TROJAN BATTERY COMPANY

WHITE PAPER

Flooded Lead Acid Battery Test Report

(THIS TEST RESULT COVERS ALL SOLAR PREMIUM MODELS: SPRE 12 225, SPRE 06 255, SPRE 06 415, SPRE 02 1255)

Product group: Flooded/wet lead acid cells with flat plates

Type designation: SPRE 06 415, 6V, 346Ah (10-hr rate) battery

Endurance in cycles according to 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 summarizes the test methodology for Phase A low state of charge (LSOC) and Phase B high state of charge (HSOC) cycles.

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

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 (b) 99 times			

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 v/cell.
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 v/cell.

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 complete when either of the following criteria was met:

- The voltage measured during Phase A discharge was less than 1.5 v/cell.
- The capacity delivered after Phase B was 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.

Conclusion

As shown in Table 2 and Figures 1, the SPRE 06 415 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. Because of the two factors (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.

Since the SPRE 06 415 battery delivered approximately 1,350 IEC cycles before reaching 80% of it's rated capacity, the test concludes that the Trojan Solar Premium battery line has a service life of between eight and nine years, and this is reflected in Table 3 to the right.

The IEC test has shown real-life endurance of ~1,350 cycles at 40°C at an average 25% DOD. This result when adjusted to 25°C battery temperature corresponds to ~4,000 cycles at 25% DOD, which is included in the cycle life vs DOD curve chart included in the Solar Premium battery data sheets.

Finally, the results obtained from testing the SPRE 06 415 battery apply to all other Solar Premium models (current and future) by virtue of similarity of design.

Table 2: Capacity test results after each macro cycle.

IEC macro cycle #	Phase A + Phase B cycles	Capacity at C_{10} rate	Percent of rated C_{10} capacity
1	150	323.9	113.5%
2	300	332.6	116.5%
3	450	320.0	112.1%
4	600	309.0	108.2%
5	750	317.0	111.0%
6	900	305.0	106.8%
7	1050	298.3	104.5%
8	1200	294.3	103.1%
9	1,350	241.9	84.7%

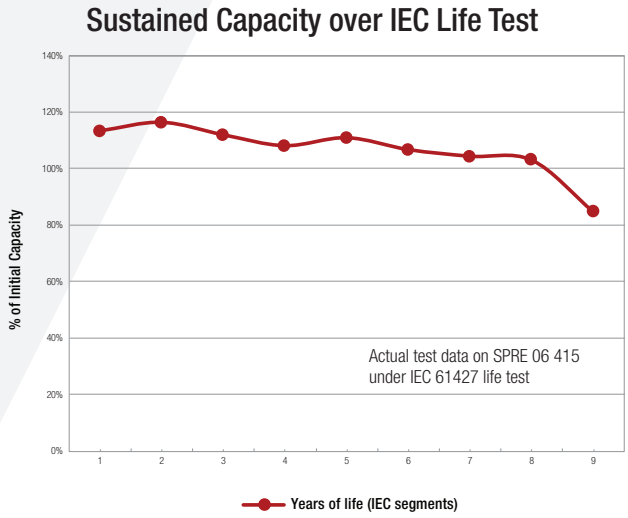

Figure 1

Table 3: IEC service life of the Trojan Battery Solar Premium line.

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

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