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28 Jun 12

From: Commanding Officer, Naval Surface Warfare Center, Crane Division  
To: Advanced Research Products Agency – Energy (ARPA-E), Dawson Cagle

Subj: VERIFICATION AND VALIDATION OF PROTOTYPE CELLS FROM ENVIA  
SYSTEMS

Ref: (a) GXS-SOP-397 Rev B CH1

Encl: (1) Naval Surface Warfare Center, Crane Division Test Report: GDD GXS 12-075

1. Verification and Validation tests were conducted in accordance with reference (a) at Naval Surface Warfare Center, Crane Division (NSWC Crane) on one additional high capacity lithium ion pouch prototype cell manufactured by Envia Systems of Newark, CA for use in vehicle applications.

2. Results of the tests are forwarded as enclosure (1).

3. NSWC Crane points of contacts are Mr. Dave Miller, Branch Manager, Test and Evaluation Branch, telephone DSN 482-1226 or commercial 812-854-1226 and Angela Mishler, Test and Evaluation Branch, telephone DSN 482-8594, or commercial 812-854-8594.

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Envia Systems (Herman Lopez)  
DOE (Dawson Cagle)

TEST AND EVALUATION BRANCH CODE GXSM  
Energy Power & Interconnect Technologies Division  
Global Deterrence and Defense Department  
Naval Surface Warfare Center, Crane Division



**TEST SUMMARY  
FOR THE  
ARPA-E Program Envia Systems Prototype Cell  
SN 400WhK-07-009-111205**

**GDD GX5 12-075  
SUMMARY REPORT DATE: 26 JUNE 2012**

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## Envia Systems Prototype Cell Test

### GDD GX5 12-075

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#### 1 Introduction

- 1.1 Naval Service Warfare Center, Crane Division (NSWC Crane) Test & Evaluation Branch was tasked by Advanced Research Products Agency – Energy (ARPA-E) to perform Verification & Validation testing on one additional high capacity lithium ion pouch type cell, manufactured by Envia Systems of Newark, California.
- 1.2 This cell has the same cathode loading as cells 5 & 6, which is  $\sim 1.7\%$  ( $\text{mg}/\text{cm}^2$ ) higher than cells 11 & 12. They also have the same  $\sim 60\text{mm}$  pouch as cells 11 & 12, which was added for out gassing.
- 1.3 The testing included verification of cell capacity and energy density at  $C/10$  and  $C/3$ , 100% state of charge (SOC) and depth of discharge (DOD), as well as cell capacity and energy density at  $C/3$ , 80% SOC/DOD. One cycle at  $C/20$  was performed at the manufacturer, therefore Crane's cycling started at cycle 2. Total testing cycles were 409, with 408 of those being performed at Crane (Cycles 2-408).

#### 2 Test Samples

- 2.1 The Envia Systems cells are prototype lithium pouch rechargeable cells. The cells have a capacity of 46 Ah and an energy density of 400Wh/Kg. The cell's dimensions are approximately 157 mm wide, 190 mm long and 10 mm thick. The cell's approximate weight is 366 grams, including labels and pouch. The serial number is 400WhK-07-009-111205 (designated as 009).

#### 3 Test Description

Upon receipt, the Envia Systems cell was subjected to a visual inspection. Weight, dimensions and open circuit voltage (OCV) were recorded. Verification & Validation testing on the Envia Systems cell included one  $C/10$  charge discharge cycle at 100% DOD, one  $C/3$  charge discharge cycle at 100% DOD followed by  $C/3$  charge discharge cycles at 80% DOD until the energy efficiency dropped below 75% of the initial two  $C/3$  80% SOC/DOD cycles.

- 3.1 **Initial Inspection:** For the initial inspection, the cell was visually inspected for general defects. The weight of the cell was also recorded; the weight should be approximately 365 grams. The dimensions of the cell were recorded; the dimensions are approximately 157 mm wide, 190 mm long and 10 mm thick. In addition, the OCV was recorded.



- 3.2 Cycling Test:** The MACCOR test system used to perform the cycling on this cell was a different system than used on cells 5, 6, 11 & 12, but cabling, interconnects, calibration, and profiles were identical for each test configuration to maintain data compatibility. The cell was also located in a different temperature chamber and the temperature was maintained at approximately 25°C. The cell was restrained by manufacturer supplied clamps torqued to 3Nm.

