Improved Methods for Soft Short Detection in Li-ion Cells

And Automated Cell Screening

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NASA's standard method for screening Li-ion with soft shorts has been to measure their OCV after resting at room temperature for at least 1 year as received after fabrication. Recent comparison tests with ΔOCV methods at 30% and 0% SoC over 3-6 month periods indicate that they are more discriminatory than the 1-year method. Separately a rapid (1 week) high resolution OCV method with tight temperature control was found to also be more discriminatory than the 1-year wait method. Tear downs of cells with outlying ΔOCVs are being examined for separator bridging defects to validate the method. Incorporating these methods into an automated cell screening process will be presented.

Despite extensive quality improvements in the world-wide Li-ion cell manufacturing process since 1991 along with standardize cell screening prior to release of the cells by the manufacturer, catastrophic field failures are still occurring along with major product recalls. Many of these safety incidents in the field originate due to an internal short defect that was not detectable with current techniques at the point of manufacture due to its latency. These incidents have been found to occur with cells from nearly all manufacturers, even from the most experienced, reputable, and highest volume suppliers.

With the expansion and contraction of the electrode jellyroll or stack inside Li-ion cells, latent conductive defects between anode and cathode can potentially grow from soft shorts to hard internal shorts. This was demonstrated experimentally with strategically implanted Ni particles in cells and reported by Barnett at the 2012 Power Sources Conference.[1] Such experimental cells with their implanted particle behaved normally through initial cycling and several failed catastrophically into thermal runaway with many cycles.

NASA and NAVSEA have a centralized the process of procuring, validating, screening, and distributing commercial cylindrical 18650 cell designs to its programs. Two high energy and two high power cell designs were selected after a series of performance, quality, and safety tests and establish channels for procuring these with chain of custody evidence from the manufacturer. The designs are listed in Table 1.

Figure 1 show a plot of the OCV of 1000 M35A cells at the as received SOC and > 1 year old. Note that about 5% of the cells are about 5mV higher than the mean at 3.4990V mostly likely set at slightly higher SOC by the manufacturer. This causes a wider than expected standard deviation and only 2 cells breach the -3 sigma threshold with the 1 year method. The ΔOCV method with the same cells at the same state of charge over 6 months is shown in Figure 2 yields a mostly uniform distribution and detects the same 2 plus 4 more cells breaching the -3 sigma threshold. Figure 3 shows the ΔOCV method at 0% SoC on half of the same 1000 cells. Here the cells were given 2 months to stabilize after the full discharge and the ΔOCV was measured at end of months 2 and 3. This detects 5 outliers out of 500 cells of which 3 were detected by the other methods.

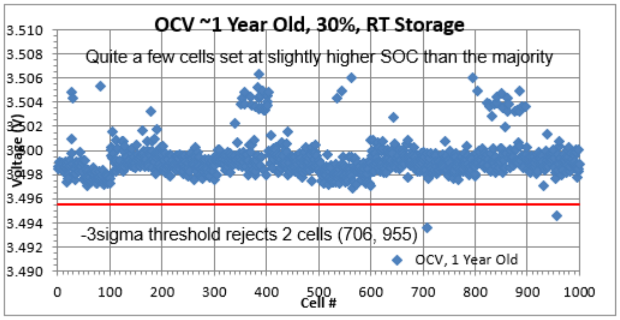

Figure 1. Cell OCVs at 1 year after their date of manufacture in as received 30% SOC.

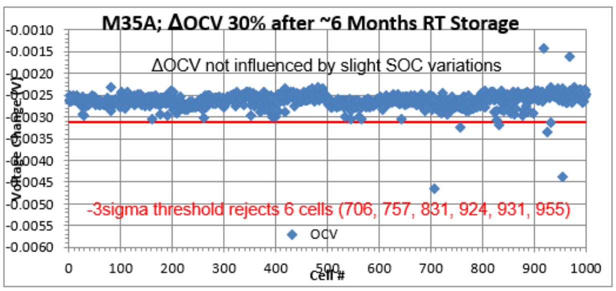

Figure 2. Calculated ΔOCV at 30% SOC about 6 months apart using the same cells as in Figure 1.

Table 1. Attributes of Cell Designs in NASA-NAVSEA Cell Reserve

Item	Cell Model	Cap (Ah)	Wh/kg	Wh/L	ACR (mΩ)	DCR (mΩ)
1	LG INR18650 M36	3.4	270	710	23.9	29.8
2	Molicel INR18650-M35A	3.5	277	725	24.4	32.5
3	Samsung INR18650-30Q	3	207	528	12.4	9.2
4	Molicel INR18650-P28B	2.75	202	510	9.2	22.3

Cell tear downs are planned for the ΔOCV rejects to look for bridging defects across the separator, similar to those found for the outliers of the 1-year method.[2] Overall, the ΔOCV methods at the as received and 0% SoC are more discriminatory than the wait 1-year method. Note that an instrument is in development by CAMX Power and is capable of rapidly (~1 week) grading the microvolts of self-discharge rates of cells against a known good cell from the same lot. It also has been shown to be superior to the wait 1-year method.[3] This will be reported on separately at this conference.

