



TEST REPORT

Zenlabs _ Capacity and HPPC Testing EA4758C (3 of 3)

- Interim Data
 Final Report

Revision History

Release Number	Release Date	Description
1	4/11/2022	Initial DRAFT
2	4/11/2022	Add picture of set up and discharge power pulse formula
3	4/12/2022	Reconfigured data tables under HPPC

Customer name	Zenlabs Energy Inc.
Customer Address	Fremont, CA 94538
Product type (cell/battery/other)	cell
Model number/Name	14640
S/N (if available)	(ZL-201306006-249) , (ZL-201306006-257), (ZL-201306006-259)
Notes	This report is only representative of the product provided to the lab for testing. Testing is completed in accordance with the defined method and based on information related to the product under test that is provided by the customer.
Modifications made to samples	No modifications made to samples for testing

Chara Eirene Abiera

4/11/2022

Cindy Millsaps & JC Copeland

4/12/2022

Written by

DATE

Reviewed by

DATE



Device Under Tests

Model Number	14640
Part Description	cell
Ratings	32 Ah
Sample Receive Date	April 4, 2022
Name and address of Test Facility	Energy Assurance LLC <input checked="" type="checkbox"/> 2350 Centennial Drive, Gainesville, GA 30504 <input type="checkbox"/> 10 Avenue E, Hopkinton, MA 01748 <input type="checkbox"/> Other – please add specific information

Executive Test Summary

All testing performed per customer provided test specification. The data for the third set of three samples are provided in this report.

Test Name	Protocol Section	Report Page	Sample ID's	Result/Notes
Capacity/Energy (C/3:C/3)	1	3	4, 8, 10	Details provided in the respective protocol below
Capacity/Energy (1C:1C)	2	4	4, 8, 10	Details provided in the respective protocol below
HPPC	3	5	4, 8, 10	Details provided in the respective protocol below

The capacities shown below are used for calculating C-rates for all three tests.

Unit/Sample #	Cell Notes/Shipping Label	Capacity (Ahr)	Mass (g)
4	ZL-201306006-249	32.500	336.350
8	ZL-201306006-257	33.200	341.400
10	ZL-201306006-259	32.800	339.100

The capacities used for C-rate calculation were provided for each individual sample.

TEST 1: Capacity/Energy (C/3:C/3)

Capacity and Energy testing on 3 cells at 30°C. All cells are measured at C/3 charge and discharge rates.

METHOD

Test conditions are as follows:

- C/3:C/3 CC-CV (CV: reaching C/20 or 90 min)
- 30 degree C
- 4.2V to 2.5 V
- 2 Cycles
- C will be provided for each cell by ZL

Testing parameters are summarized in the table below:

Sample	Serial Number	Rated Capacity (Ah)	Charge C-rate	Charge Current (A)	Taper C-rate	Taper Current (A)	Max Voltage (V)	Discharge C-rate	Discharge Current (A)	Minimum Voltage (V)
4	ZL-201306006-249	32.500	0.333	10.833	0.050	1.625	4.200	0.333	10.833	2.500
8	ZL-201306006-257	33.200	0.333	11.067	0.050	1.660	4.200	0.333	11.067	2.500
10	ZL-201306006-259	32.800	0.333	10.933	0.050	1.640	4.200	0.333	10.933	2.500

Pictures of the set up shown below:





RESULTS

Start Date April 5, 2022 Test Ambient (°C) 30°C
 Finish Date April 8, 2022 Tested By Roderick Arceneaux

Data is summarized in the table below.

Sample	Serial Number	Discharge Capacity 1 (Ah)	Discharge Energy 1 (Wh)	Discharge Capacity 2 (Ah)	Discharge Energy 2 (Wh)
4	ZL-201306006-249	31.748	109.221	31.759	109.239
8	ZL-201306006-257	32.554	112.236	32.571	112.288
10	ZL-201306006-259	32.352	111.588	32.374	111.657

Average Discharge Capacity: 32.226 Ah
 Average Discharge Capacity Density: 95.162 Ah/kg
 Average Discharge Energy: 111.038 Wh
 Average Energy Density: 327.546 Wh/kg

TEST 2: Capacity/Energy (1C:1C)

Capacity and Energy testing on 3 cells at 30°C. All cells are measured at 1C charge and discharge rates.

