Testing Update on 20 and 25-Ah Lithium Ion cells

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Testing Update on Large Lithium Ion cells

Topics

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  - Test Results, Cell cycling at various temperatures and storage
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Testing Update on
Large Lithium Ion cells

Introduction

- Eagle-Picher Energy Products has worked on lithium ion batteries for approximately 8 years
- During that period EPEPC developed and delivered several cell sizes on a program funded by the USAF and Canadian DND
- Designs are wound cylindrical cells from 7 to 40-Ah
- Most cells delivered were approximately 25-Ah due to requirements of Mars missions
- Several iterations of cells were manufactured and delivered for evaluation
- The first design was 20-Ah, Design I, and the second was a 25-Ah, Design II
Testing Update on Large Lithium Ion cells

Introduction

- Deliveries related to the program were:

- 10, 20-Ah cells to JPL 05/97
- 12, 7-Ah cells to JPL 05/98
- 12, 25-Ah cells to JPL 05/98
- 10, 37.5-Ah cells to Phillips 05/98
- 10, 25-Ah cells to LMA 08/98
- 30, 25-Ah cells to JPL 09/98
Testing Update on Large Lithium Ion cells

Introduction

- Cells have been under test at JPL for over 5 years
- All results presented were supplied by JPL
- No events of significance to report
- The “25-Ah” cell designs evolved over time
- Increased rate capability; tabbing issues
- Increased low temperature performance; electrolyte
**Design Features - Design I**

- Drawn Can - SS304
  - 3.50” diameter x 2.50” x 0.19”
- Standard Penetrations
  - TA-23, 0.125” Mo
  - Fill Tube, Rupture disc 235 psi
- Positive electrode, 1300 x 4.40 x 0.017 cm (LiCoO₂)
- Negative electrode, 1330 x 4.70 x 0.011 cm (Graphite)
- Delivered May 1997
20 - Ah Cylindrical Cell

Cell Design - Design I
Cycling at 23°C - C/5, 100% DOD

- BS09
- BS15

Constant current charge = 4.6 A (C/5)
Constant voltage (4.1V) taper to 0.46 A
Discharge current = 4.6 A (C/5)
Discharge cut-off voltage = 3.0V

Capacity fade rate: 0.019% per cycle.
Cell Cycling and Storage - Cycling at 100% DOD, C/5 at 23°C

- Cells cycled for 1000 cycles at 100% DOD, at RT before storage.
- Cells stored at RT, probably at 100% SOC for about 1.5 years (18 months).
- Total storage (including the cycling time) since manufacture: > 30 months.
- Cells then placed back on 100% DOD, C/5 cycling for 1500 more cycles, approximately 2 years.
EPEPC cell cycled and stored at RT

Eagle-Picher Lithium-Ion Cell
Cell BS 15

28 Month Testing Period
20.6 % Capacity Loss
(0.74 % per month)

Cell completed >1000 cycles
(100% DOD, 23 °C)

18.927 Ahr
23.839 Ahr
(79.4 % Reversible Capacity)

4.0 Amp Discharge Current (C/5 Rate)

Initial Capacity (Aug 1997)
Capacity After Prolonged Storage (Dec 1999)
20 - Ah Cylindrical Cell

Capacity Changes upon RT Cycling (100% DOD) and storage

- 17-20% loss during cycling (1000 cycles over 500 days) and 3-4% loss during storage (1.5 years).

Cell #
Cycle Life and Storage Performance (Gen I 20 Ahr), 4.5 years Testing

Eagle-Picher 20 Ahr Prototype Lithium Ion Cells

Cell BS09

5.0 Amp Charge Current (C/10) to 4.1 V
0.500 Amp taper current cut-off (C/50)
5.0 Amp Discharge Current to 3.0 V
Temperature = 23°C
Cell Cycling and Storage - Cycling at 50% DOD at 0ºC

- Cells cycled for 1000 cycles at 50% DOD and 0ºC before storage
- Cells stored at 0ºC, probably at 100% SOC for about 1.5 years (18 months) after cycling.
- Total storage (including the cycling time) since manufacture: > 30 months.
- Post storage tests in Jan-Feb. 00
  - Capacity check at RT
- Further storage at 0ºC in progress
• End of discharge voltage depression: 7-8 mV/100 cycles.
Eagle-Picher Lithium-Ion Cell
Cell BS 06

28 Month Testing Period
8.1 % Capacity Loss
(0.29% per month)

4.0 Amp Discharge Current (C/5 Rate)
(91.9 % Reversible Capacity)

Initial Capacity (Aug 1997)
Capacity After Prolonged Storage (Dec 1999)