## 4 Test Results

- 4.1 Initial Inspection:** During the initial inspection no defects were visually detected. The complete set of data recorded during the initial inspection can be found in Table 1.

**Table 1: Initial Inspection Results**

Cell SN	Visual	Weight (g)	Dimensions (WxLxD) (mm)	OCV
400WhK-07-009-111205	No Defects	366.28	156.5x190x10	2.51

- 4.2 Cycling Test:** The MACCOR test system used to perform the cycling on this cell was a different system than used on cells 5, 6, 11 & 12, but cabling, interconnects, calibration, and profiles were identical for each test configuration to maintain data compatibility. The cell was also located in a different temperature chamber and the temperature was maintained at approximately 25°C. The cell was restrained by manufacturer supplied clamps torqued to 3Nm.

No significant expansion of the extra pouch was noticed due to out gassing.

The numerical results are shown in Table 2. The graphical results are shown in Figure 1. Figure 2 is a plot of the first 23 cycles just so the detail can be seen graphically of the different C-rates and DOD cycles. Figure 3 compares cell 9 to cells 5, 6, 11 & 12 previously tested at Crane, as well as cell 7, tested at Envia Systems in Newark, CA. Figure 4 shows the graph of the data for cells 9, 11 & 12 down to the cut-off below the 75% energy density efficiency.

Photographs of the cells and test configuration are presented in Appendix A.

**Table 2: Energy Density Results**

Cycle	SN9	Cycle	SN9	Cycle	SN9
1	426.89	39	288.03	77	273.94
2	406.83	40	287.71	78	273.55
3	378.90	41	287.38	79	273.22
4	306.06	42	287.03	80	272.85
5	302.93	43	286.81	81	272.54
6	300.65	44	286.48	82	272.20
7	299.74	45	286.15	83	271.90
8	298.96	46	285.81	84	271.54
9	298.38	47	285.51	85	271.18
10	297.86	48	285.22	86	270.87
11	297.29	49	285.00	87	270.59
12	296.80	50	284.81	88	270.25
13	296.43	51	284.45	89	269.95
14	296.14	52	284.16	90	269.65
15	295.75	53	283.78	91	269.39
16	295.38	54	283.48	92	269.07
17	295.06	55	283.02	93	268.79
18	294.85	56	281.85	94	268.52
19	294.49	57	281.53	95	268.22
20	294.08	58	281.14	96	267.95
21	293.11	59	280.83	97	267.68
22	292.25	60	280.42	98	267.45
23	291.88	61	280.09	99	267.22
24	291.62	62	279.69	100	266.98
25	290.95	63	279.30	101	266.72
26	291.16	64	278.90	102	266.48
27	290.95	65	278.55	103	266.25
28	290.66	66	278.17	104	266.03
29	290.43	67	277.79	105	265.79
30	290.57	68	277.29	106	265.63
31	290.41	69	277.00	107	265.47
32	290.00	70	276.59	108	265.22
33	289.33	71	276.18	109	264.99
34	289.15	72	275.81	110	264.76
35	288.88	73	275.44	111	264.52
36	288.49	74	275.05	112	264.34
37	287.96	75	274.71	113	264.10
38	287.93	76	274.30	114	263.92

Cycle	SN9		Cycle	SN9		Cycle	SN9
115	263.56		153	256.52		191	251.13
116	263.32		154	256.37		192	251.00
117	263.13		155	256.19		193	250.82
118	262.89		156	255.97		194	250.73
119	262.68		157	255.83		195	250.57
120	262.49		158	255.69		196	250.43
121	262.28		159	255.53		197	250.32
122	262.14		160	255.40		198	250.15
123	261.91		161	255.25		199	250.05
124	261.71		162	255.10		200	249.87
125	261.56		163	254.95		201	249.75
126	261.34		164	254.79		202	249.64
127	261.13		165	254.66		203	249.52
128	260.98		166	254.51		204	249.38
129	260.78		167	254.35		205	249.25
130	260.57		168	254.25		206	249.13
131	260.41		169	254.10		207	249.06
132	260.20		170	253.97		208	248.89
133	260.03		171	253.99		209	248.76
134	259.85		172	253.83		210	248.64
135	259.68		173	253.74		211	248.54
136	259.52		174	253.58		212	248.41
137	259.38		175	253.44		213	248.25
138	259.15		176	253.20		214	248.05
139	258.98		177	253.17		215	247.99
140	258.79		178	253.02		216	247.83
141	258.66		179	252.86		217	247.70
142	258.48		180	252.74		218	247.58
143	258.28		181	252.57		219	247.39
144	258.14		182	252.47		220	247.34
145	257.97		183	252.32		221	247.23
146	257.81		184	252.17		222	246.42
147	257.64		185	252.02		223	246.82
148	257.42		186	251.76		224	246.69
149	257.32		187	251.59		225	246.66
150	257.17		188	251.53		226	246.55
151	257.02		189	251.41		227	246.33
152	256.68		190	251.21		228	246.22