METHOD

Test conditions are as follows:

- 1C:1C CC-CV (CV: reaching C/20 or 90 min)
- 30 degree C
- 4.2V to 2.5 V
- 2 Cycles
- C will be provided for each cell by ZL

Testing Parameters are summarized in the table below:

Sample	Serial Number	Rated Capacity (Ah)	Charge C-rate	Charge Current (A)	Taper C-rate	Taper Current (A)	Max Voltage (V)	Discharge C-rate	Discharge Current (A)	Minimum Voltage (V)
4	ZL-201306006-249	32.500	1.000	32.500	0.050	1.625	4.200	1.000	32.500	2.500
8	ZL-201306006-257	33.200	1.000	33.200	0.050	1.660	4.200	1.000	33.200	2.500
10	ZL-201306006-259	32.800	1.000	32.800	0.050	1.640	4.200	1.000	32.800	2.500



RESULTS

Start Date	<u>April 5, 2022</u>	Test Ambient (°C)	<u>30°C</u>
Finish Date	<u>April 8, 2022</u>	Tested By	<u>Roderick Arceneaux</u>

Sample	Serial Number	Discharge Capacity 1 (Ah)	Discharge Energy 1 (Wh)	Discharge Capacity 2 (Ah)	Discharge Energy 2 (Wh)
4	ZL-201306006-249	31.149	106.448	31.185	106.573
8	ZL-201306006-257	31.887	109.178	31.925	109.315
10	ZL-201306006-259	31.508	108.104	31.549	108.263

Average Discharge Capacity: 31.534 Ah
 Average Discharge Capacity Density: 93.021 Ah/kg

Average Discharge Energy: 107.980 Wh
 Average Energy Density: 318.525 Wh/kg

TEST 3: HPPC

HPPC testing is conducted on 3 cells at 30°C after finishing tests 1 and 2

METHOD

Test conditions are as follows:

- Charge: CC-CV (4.2V, C/20 cutoff)
- Rest: 1h
- From 100% SoC to 40% SoC:
 - Discharge Pulse at 1C, 4C, 8C, 12C (30 sec)
 - Charge at 1C to return the charge drawn during pulses
 - Discharge at C/3 to reduce 10% SoC
 - Rest for 30 min
 - Repeat the discharge pulse
- From 40% SoC until lower pulse voltage of 2.0V stops the test
 - Repeat the discharge pulse at every 5% SoC

For higher C-rates, channels on the Neware system (rated at 100A) were combined to achieve necessary current values. Due to the size of the tabs, ring connectors were also used instead of clamps when channels were combined.

Values provided in the HPPC tables below were calculated using the formulas below:



$$\text{Discharge Resistance} = \frac{\Delta V_{\text{discharge}}}{\Delta I_{\text{discharge}}} = \left| \frac{V_{t1} - V_{t0}}{I_{t1} - I_{t0}} \right|$$

V_{t1} = Voltage at end of rest
 V_{t0} = Voltage at end of pulse
 I_{t1} = Current at end of rest
 I_{t0} = Current at end of pulse

$$\text{Discharge Pulse Power Capability} = V_{\text{min pulse}} \cdot (OCV_{\text{dis}} - V_{\text{min pulse}}) \div R_{\text{discharge}}$$

$V_{\text{min pulse}}$ = 2.0 V (minimum Voltage)
 $OCV_{\text{dis}} = V_{t0}$ = Voltage at end of pulse
 I_{t1} = Current at end of rest
 $R_{\text{discharge}}$ = Discharge Resistance

RESULTS

Start Date	April 5, 2022	Test Ambient (°C)	30°C
Finish Date	April 8, 2022	Tested By	Roderick Arceneaux

