Thunder Sky LiFeYPO4 Power Battery

Performance Test Instructions

Thunder Sky Energy Group Limited

Battery Standard Research Institute

Thunder Sky LiFeYPO4 power battery

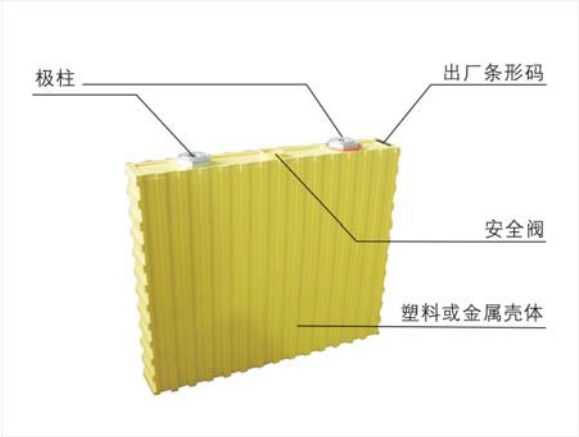
Performance Testing Methods and Instructions

1. Scope

The codes regulate the label, structure, testing code and testing methods of Thunder Sky LiFeYPO4 power battery.

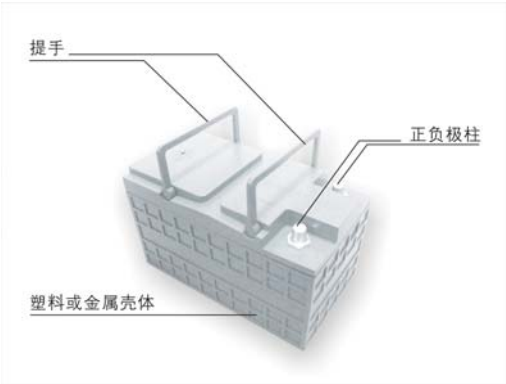
2. Structure of single cell

(1). TS-LFP300AHA



极柱：Terminal
出厂条形码：Bar-code
安全阀：Safety valve
塑料或金属壳体: plastic or metal case

(2). TS-LP12V100AH



提手：Handle
正负极柱：Positive and negative terminal
塑料或金属壳体：Plastic or metal case

Testing instructions for TS －LFP Cell

3. Testing items for single cell

3.1 Conventional items
Appearance, terminals (anode and cathode), weight & size, discharge capacity at 20℃, discharge capacity at 75℃, discharge capacity at -25℃, high rate discharge capacity, energy retain ability and restorability, cycling life.
3.2 Safety items
Short circuit, shooting test, overcharge/overdischarge, water immersion test, fire test
3.3 Requirement of cell
3.3.1 The terminals of single cell must use connector that could bear the maximum current in accordance with Testing code.
3.3.2 $\mathbf{C_3}$ is the rated capacity of 3 hours, and $\mathbf{C_1}$ is the rated capacity of 1 hours.

4 Conventional test methods

4.1 Test conditions
4.1.1 Environment condition
Laboratory room temperature 15℃~35℃
Laboratory room humidity 25－85%

5.1.2 Instrument

5.1.2.1 Measurement range of instrument
Measurement range accordingly change with voltage and current fluctuation; instrument value should fall in last 1/3 range of measurement instrument.

5.1.2.2 Accuracy
a) Accuracy level of voltage meter ≥ 0.5 class; resistance of voltage meter: 1kΩ/v;
b) Accuracy level of current meter ≥ 0.5 class;
c) Thermometer has applicable measurement range; dividing value of thermometer ≤1℃;
d) Time measuring instrument can record dividing values of hour, minute and second; accuracy deviation: ±1%;
e) Dividing value ≤1mm for instruments of measuring external dimension.
f) Accuracy deviation of weighing machine: ±0.5%

5.2 Single cell
5.2.1 Appearance
5.2.1.1 Visual examination: whether the cell surface is dry, flat, no-damage;
5.2.2.2 Visual examination: whether the cell identifications are complete and clear;
5.2.2 Terminal
To detect if I/O voltage of the cell is consistent with terminals by voltage meter

5.2.3 Weight & Dimension

5.2.3.1 Measure external dimension of the cell by measuring tools (not including the jigs and straps)

5.2.3.2 Measure weight of the cell by weighing machine (not including the jigs and straps)

5.2.4 Charging

At 20℃±5℃ temperature, the cell is discharged at a current of C_3 till voltage of the cell reach 2.8V, and then start to perform constant current charge at a current of C_3 till voltage of the cell reach 4.0V.