Cycle	SN9		Cycle	SN9		Cycle	SN9
229	246.13		267	241.42		305	237.08
230	246.07		268	241.38		306	237.01
231	245.90		269	241.15		307	236.89
232	245.71		270	241.04		308	236.79
233	245.60		271	240.91		309	236.66
234	245.60		272	240.77		310	236.56
235	245.48		273	240.67		311	236.39
236	245.36		274	240.60		312	236.27
237	245.13		275	240.50		313	236.16
238	245.03		276	240.36		314	236.00
239	244.91		277	240.23		315	235.99
240	244.84		278	240.09		316	235.86
241	244.65		279	239.98		317	235.73
242	244.52		280	239.87		318	235.54
243	244.41		281	239.78		319	235.44
244	244.32		282	239.66		320	235.34
245	244.22		283	239.54		321	235.27
246	244.11		284	239.42		322	235.16
247	243.96		285	239.31		323	235.06
248	243.91		286	239.20		324	234.95
249	243.81		287	239.07		325	234.82
250	243.66		288	238.94		326	234.68
251	243.70		289	238.83		327	234.54
252	243.57		290	238.73		328	234.41
253	243.51		291	238.64		329	234.25
254	243.39		292	238.52		330	234.20
255	242.79		293	238.43		331	234.07
256	242.76		294	238.42		332	233.93
257	242.72		295	238.32		333	233.78
258	242.62		296	238.22		334	233.65
259	242.31		297	238.11		335	233.56
260	242.06		298	237.91		336	233.45
261	241.95		299	237.73		337	233.31
262	241.93		300	237.66		338	233.14
263	241.80		301	237.58		339	233.06
264	241.64		302	237.46		340	232.96
265	241.51		303	237.29		341	232.84
266	241.55		304	237.18		342	232.69



Cycle	SN9		Cycle	SN9
343	232.52		382	227.06
344	232.47		383	226.89
345	232.38		384	226.75
346	232.28		385	226.59
347	232.09		386	226.45
348	231.93		387	226.30
349	231.82		388	226.15
350	231.71		389	225.99
351	231.57		390	225.85
352	231.45		391	225.68
353	231.33		392	225.53
354	231.20		393	225.39
355	231.09		394	225.21
356	230.95		395	225.07
357	230.84		396	224.90
358	230.71		397	224.78
359	230.42		398	224.59
360	230.24		399	224.43
361	230.13		400	224.29
362	229.99		401	224.11
363	229.81		402	223.95
364	229.65		403	223.82
365	229.48		404	223.59
366	229.41		405	223.39
367	229.24		406	223.24
368	229.15		407	223.03
369	229.01		408	222.87
370	228.87		409	222.71
371	228.82			
372	228.65			
373	228.31			
374	228.21			
375	228.05			
376	227.89			
377	227.75			
378	227.60			
379	227.46			
380	227.31			
381	227.18			