Data for each unit is provided in the tables below:

1C Pulse

Unit 4 at 1C Pulse					
SOC	V_t1 (V)	V_t0 (V)	I_discharge (A)	R_discharge (Ω)	Discharge Pulse Power Capability (W)
100%	4.011	4.165	32.478	0.005	914.399
90%	3.878	3.983	32.484	0.003	1232.706
80%	3.762	3.875	32.484	0.003	1078.727
70%	3.638	3.752	32.484	0.003	1005.219
60%	3.511	3.633	32.478	0.004	872.194
50%	3.365	3.492	32.478	0.004	762.495
40%	3.249	3.380	32.484	0.004	684.068
35%	3.196	3.333	32.484	0.004	632.912
30%	3.144	3.290	32.484	0.004	574.118
25%	3.086	3.247	32.484	0.005	505.191
20%	3.016	3.198	32.478	0.006	426.787
15%	2.921	3.142	32.471	0.007	335.587
10%	2.774	3.080	32.478	0.009	229.415
5%	2.487	3.011	32.478	0.016	125.383



Unit 8 at 1C Pulse					
SOC	V_t1 (V)	V_t0 (V)	I_discharge (A)	R_discharge (Ω)	Discharge Pulse Power Capability (W)
100%	4.015	4.163	33.166	0.004	966.253
90%	3.883	3.989	33.172	0.003	1240.209
80%	3.757	3.870	33.172	0.003	1099.969
70%	3.638	3.752	33.172	0.003	1021.278
60%	3.513	3.635	33.166	0.004	888.333
50%	3.375	3.502	33.172	0.004	783.809
40%	3.260	3.392	33.172	0.004	700.639
35%	3.205	3.343	33.184	0.004	647.108
30%	3.152	3.298	33.172	0.004	589.558
25%	3.094	3.255	33.166	0.005	519.432
20%	3.024	3.207	33.172	0.006	438.357
15%	2.931	3.152	33.166	0.007	344.888
10%	2.779	3.092	33.166	0.009	231.145
5%	2.470	3.027	33.166	0.017	122.251

Unit 10 at 1C Pulse					
SOC	V_t1 (V)	V_t0 (V)	I_discharge (A)	R_discharge (Ω)	Discharge Pulse Power Capability (W)
100%	4.026	4.166	32.819	0.004	1012.608
90%	3.891	3.989	32.800	0.003	1339.412
80%	3.767	3.871	32.806	0.003	1181.465
70%	3.647	3.752	32.800	0.003	1096.734
60%	3.522	3.635	32.800	0.003	950.967
50%	3.382	3.501	32.800	0.004	827.442
40%	3.267	3.392	32.800	0.004	733.834
35%	3.213	3.342	32.800	0.004	682.291
30%	3.160	3.298	32.812	0.004	616.057
25%	3.103	3.254	32.800	0.005	542.715
20%	3.033	3.206	32.800	0.005	456.588
15%	2.941	3.152	32.794	0.006	357.889
10%	2.794	3.092	32.806	0.009	240.564
5%	2.501	3.025	32.806	0.016	128.346



4C Pulse

Please note that the 2.0V limit was reached at the 10% SOC pulse, therefore data for 5% SOC is unavailable.

Unit 4 at 4C Pulse					
SOC	V_t1 (V)	V_t0 (V)	I_discharge (A)	R_discharge (Ω)	Discharge Pulse Power Capability (W)
100%	3.780	4.165	129.985	0.003	1461.392
90%	3.698	3.980	129.991	0.002	1824.482
80%	3.576	3.872	129.985	0.002	1646.738
70%	3.456	3.748	129.985	0.002	1559.282
60%	3.320	3.629	129.985	0.002	1372.933
50%	3.180	3.488	129.985	0.002	1253.921
40%	3.065	3.377	129.991	0.002	1145.834
35%	3.000	3.331	129.985	0.003	1047.515
30%	2.930	3.288	129.991	0.003	934.310
25%	2.840	3.245	129.985	0.003	800.089
20%	2.714	3.197	129.985	0.004	643.819
15%	2.485	3.141	129.991	0.005	452.234
10%	2.000	3.078	129.985	0.008	259.873
5%					