5.2.4.1 Low temperature charging

At -18℃±5℃ temperature, the cell is discharged at a current of C_3 till voltage of the cell reach 2.2V, and then start to perform constant current charge at a current of C_3 till voltage of the cell reach 4.2V.

5.2.5 Discharge capacity (energy density) at 20℃

When item 5.2.4 is finished, the cell will standby 1 hour at 20℃±5℃ temperature, and then discharges at current of C_3 (A) till voltage of the cell reach 2.8V. If value of discharge capacity does not reach the standard of rated capacity, this test is allowed to repeat 3 times.

5.2.6 High rate discharge capacity

When item 5.2.4 is finished, the cell will standby 1 hour at 20℃±5℃ temperature, and then discharges at current of C_1 (A) till voltage of the cell reach 2.5V.

5.2.7 Discharge capacity at -25℃

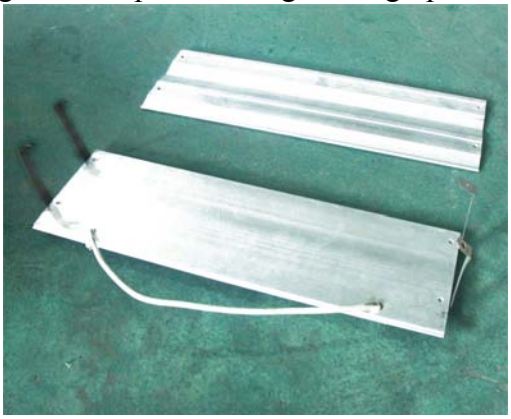
When item 5.2.4 is finished, the cell will standby 8 hours at -25℃±2℃ temperature, and then performs constant current discharge at current of C_3 (A) till voltage of the cell reach 2.5V. Calculates discharge capacity by AH.

5.2.8 Discharge capacity at 75℃

When item 5.2.4 is finished, the cell will standby 5 hours at 75℃±2℃ temperature, and then performs constant current discharge at current of C_3 (A) till voltage of the cell reach 2.8V. Calculates discharge capacity by AH.

5.2.9 Quick charge and discharge capacity

1. Fasten the plastic casing of the cell with jigs and straps according to the graph below.



2. After the cell is charged as 5.2.4, discharge by 2CA (twice nominal capacity current) constant current until voltage drops to 2.8 V (calculate the capacity).

At first phase, keep the cell for 30 to 60 minutes, then charge by 2CA(twice nominal capacity current) constant current, until the voltage reach 4.0V, then after resting the cell for 30 to 60 minutes, discharge it by 3CA(3 times of nominal capacity current) constant current, until the voltage drops to 2.8 V (calculate the capacity).

At second phase, after keeping the cell still for 30 to 60 minutes, charge by 3CA(3 times of nominal capacity current) constant current, until the voltage reach 4.0V, then after resting the cell for 30 to 60 minutes, discharge by 3CA(3 times of nominal capacity current) constant current, until the voltage drops to 2.8V (calculate the capacity).

5.3 Retaining Ability and restorability
Retaining Ability: after charge according to 5.2.4, the cell is stored under open circuit condition at 20℃±5℃, and then discharge by C_3 (A) constant current at the same temperature, until the voltage reach final voltage (2.8V). Calculate the capacity (by Ah)
Restorability: after charge according to 5.2.4, keep it still for 30min at 20℃±5℃, and then discharge by C_3 (A) constant current, until the voltage reach 2.8V. Calculate the capacity (by Ah).