Figure 1: Energy Density Plot

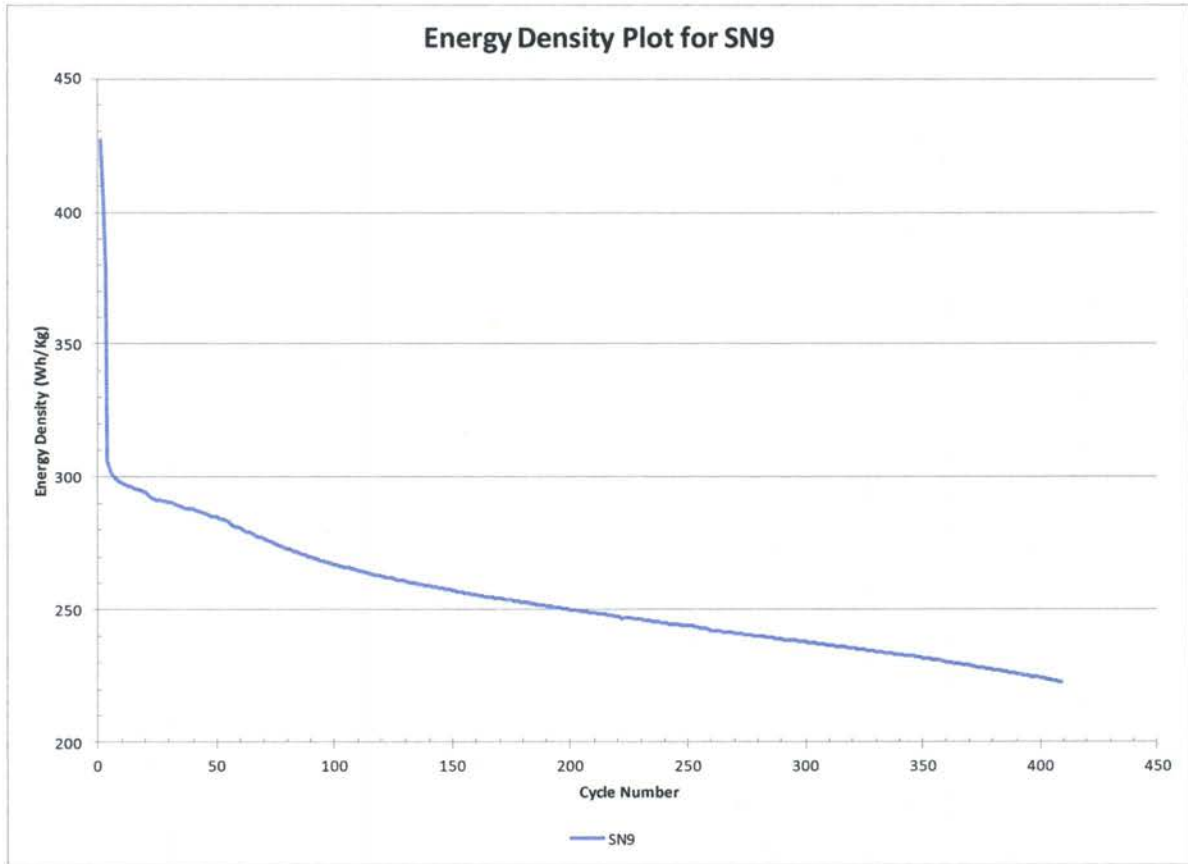


