Lithium-Ion Cell Storage Study

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Objective of Storage Study

- To establish a best long term storage for the lithium ion cells
- To determine the preferred solstice condition for the lithium ion chemistry (polymer and liquid electrolyte)
- To compare voltage clamped with trickle charge storage

Experimental

- Three levels of testing were performed
  - Cell characterization
  - Test parameter evaluation
  - Storage testing
- Cells used in study
  - 2 SAFT 4Ah - liquid electrolyte
  - 2 Wilson Greatbatch 1.5Ah - liquid electrolyte
  - 1 Lithium Technology 8Ah - polymer

Cell Characterization

- Capacity at ~20°C
  - C/10 Charge for 12 hours with voltage clamp at 4V
  - Discharge to 2.7V
- 72 hour charge retention
  - C/10 Charge for 12 hours with voltage clamp at 4V
  - Open circuit for 72 hours
  - Discharge to 2.7V

WGB 1.5Ah Characterization Test Results

	Cell#1	Cell#2
Capacity In at 20°C	1.30Ah	1.25Ah
Capacity Out at 20°C	to 3.0V 1.26Ah to 2.7V 1.27Ah	to 3.0V 1.24Ah to 2.7V 1.25Ah
72 Hr Charge Retention	3.96V to 3.0V 1.18Ah to 2.7V 1.18Ah	3.99V to 3.0V 1.23Ah to 2.7V 1.23Ah
Retention Percent	to 3.0V 93.7 to 2.7V 92.9	to 3.0V 99.2 to 2.7V 98.4

SAFT 4Ah
Characterization Test Results

	Cell#1	Cell#2
Capacity In at 20°C	3.56Ah	3.58Ah
Capacity Out at 20°C	to 3.0V 3.49Ah to 2.7V 3.57Ah	to 3.0V 3.50Ah to 2.7V 3.60Ah
72 Hr Charge Retention	3.98V to 3.0V 3.44Ah to 2.7V 3.55Ah	3.98V to 3.0V 3.47Ah to 2.7V 3.57Ah
Retention Percent	to 3.0V 98.6 to 2.7V 99.4	to 3.0V 99.1 to 2.7V 99.2

LTC 8Ah
Characterization Test Results

	Cell#1
Capacity In at 20°C	7.07Ah
Capacity Out at 20°C	to 3.0V 7.01Ah to 2.7V 7.12Ah
72 Hr Charge Retention	3.99V to 3.0V 6.94Ah to 2.7V 7.03Ah
Retention Percent	to 3.0V 99.0 to 2.7V 98.7

Test Parameter Evaluation

- Determine the best voltage clamp and trickle charge current for storage testing
- SAFT cells selected
  - Well matched
  - Convenient for existing charger/discharger unit

Test Parameter Evaluation

- Cell #1 left open circuit for 6 weeks
  - Performed to determine how much charge might be lost during 6 weeks open circuit storage
- Cell #2 trickle charged at C/500
  - Performed to determine the time it would take to reach a voltage clamp set at 4.1V

Test Parameter Evaluation Results

- Cell #1
  - 3.97V after 6 weeks open circuit
  - Residual capacity found to be 3.40Ah (3.54Ah)
  - Capacity test performed after open circuit test found 3.44Ah at 3.0V and 3.57Ah at 2.7V.
- Cell #2
  - 4.1V voltage clamp reached in 4 days
  - Residual capacity found to be 3.84Ah (4.01Ah)
  - Capacity test performed after trickle charge storage test found 3.48Ah at 3.0V and 3.60Ah at 2.7V.

Storage Test

- Storage Conditions
  - Stored in 0°C for 4 weeks
  - Trickle charge with a 4.1 voltage clamp
- Capacity tests at 20°C after storage period

Storage Test
Trickle Charge Current

Cell	Trickle Charge Current
SAFT 4Ah	0.002Amp
SAFT 4Ah	0.004Amp
WGB 1.5Ah	0.002Amp
WGB 1.5Ah	0.003Amp
LTC 8Ah	0.004Amp

Storage Test Results

	SAFT Cell#1	SAFT Cell#2	WGB Cell#1	WGB Cell#2	LTC Cell#1
Residual capacity	3.67Ah 3.83Ah	3.77Ah 3.94Ah	1.18Ah 1.21Ah	1.24Ah 1.27Ah	7.38Ah 7.49Ah
Standard Capacity Test	3.40Ah 3.54Ah	3.44Ah 3.56Ah	1.18Ah 1.21Ah	1.02Ah 1.17Ah	6.74Ah 6.86Ah

Conclusions

- Voltage clamped storage at cold temperatures up to 6 weeks appears to be beneficial over trickle charged storage
  - Coulombic losses at 0°C is neglible
  - Voltage clamp eventually reached
  - Trickle charge storage may still be an option in larger capacity cells where charge rates may be relatively smaller
- Future work
  - Short term study at temperatures around 10°C and 20°C
  - Long term study for extended storage
  - Study a lower voltage clamp