6. Safety testing methods

6.1 Short circuit test
Place the cell under 20℃±5℃ condition for 1h after charging it to 90% of the nominal capacity as 5.2.4 instructed. The cell remains situation of external short circuit for 10 minutes. External circuit resistance should be less than or equal to 10mΩ.

The cell should not get fire or explode during the test, but smoke is acceptable.

6.2 Shooting test
Place the cell under 20℃±5℃ condition for 1h after charging after charging it to 90% of the nominal capacity as 5.2.4 instructed, shoot the cell with AK47 or pistol from the direction vertical to the cell, the bullet goes through the cell immediately, the test should only be conducted under condition with sufficient protection. (This test could be replaced with extrusion test or penetration test.)

The cell should not explode in the test, but smoke is acceptable.

6.3 Overcharge/Forced discharge test
Overcharge test: Place the cell under 20℃±5℃ condition for 1h after charging the cell to 4.0V as 5.2.4 instructed, charge the cell with 1CA current under 20℃±5℃ condition until the cell voltage reach 8V.
Forced discharge test: Place the cell under 20℃±5℃ condition for 1h after charging the cell to

2.8V as 5.2.4 instructed, discharge the cell with 1CA current under 20℃±5℃ condition until the cell voltage reach 0V.

The cell should not leak, explode or get fire in the test, but smoke is acceptable.

6.4 Water immersion test
Place the cell under 20℃±5℃ condition for 1h after charging the cell to 90% of the nominal capacity as 5.2.4 instructed, put the cell in pool full of tap water, seawater or river water for 1h.

The cell should not get fire or explode in the test.

6.5 Fire test
Place the cell under 20℃±5℃ condition for 1h after charging the cell to 90% of the nominal capacity as 5.2.4 instructed, put the cell in a fire until the cell turn to ash.

The cell should not explode in the test.

6.6. Cycle life test (80DOD %)
Place the cell under 20℃±5℃ condition and charge the cell with C_3 (A) constant current. When the cell voltage reach 4.0V, stop charge and place the cell for 1 hour.

Place the cell under 20℃±5℃ condition and discharge the cell with C_3 (A) current until the discharge capacity reach 80% of rated capacity. There can be a 30 minutes to 1h interval between the charge and discharge of the cell. Repeat 100 times and the cell nominal capacity decrease rate should be less than 1‰ AH.

7. Simple working environment simulation

7.1 Place the cell under 20℃±5℃ condition for 1h after charging the cell as 5.2.4 instructed and then pulsed discharge the cell in the same temperature, in the first stage discharge the cell with 1CA current for 5 minutes and change to 1CA pulsed discharge for one minute;

in the second stage pulsed discharge the cell with 2CA current for 5 minutes and change to 2CA pulsed discharge current for 1 minute;

in the third stage discharge the cell with 3CA current for 5 minutes and change to 3CA pulsed discharge for 1 minute;

in the fourth stage discharge the cell with 3CA current for 5 minutes and change to 10CA pulsed discharge current for 8 seconds; place the cell for 30 minutes between each stages and discharge the cell with C_3 (A) current until 100DOD%. Record the voltage of single cells during discharging. Stop discharging if in some stage the voltage of single cells gets lower than 2.0V.

8 Vibration test

8.1 Fasten the cell to vibration test machine after charging as 5.2.4 instructed, test as follows:
Vibrate direction: rack vibration;
vibrate frequency: 10～55HZ;
Maximal acceleration: 30m/S2;
Vibration duration: 2h;
Discharge: discharge the cell with 3CA current until the voltage reach 2.5V.
There should not be significant discharge current transformation, abnormal voltage, case distortion and electrolyte leakage.

Testing instructions for TS-LP cell

9 Testing items for single cell

9.1 Conventional items
Appearance, terminals (anode and cathode), weight & size, discharge capacity at 20℃, discharge capacity at 85℃, discharge capacity at -25℃, high rate discharge capacity, energy retain ability and restorability, cycling life.