Figure 2: Energy Density Plot of First 23 Cycles

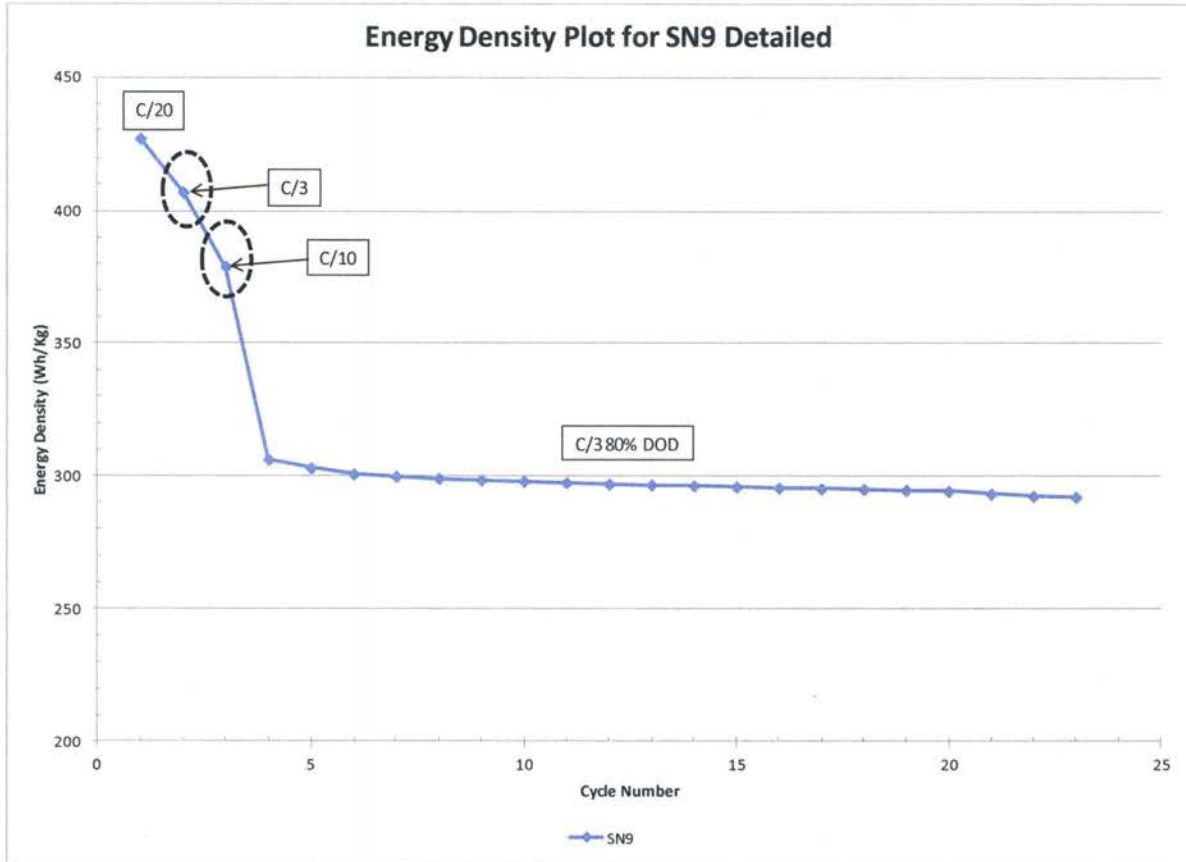
