelerated simulation in extreme conditions of the battery operation in a PV energy system and is conducted by submitting the single 2V cell repeatedly to 150-cycle sequences (50 cycles with the Phase A and 100 cycles with Phase B) until the cell reaches end of life.

Each of these 150-cycle sequences is considered one macro cycle, while the Phase A and Phase B cycles themselves are considered micro cycles. Thus, 50 Phase A micro cycles plus 100 Phase B micro cycles equal one macro cycle.

Table 1 below summarizes the test methodology for Phase A low state of charge (LSOC) and Phase B high state of charge (HSOC) cycles.

Phase A: Low state of charge (LSOC) cycling protocol			
Step	Discharge Time (hrs)	Charge Time (hrs)	Current, A
(a)	9		I_{10}
(b)		3	$1.03I_{10}$
(c)	3		I_{10}
Repeat steps (b) and (c) 49 times, then proceed to Phase B			
Phase B: High state of charge (HSOC) cycling protocol			
Step	Discharge Time (hrs)	Charge Time (hrs)	Current, A
(a)	2		$1.25I_{10}$
(b)		6	I_{10} (Voltage limited to manufacturer's recommendation)
Repeat steps (a) and (c) 99 times			

Table 1: LSOC and HSOC micro cycles per IEC 61427.

Test Process

The test began with a fully charged battery, which was brought to a temperature of 40° C ± 3° C and stabilized for 16 hours. The temperature was maintained for the entire duration of the test.

The Phase A micro cycles (see Table 1) of the test simulated shallow cycling at a LSOC. Each micro cycle subjected the cell to the following steps. As shown in Table 1, the three steps were repeated 49 times, thus subjecting the battery to a total of 50 Phase A LSOC micro cycles.

1. **Discharge at I_{10} amps for 9 hours or until the voltage drops to 1.75 VPC.**
2. **Recharge the battery for 3 hours with a current 1.03 times the I_{10} amps.**
3. **Discharge at I_{10} amps for 3 hours.**

The Phase B micro cycles of the test (see Table 1 above) simulated shallow cycling at a HSOC. Each micro cycle subjected the cell to the following steps. As shown in Table 1, the two steps were repeated 99 times, thus subjecting the battery to a total of 100 Phase B HSOC micro cycles.

1. **Discharge at 1.25 times the I_{10} amps for 2 hours.**
2. **Recharge the battery for 6 hours with a current of I_{10} amps; the charge voltage was limited to 2.40 VPC.**

A capacity check at the 10-hour rate (C_{10}) was performed after completing the Phase B micro cycles. The battery was first cooled down to room temperature and stabilized at this value for 16 hours before performing the capacity tests.

The capacity was checked after each period of 150 Phase A and Phase B micro cycles. The value of actual capacity delivered after each macro cycle (or after 150 micro cycles) is recorded in Table 1. The cycle life is expressed in number of 150 micro cycle sequences completed, or the number of macro cycles completed with one macro cycle being equal to 150 micro cycles.

The test was completed when either of the following criteria was met:

- **The voltage measured during a Phase A discharge was less than 1.5 VPC.**
- **The capacity delivered after Phase B is less than 80% of rated capacity**.

The test standard requires measuring the water consumption of flooded battery types and cells with partial gas recombination (Chapter 8.4.5). During the cycle endurance test, the battery was topped off with water and the amount of water added was measured.

Test Results

Table 2 shows the raw results of the 10-hour (C_{10}) capacity tests, each performed after 150 micro cycles or after 1 macro cycle. As noted before, the test concluded when the C_{10} capacity delivered by the battery was less than 80% of its rated capacity.

The data presented in Table 2 is reproduced in graphical form in Figure 1 for the amp-hour capacity, and percent of rated capacity in Figure 2.

IEC macro cycle #	Phase A + Phase B cycles	Capacity at C_{10} rate	Percent of rated C_{10} capacity
1	150	318.2	96%
2	300	326.7	99%
3	450	314.3	95%
4	600	303.5	92%
5	750	311.4	94%
6	900	299.6	91%
7	1050	293.0	89%
8	1200	289.1	88%
9	1,350	237.6	72%

Table 2: Capacity test results after each macro cycle.

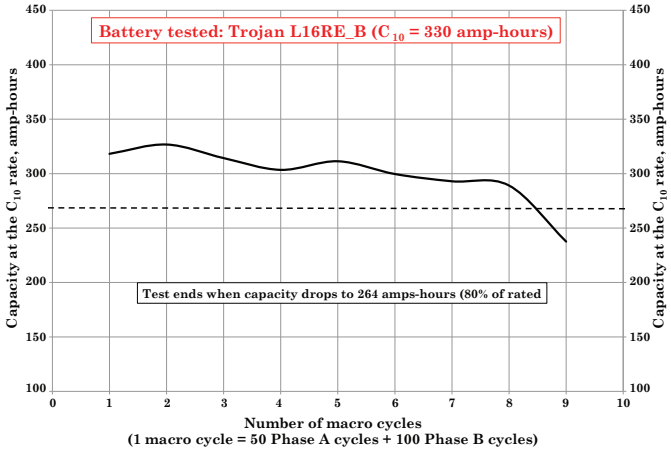

Figure 1: Capacity delivered after each macro cycle.

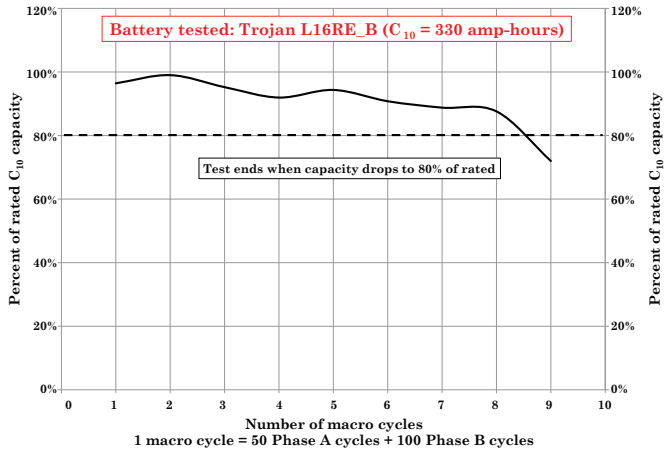

Figure 2: Percent capacity remaining after each macro cycle.

Conclusion

As shown in Table 2 and Figures 1 and 2, the Premium battery has performed well when subjected to the IEC 61427 test protocol. This is a particularly harsh test because not only does it subject the battery to partial state of charge (PSOC) cycling but is done at an elevated temperature of 40°C ± 3°C that the battery is exposed to throughout the test.

The Premium battery reached its end of life after eight macro cycles, or after a total of 1,200 micro cycles. Because of the two factors mentioned in the previous paragraph (PSOC cycling and cycling at a continuous temperature of 40°C ± 3°C), each macro cycle that the battery successfully delivered is considered to be the equivalent of one year of the battery's service life.

Therefore, since the Premium battery delivered between eight and nine macro cycles before its delivered capacity dropped to under 80% of its rated capacity, Trojan Battery Company's Premium battery line has a service life of between eight and nine years, and this is reflected in Table 3 below.

Finally, the results obtained from testing the L16RE-B battery apply to all other Premium models (current and future) by virtue of similarity of design.

Battery type	Equivalent service life
All Premium models	8 to 9 years

Table 3: Service life of the Trojan Battery Premium line.

Trojan BATTERY COMPANY

Trojan batteries are available worldwide through Trojan's Master Distributor Network.
We offer outstanding technical support, provided by full-time application engineers.

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