9.2 Safety Items
Short circuit, shooting test, overcharge/overdischarge, water immersion test, fire test

9.3 Requirement of cell
9.3.1 The terminals of single cell must use connector that could bear the maximum current in accordance with Testing code.
9.3.2 C_3 is the rated capacity of 3 hours; C_1 is the rated capacity of 1 hour.

10 Conventional test method

10.1 Test condition
10.1.1 Environment condition
Laboratory room temperature 15℃~45℃
Laboratory room humidity 25－85%

11.1.2 Instrument

11.1.2.1 Measurement range of instrument
Measurement range accordingly change with voltage and current fluctuation; instrument value should fall in last 1/3 range of measurement instrument.

11.1.2.2 Accuracy

a) Accuracy level of voltage meter ≥ 0.5 class; resistance of voltage meter: 1kΩ/v;
b) Accuracy level of current meter ≥ 0.5 class;
c) Thermometer has applicable measurement range; dividing value of thermometer ≤1℃;
d) Time measuring instrument can record dividing values of hour, minute and second; accuracy deviation: ±1%;
e) Dividing value ≤1mm for instruments of measuring external dimension.
f) Accuracy deviation of weighing machine: ±0.5%

11.2 Single cell
11.2.1 Appearance
11.2.1.1 Visual examination: whether the cell surface is dry, flat, no-damage;
11.2.1.2 Visual examination: whether the cell identifications are complete and clear;

11.2.2 Terminal
To detect if I/O voltage of the cell is consistent with terminals by voltage meter

11.2.3 Weight & Dimension
11.2.3.1 Measure external dimension of the cell by measuring tools
11.2.3.2 Measure weight of the cell by weighing machine

11.2.4 Charge
At 20℃±5℃ temperature, the cell is discharged at a current of C_3 (A) till voltage of the cell reach 11V, and then start to perform constant current charge at a current of C_3 (A) under 20℃±5℃ temperature till voltage of the cell reach 16V and simultaneously switch to constant voltage charge. When charging current value decreases to 5% of initial value, charging completes.

11.2.4.1 Low temperature charging
At -18℃±5℃ temperature, the cell is discharged at a current of C_3 (A) till voltage of the cell reach 10V, and then start to perform constant current charge at a current of C_3 (A) under -18℃±5℃ temperature till voltage of the cell reach 17V and simultaneously switch to constant voltage charge and duration is 1 hours. After that, Trickle charge will begin. Charging completes when charging current value decreases to 5% of initial value.

11.2.5 Discharge capacity (energy density) at 20℃
After charging according to 11.2.4, set aside the cell for 1h at 20℃±5℃, then discharge by C_3 (A) current at the same temperature, until voltage of the cell drop to 11V. If discharge capacity cannot reach the rated capacity, this test is allowed to repeat 3 times.

11.2.6 High-rate discharge capacity
After charging according to 11.2.4, set aside the cell for 1h at 20℃±5℃, then discharge by $1C_1$ (A) current at the same temperature, until voltage of the cell arrive at 11V, and stop.

11.2.7 Discharge capacity at -25℃
After charging according to 11.2.4, set aside the cell for 10h at -25℃±2℃, then discharge by C_3 (A) current at the same temperature, until voltage of the cell drop to final voltage (10V). Calculate the discharge capacity (by Ah)

11.2.8 Discharge capacity at 85℃
After charging according to 11.2.4, set aside the cell for 3h at 85℃±2℃, then discharge by C_3 (A) current at the same temperature, until voltage of the cell drop to final voltage (11V). Calculate the discharge capacity (by Ah)

11.2.9 Retaining Ability and restorability
Retaining Ability: after charging according to 11.2.4, set aside the cell by open circuit for 30days at 20℃±5℃, then discharge by C_3 (A) constant current at the same temperature, until voltage of the cell drop to final voltage (11V). Calculate the discharge capacity (by Ah).
Restorability: after charging according to 11.2.4, set aside the cell by open circuit for 30days at 20℃±5℃ condition, then discharge by C_3 (A) constant current at the same temperature, until voltage of the cell arrive at final voltage (11V). Calculate the discharge capacity (by Ah).