Discharge Capacity (Ahr)
Cell Voltage (V)
Conclusions - Design I

- The cycling results from the Design I cell were quite impressive with slightly greater than 50% of initial capacity after 2500 cycles at 23°C and 100% DOD, total test time approximately 4.5 years
- Storage advantage of 0°C over RT is quite evident with only a 8% loss in capacity after 1000 cycles at 0°C and 18 months storage at 100% SOC versus 20% loss with 100% DOD and storage both at 23°C
25 - Ah Cylindrical Cell

Design Features

- Drawn Can - SS304
  2.625” diameter x 4.50” x 0.19”
- Standard Penetrations
  TA-23, 0.187” Ta - 4-40 thread
  Fill Tube, Rupture disc 150 psi
- Positive electrode, 639 x 8.80 x 0.017 cm (LiCoO$_2$)
- Negative electrode, 656 x 9.10 x 0.011 cm
- Cells delivered September 1998
25 - Ah Cylindrical Cell

Cell Design - Design II

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<th>QTY</th>
<th>DESCRIPTION / DWG. NUMBER</th>
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<td>7</td>
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<td>9</td>
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- ELECTROLYTE WEIGHT 200 ± 10g.

NOTE:
1) Dimensions given are nominal and must not exceed ± 0.100.
2) All drawings are planned with a primary purpose of providing essential information for manufacturing.

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Eagle-Picher 25 Ah Lithium - Ion Cells for Lander Applications
Room Temperature Rate Capability

Cell voltage (V)

Discharge Capacity (Ah)

2.5 A Charge Current (C/10)
4.1 V (Taper to C/50)

Cell BS C016

- 2.5 Ah Discharge (C/10)
- 5.0 Ah Discharge (C/5)
- 7.5 Ah Discharge (C/3.3)
Cycle Life Characteristics at Different Temperatures (Gen II)

Discharge Capacity (Ah) vs Cycle Number

- 5.0 A Charge Current (C/5)
- 4.1 V (Taper to C/50)
- 5.0 A Discharge Current (C/5)
- 3.0 V Cut-off voltage

Temperature = 40 °C
Temperature = 23 °C
Temperature = -20 °C
Room Temperature Cycle Life Performance (100% DOD at 23°C)

Eagle-Picher 25 Ahr Lithium-Ion Cell (Generation II)
Cell BC 75

Temp = 23°C

- 5.0 A Charge Current (C/5)
- 4.1 V (Taper to C/50)
- 5.0 A Discharge Current (C/5)
- 3.0 V Cut-off voltage

Discharge Capacity (Ah)

Cycle Number
Room Temperature Cycle Life Performance (100% DOD at 23°C)

Eagle-Picher 25 Ahr Lithium-Ion Cell
Cell BS C022
Test Started July 1998

- 5.0 A Charge Current (C/5)
- 4.1 V (Taper to C/50)
- 5.0 A Discharge Current (C/5)
- 3.0 V Cut-off voltage
- 23°C
Eagle-Picher 25-Ah Cell - JPL LEO Test Results

- **Test Started 12/98**
  (>17 months to date)

- **(a) 15 A Discharge current (0.6C)**
  30 min Discharge (7.5 Ahr)

- **(b) 10 A Charge current (0.4 C)**
  4.1 V Con. potential charge
  60 min Charge period

**BS C074**

**Temperature = 23°C**
Eagle-Picher 25-Ah Cell - JPL LEO Test Results

Test Started 12/98
(a) 15 A Discharge current (0.6 C)
   30 min Discharge (7.5 Ahr)
(b) 10 A Charge current (0.4 C)
   4.1 V Con. potential charge
   60 min Charge period

Temperature = 23°C

BS C074

~ 9000 Cycles
~ 14000 Cycles
~ 17000 Cycles
Conclusions - Design II

- Design changes from Design I to II resulted in improved low temperature performance and rate capability.
- Effect of temperature on capacity fade as expected.
- Very good cycle life at 60% initial capacity at 2000, 100% DOD, C/5 cycles.
- Simulated LEO test protocol, 30% DOD, shows 9000 cycles at 23°C. Better results would be expected at lower temperatures.
- One cell vented after 2000 cycles with only a loss in capacity.
Conclusions - General

- One of the first large lithium ion cells delivered for evaluation
- Showed the potential for the technology to replace existing technologies and to be mission enabling
Acknowledgements

- EPEPC gratefully acknowledges the cooperation and test results provided by JPL.