Unit 8 at 4C Pulse					
SOC	V_t1 (V)	V_t0 (V)	I_discharge (A)	R_discharge (Ω)	Discharge Pulse Power Capability (W)
100%	3.783	4.163	132.781	0.003	1512.547
90%	3.695	3.986	132.775	0.002	1808.146
80%	3.567	3.866	132.775	0.002	1656.051
70%	3.449	3.746	132.781	0.002	1561.098
60%	3.316	3.628	132.788	0.002	1383.626
50%	3.181	3.495	132.788	0.002	1267.653
40%	3.066	3.386	132.788	0.002	1150.881
35%	3.000	3.338	132.788	0.003	1052.232
30%	2.928	3.294	132.775	0.003	940.624

Unit 8
at 4C
Pulse



25%	2.836	3.250	132.769	0.003	802.846
20%	2.701	3.201	132.775	0.004	637.958
15%	2.425	3.146	132.781	0.005	422.153
10%	2.000	3.086	132.769	0.008	265.440
5%					

Unit 10 at 4C Pulse					
SOC	V_t1 (V)	V_t0 (V)	I_discharge (A)	R_discharge (Ω)	Discharge Pulse Power Capability (W)
100%	3.816	4.166	131.213	0.003	1624.036
90%	3.727	3.987	131.219	0.002	2008.986
80%	3.601	3.868	131.219	0.002	1835.882
70%	3.484	3.747	131.213	0.002	1742.055
60%	3.350	3.631	131.213	0.002	1524.983
50%	3.215	3.496	131.200	0.002	1396.356
40%	3.101	3.388	131.219	0.002	1266.304
35%	3.035	3.339	131.219	0.002	1155.346
30%	2.965	3.296	131.213	0.003	1028.658
25%	2.876	3.252	131.213	0.003	873.866
20%	2.750	3.205	131.219	0.003	694.358
15%	2.507	3.151	131.206	0.005	469.389
10%	2.000	3.090	131.219	0.008	262.341
5%					

8C Pulse

Please note that the 2.0V limit was reached at the 15% SOC pulse, therefore data for 10% and 5% SOC are unavailable.

Unit 4 at 8C Pulse					
SOC	V_t1 (V)	V_t0 (V)	I_discharge (A)	R_discharge (Ω)	Discharge Pulse Power Capability (W)
100%	3.560	4.165	260.007	0.002	1861.014
90%	3.485	3.978	260.007	0.002	2084.378
80%	3.363	3.870	260.007	0.002	1919.793
70%	3.237	3.745	260.001	0.002	1786.624
60%	3.100	3.625	260.001	0.002	1608.295
50%	2.970	3.485	260.007	0.002	1499.055
40%	2.844	3.375	260.007	0.002	1345.597
35%	2.760	3.338	260.001	0.002	1205.050
30%	2.662	3.296	260.007	0.002	1061.816



25%	2.526	3.253	260.001	0.003	895.710
20%	2.301	3.206	260.007	0.003	693.199
15%	1.998	3.150	260.007	0.004	519.247
10%					
5%					

Unit 8 at 8C Pulse					
SOC	V_t1 (V)	V_t0 (V)	I_discharge (A)	R_discharge (Ω)	Discharge Pulse Power Capability (W)
100%	3.528	4.164	265.631	0.002	1809.486
90%	3.448	3.984	265.631	0.002	1967.266
80%	3.326	3.862	265.612	0.002	1843.203
70%	3.202	3.740	265.619	0.002	1718.447
60%	3.074	3.621	265.612	0.002	1574.248
50%	2.947	3.487	265.625	0.002	1463.544
40%	2.817	3.381	265.619	0.002	1300.034
35%	2.726	3.341	265.612	0.002	1158.895
30%	2.612	3.298	265.625	0.003	1005.322
25%	2.437	3.254	265.625	0.003	815.845
20%	2.111	3.204	265.606	0.004	585.092
15%	1.996	3.149	265.612	0.004	529.152
10%					
5%					