12 Safety test methods

12.1 Short circuit test
After charging the cell to 90% of the nominal capacity according to 11.2.4, set aside the cell for 1h at 20℃±5℃, and short-circuit the cell by external for 10min, external circuit and resistance should be less than 10mΩ.

The cell must not explode, low fire burning during the test is allowed.

12.2 Extrusion test
After charging according the cell to 90% of the nominal capacity to 11.2.4, set aside the cell for 1h at 20℃±5℃, test according to following conditions.
a) Extrusion direction: press perpendicularly upon the cell plates
b) Extrusion area: outside surface of pressing direction
c) Extrusion level: until the cell case is broken or internal short circuit occurs

The cell must not explode, low fire burning during the test is allowed.

12.3 Nail test
After charging the cell to 90% of the nominal capacity according to 11.2.4, set aside the cell for 1h at 20C±5C. Using Φ3mm~Φ8mm steel nail run through quickly along the perpendicular direction (steel nail must not stay in the cell), this test must be carried out under full environment protection condition.
The cell must not explode, low fire burning during the test is allowed.

12.4 Overcharge and overdischarge test

Over charge: After charging the cell to 90% of the nominal capacity according to 11.2.4, set aside the cell for 1h at 20℃±5℃, then charge by C_3 (A) current at the same temperature, until the voltage arrive at 20V.

Over discharge: After charging according to 11.2.4, set aside the cell for 1h at 20℃±5℃, then discharge by C_3 (A) current at the same temperature, until the voltage drops to 0V.

The cell must not leak, explode and burn during the test.

12.6 Fire test
After charging the cell to 90% of the nominal capacity according to 11.2.4, set aside the cell for 1h at 20℃±5℃, and then burns it in the blaze, until the cell is laid into ashes.

The cell must not explode during the test.

12.7 Cycle life test (80D0D %)

Place the cell under 20℃±5℃ condition and charge the cell with C_3 (A) constant current, when the cell voltage reach 16V, turn to constant voltage charge until the charging current drops to the 5% of initial value and place the cell for 1 hour.

Place the cell under 20℃±5℃ condition and discharge the cell with C_3 (A) current until the discharge capacity reach 80% of rated capacity. There can be a 30 minutes to 1h interval between the charge and discharge of the cell. Repeat 200 times and the cell nominal capacity decrease rate should be less than 2‰ AH.

25 times a cycle, carry out full discharging in the 25th circulation, then go to next cycle test. When the 25th circulation discharge capacity is less than 80% of the rated capacity in some cycle, stop the cycle life test.

13 Simple working environment simulation

Place the cell under 20℃±5℃ condition for 1h after charging the cell as 11.2.4 instructed and then pulsed discharge the cell in the same temperature, in the first stage discharge the cell with C_3 (A) current for 6 minutes and change to $1C_1$ (A) pulsed discharge for one minute;

in the second stage pulsed discharge the cell with 3CA current for 6 minutes and change to 2CA pulsed discharge current for 1 minute;

in the third stage discharge the cell with C_3 (A) current for 6 minutes and change to 3CA pulsed discharge for 1 minute;

in the fourth stage discharge the cell with C_3 (A) current for 6 minutes and change to 10CA

pulsed discharge current for 1 minute; place the cell for 30 minutes between each stages and discharge the cell with C_3 (A) current until 100DOD%. Record the voltage of single cells during discharging. Stop discharging if in some stage the voltage of single cells gets lower than 8.0V.

14 Vibration tests

Fasten the cell to vibration test machine after charging as 11.2.4 instructed, test as follows:
a)Vibrate direction: rack vibration;
b)vibrate frequency: 10～55HZ;
c)Maximal acceleration: 30m/S2;
d)Vibration duration: 2h;
e)Discharge: discharge the cell with C_3 (A) current until the voltage reach 10V.
There should not be significant discharge current transformation, abnormal voltage, case distortion and electrolyte leakage.