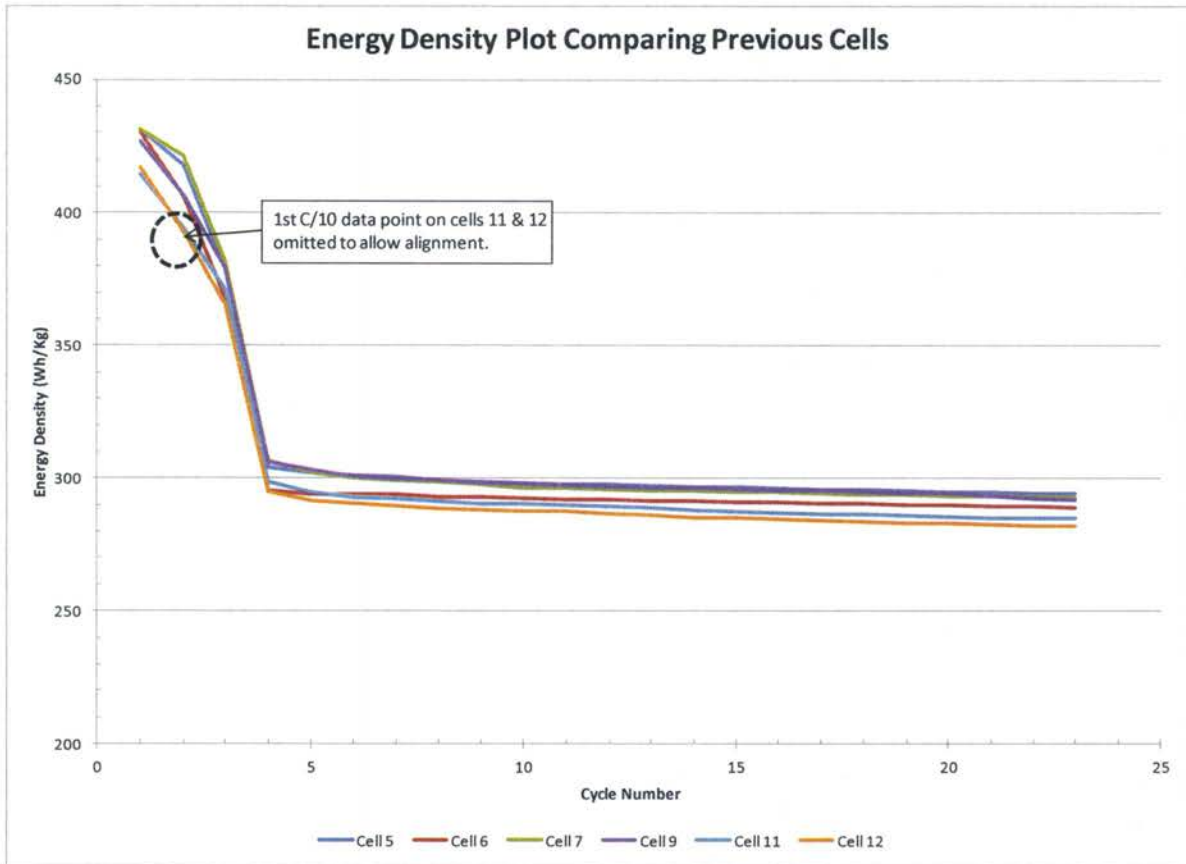
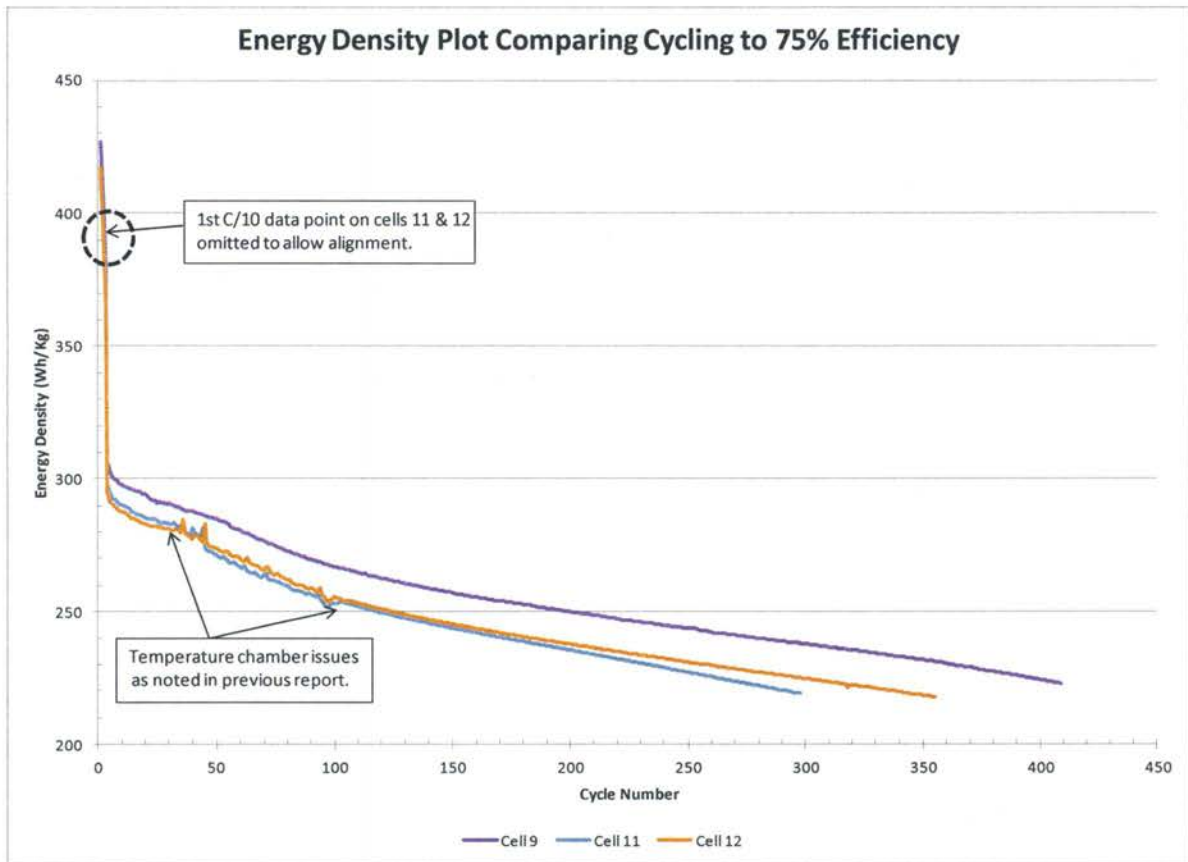