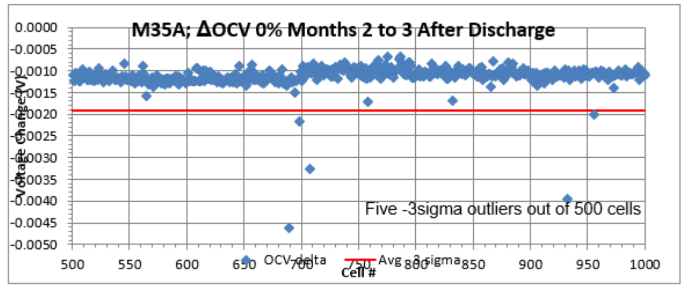

Figure 3. Only half of the cells, discharged to 0% SoC with ΔOCV taken at end of months 2 and 3.

Battery cell safety is of utmost importance in the development and production of lithium-ion batteries. To ensure that these batteries are safe, it is critical to subject the battery cells to rigorous testing, such as EP-WI-037. This technical paper explores the reasons for subjecting battery cells to EP-WI-037, which includes various tests such as OCV, self-discharge, ΔOCV, visual inspection, mass, dimensions, DCIR, and capacity. These tests help identify various defects such as separator bridging defects, seal corrosion, defects in can wall or header, insufficient or too much electrolyte, bulged bottom, and matching performance in cells that populate a battery. By identifying these defects early on, it is possible to prevent potential safety hazards and ensure that the battery performs optimally throughout its service life.

KULR Technology Group has developed an automated and comprehensive screening process for lithium-ion battery cells intended for use in manned space applications, adhering to NASA's EP-WI-37B testing standard. This standard ensures the safety and reliability of these cells in space conditions, where failure or poor performance could have catastrophic consequences. This screening process is critical to ensuring the safety and reliability of battery products.

KULR's automated screening process begins with vision cameras that extract the unique manufacturer ID and date of manufacture, and a laser engraver that cuts the sleeve without damaging the cell body. Vision inspections are performed, and the length and diameter of each cell are measured twice, with the system only keeping the highest and lowest values. A custom-designed SCADA system manages the machine operation, collects data, performs mean and standard deviation calculations, and generates data reports. KULR also uses a custom-designed SQL database to securely house all collected data.

The cells are then subjected to the advanced Chroma process, involving several tests to ensure safety and reliability. The Chroma system can test batches of 576 cells simultaneously, with 18-bit analog-to-digital conversion resolution and 9 units with 64 channels each. The cells undergo continuity checks, OCV measurements, charging and discharging to calculate charge and discharge capacity, and measure DCIR. KULR's screening process selects only high-quality cells, ensuring optimal performance and safety.

When all the tests are complete the SCADA system pulls the necessary data from the database and performs the Mean and Standard Deviation calculations. The system analyzes the results of the calculations and rejects cells with measurements that lie outside of three standard deviations. All of the data is saved, and reports can be generated for every batch of cells processed.

KULR’s Automated Cell Screening System can process cells without human handling, under strict quality control to ensure temperature and humidity requirements are maintained. The system assigns a unique KULR ID electronically to all cells and sequences them in series for data tracking integrity. The system uses a sophisticated laser cutting process to cut cell sleeves without impacting cell can surfaces, and an array of cameras and rotating turntable for visual inspection of cells. Cells are optically measured for length and diameter and then electronically tested in nine identical systems. After electronic testing, cells are charged to 10% SOC and packed in closed cell egg crate boxes holding 100 cells. The KULR system achieves all requirements for NASA flight certification and can process 5000+ cells a week, eliminating nearly all operator handling potential damage due to human interaction. KULR can perform both the 1 year and 6-month delta OCV methods mentioned previously in its process. The most important aspect of the KULR Automated Cell Screening System is it’s calibrated and its controlled repeatability in each step ensures a high level of accuracy and consistency.

The ΔOCV screens at “as received” or discharge states-of-charge are superior to the single measurement method after 1-year of storage, but this requires additional OCV measurements. This is burden is reduced by automated screening.

KULR's commitment to safety is paramount in its product and battery pack design. Ensuring that battery cells meet the highest safety standards through the EP-WI-037 testing procedures is critical to KULR's goal of delivering cutting-edge battery technology that delivers high performance and unparalleled safety.

References

1. Barnett, B. et. al., *Power Sources Conference*, Las Vegas, NV, 2012
2. Darcy, E. and Weintritt, J., *NASA Aerospace Battery Workshop*, Huntsville, AL, 2013
3. Darcy, E., Adams, T., Strangways, B., and McCoy, C., NASA Aerospace Battery Workshop, Huntsville, AL, 2022.