Unit 10 at 8C Pulse					
SOC	V_t1 (V)	V_t0 (V)	I_discharge (A)	R_discharge (Ω)	Discharge Pulse Power Capability (W)
100%	3.610	4.166	262.438	0.002	2045.400
90%	3.530	3.984	262.438	0.002	2293.066
80%	3.408	3.865	262.432	0.002	2141.946
70%	3.283	3.743	262.432	0.002	1988.888
60%	3.151	3.625	262.425	0.002	1797.387
50%	3.024	3.492	262.438	0.002	1671.892
40%	2.895	3.385	262.432	0.002	1482.917
35%	2.809	3.346	262.425	0.002	1315.548
30%	2.704	3.303	262.425	0.002	1141.307
25%	2.553	3.261	262.438	0.003	935.412
20%	2.282	3.213	262.425	0.004	683.557



15%	1.998	3.160	262.425	0.004	523.812
10%					
5%					

12C Pulse

Please note that the 2.0V limit was reached at the 30% or 25% SOC pulses, therefore data for the remaining SOC ranges are unavailable.

Unit 4 at 12C Pulse					
SOC	V_t1 (V)	V_t0 (V)	I_discharge (A)	R_discharge (Ω)	Discharge Pulse Power Capability (W)
100%	3.334	4.165	390.054	0.002	2031.285
90%	3.248	3.977	390.054	0.002	2115.237
80%	3.113	3.869	390.054	0.002	1927.328
70%	2.985	3.743	390.054	0.002	1794.250
60%	2.860	3.624	390.054	0.002	1658.600
50%	2.717	3.483	390.054	0.002	1511.193
40%	2.529	3.373	390.054	0.002	1268.139
35%	2.377	3.344	390.048	0.002	1083.844
30%	2.179	3.304	390.054	0.003	904.094
25%	2.000	3.262	390.054	0.003	779.862
20%					
15%					
10%					
5%					

Unit 8 at 12C Pulse					
SOC	V_t1 (V)	V_t0 (V)	I_discharge (A)	R_discharge (Ω)	Discharge Pulse Power Capability (W)
100%	3.262	4.164	398.431	0.002	1911.373
90%	3.172	3.983	398.419	0.002	1947.879
80%	3.042	3.860	398.425	0.002	1811.394
70%	2.930	3.737	398.425	0.002	1715.562
60%	2.803	3.617	398.425	0.002	1581.959
50%	2.639	3.483	398.431	0.002	1399.627
40%	2.365	3.378	398.425	0.003	1084.103
35%	2.175	3.346	398.431	0.003	915.949
30%	2.000	3.304	398.425	0.003	796.605



25%					
20%					
15%					
10%					
5%					

Unit 10 at 12C Pulse					
SOC	V_t1 (V)	V_t0 (V)	I_discharge (A)	R_discharge (Ω)	Discharge Pulse Power Capability (W)
100%	3.409	4.167	393.626	0.002	2249.632
90%	3.324	3.983	393.638	0.002	2368.039
80%	3.196	3.864	393.638	0.002	2197.819
70%	3.077	3.742	393.626	0.002	2063.633
60%	2.952	3.624	393.626	0.002	1902.359
50%	2.799	3.491	393.626	0.002	1696.346
40%	2.568	3.384	393.626	0.002	1335.299
35%	2.381	3.353	393.626	0.002	1095.353
30%	2.202	3.312	393.620	0.003	930.806
25%	1.998	3.270	393.626	0.003	786.199
20%					
15%					
10%					
5%					



END OF TEST REPORT – THIS PAGE INTENTIONALLY LEFT BLANK