Figure 3: Energy Density Plot Comparing Previous Cells



**Figure 4: Energy Density Plot Comparing Previous Cells Down to 75% Efficiency**

## 5 Conclusions

- 5.1** One of the highest energy cells used in consumer applications is the NCR18650A manufactured by Panasonic. Their specification claims 3100 mAh capacity, 3.6 V average and weighs 45.5 grams. The calculated energy density of these cells would be approximately 245 Wh/Kg. In an effort to evaluate test results comparisons have been made to the NCR18650A.
- 5.2** The test results from cell 9 tested at Crane are in line with the results obtained from the manufacturer. The claims of 400 Wh/Kg were substantiated through the cycling test performed at Crane. This is a 166% energy density increase over the industry standard indicated in paragraph 5.1.
- 5.3** According to the claims on the Panasonic website for the NCR18650A, the capacity at 300 cycles is approximately 2300 mAh. The calculated energy density would then be 182 Wh/Kg at 300 cycles. Envia cell 9 operating at the 80% SOC/DOD provided

238 Wh/Kg after 300 cycles and 223 Wh/Kg after 409 cycles (75% efficiency). Comparing the results of this cell to the Panasonic NCR18650A at 300 cycles, this is a 131% energy density increase. Comparing the results of this cell at the 75 % efficiency mark to the Panasonic NCR18650A at 300 cycles this is a 123% energy density increase.



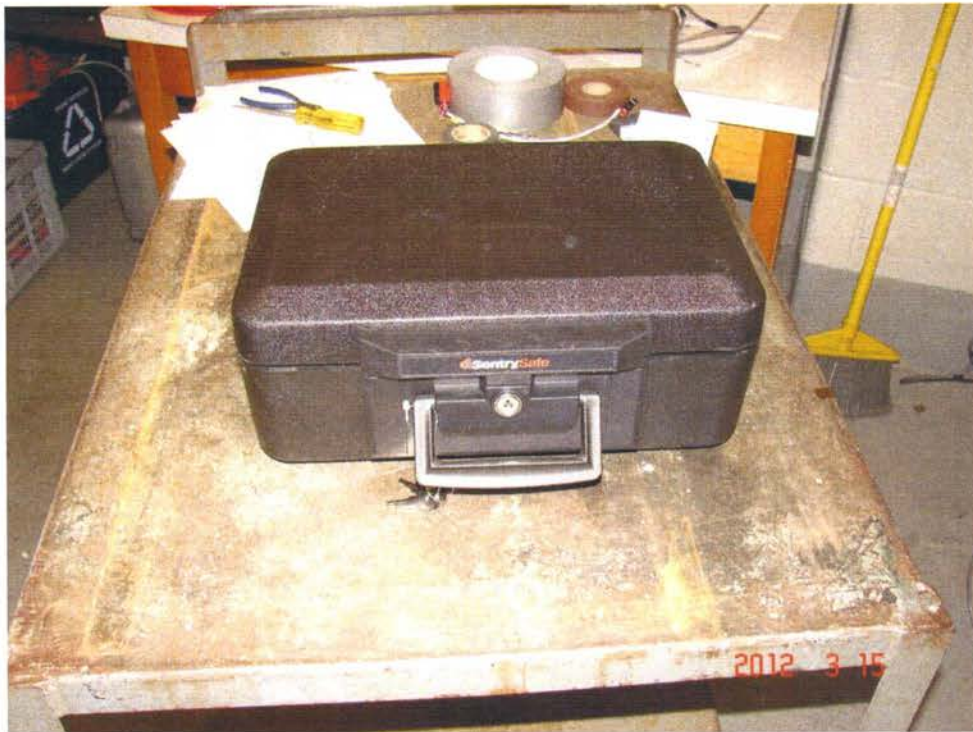
# **APPENDIX A**

## **Test Photographs**

### 1. Unpacking Cells



A-1







## 2. Before Clamping



## 3. Test Setup



