Risk Management Manual for Li-ion Cell testing in Environmental Chambers

by

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1. Introduction

In product research and development, testing becomes a critical component. Mitigating risks in testing batteries under various temperature conditions is an important aspect that will be reviewed. Common failures of lithium ion batteries include undercharging, overcharging, overheating or a crack in the separating membrane. There is a wide variety of safety risks associated with any of these failures.

Many of these involve the use of environmental chambers to subject the batteries to low and high temperatures (often while charging and discharging). Temperature, charge/discharge rates and the Depth of Discharge each have a major influence on the cycle life of the cells. Depending on the purpose of the tests, the temperature and the Humidity levels should be controlled at an agreed reference level in order to have repeatable results which can be compared with a standard.

2. Environmental Risks

a) Thermal Runaway

Risk Involved: There are a variety of hazard levels associated with Li-ion batteries. With this in mind, the most common safety feature incorporated into environmental test chambers for testing of batteries are temperature levels resulting in release of flammable gases into the test environment there by causing a thermal runaway.

Preventative Measure: Usage of High-temperature tolerant/Test-temperature tolerant materials inside the test chamber can mitigate the risk of sparking and ignition of flame. Usage of below mentioned materials for the components inside the test chamber can prevent the risk of thermal runaway as the test temperature levels are between -30^{0}C – 80^{0}C.

Table 1: Thermal Properties of the components

Component	Min (^{0}C)	Max (^{0}C)
Acrylic Thermo-Plastic	-40	80
HDPE Plastic	-45	120
PTFE Wiring	-240	260
PC-ABS Plastic	-30	230
Buna – O ring Seal	-40	120

b) Pressure Compensation

Risk Involved: In most instances the release of flammable gases into the test environment happens at high pressures for very short durations of time (usually 5 to 10 seconds per cell). The pressure at which gases are released from a battery during failure depend not only on the chemistry, but also on the size and structure type (i.e. pouch, can, prismatic cylindrical).

Preventative Measure: Most chamber manufactures have a standard pressure relief port that allows the chamber to “breathe” to account for the expansion and contraction of the air within the conditioned workspace.

3. Electrical Risk

a) Equipment – Shock Risk

Risk Involved: Electrical hazards include exposed parts and unguarded electrical equipment. Such unguarded equipment may lead to shock. Equipment without proper housing may lead to exposure to high temperature

Preventative Measure: Unguarded and Exposed parts must always carry “Shock-Risk” warning signs. Usage of insulated tools such as rubber gloves can mitigate the risk of Shock.

b) Wiring Harness – Short circuit Risk

Risk Involved: The electrical equipment inside the test chamber comprises wiring, temperature and humidity sensors and battery terminal connections. The wiring inside the chamber may subject to short circuit if proper insulation is not provided with wiring.

Preventative Measure: To prevent any chance of short circuit, the wiring inside the test chamber must be properly insulated with a material that can withstand the test temperatures too. Utilizing Polytetrafluoroethylene (PTFE) polymer insulation for wiring systems allows the wires to be operated the most demanding environments. PTFE is resistant to lubricants ad fuels, very flexible and it has excellent thermal and electrical properties

4. Other Considerations

a) Improper Sealing

Risk Involved: If the test chamber is not perfectly sealed during the test conditions, there may be a chance of leaking of fluids or gases. As the temperature and humidity levels must be maintained at different levels, leakage in the chamber may lead to inaccuracy in testing.

Preventative Measure: To prevent any kind of leakages and for accurate cell testing, Buna-O-ring seals can be used. These are perfect to seal off the bolt holes in the acrylic casing so that the chamber remains thermally insulated. They offer corrosion resistance, massive temperature range capabilities, excellent electrical properties and an almost unlimited shelf life.

b) Corrosion

Risk Involved: Placing corrosive materials inside the chamber may lead to significant reduction of the life of the chamber.

Preventative Measure: Corrosive materials like Stainless steel, resin and silicone materials must be avoided from placing inside the test chamber and thereby enhancing the test chamber life.

c) Water Sprinkling – Electrical Shock

Risk Involved: As the refrigeration unit inside the chamber leads to water condensation from the evaporator coils, there is a huge chance of water getting in contact with the electrical components leading to electrical shock and equipment failure.

Preventative Measure: For draining out the water from the test chamber, a condensate draining slope must be placed inside the chamber connected to a drain for the condensate water outlet. It helps in avoiding any contact with electrical equipment and preventing the chance of electric shock/equipment failure.

5. Cell Testing Risks

a) Functional Failure

Risk Involved: Delay might occur if the developed test-bed encounters functional failure or when an additional test method needs to be included for the test-bed.

Preventative Measure: Redundant models for the Test Chamber must be developed in order to attend the functional failures and thereby avoiding any delay.

b) Data insufficiency Risk

Risk Involved: The adaptive cell modelling requires vast data and data insufficiency may lead to improper cell modelling. This results in going back to cell testing which leads to delay in the work

Preventative Measure: Enough cells from different chemistries for different C-rates under various temperatures must be tested in order to obtain enough data for modelling the cell.

6. UL and IEC Safety Specifications

There are many UL and IEC specifications for testing batteries to ensure that they can survive their everyday environment. The following is a list of common specifications for testing lithium ion cells.

- UL 1642 - General safety testing of Li-Ion Batteries
- IEC 61960 – Safety standards for secondary lithium ion batteries
- SAE J2464 – General guidelines for rechargeable energy storage
- UN/DOT 38.3 – Standards for shipping lithium batteries
- IEC 62281 – Safety of primary cells during shipment
- UL 2580 Batteries for use in Electric Vehicles
- IEC 62660-2 Reliability and abuse testing of secondary cells
- IEC 62133 – Testing of secondary cells.

Fault Identification and Troubleshooting

1. Fault in temperature control unit

A program in the microcontroller would constantly monitor the rate of change of temperature. This program would run in the background once the refrigeration or heating module is switched ON. If the temperature seems to remain constant over a specified period of time, it would flag an error corresponding to either the refrigeration or the heater unit, whichever was ON during the time. Hence, it could be attained separately after activating the ‘Kill Switch’, in order to troubleshoot the problem.

2. Fault in humidity control unit

A program installed on the respective Microcontroller would run in the background, constantly monitoring the rate of change of humidity. If humidity seems to be constant over a specified period of time, then it would be flagged as a fault in either the humidifier or de-humidifier unit, whichever is active at the time. This would enable it to be attained separately, after the ‘Kill Switch’ has been activated, in order to troubleshoot the problem.

3. Fault in Interfacing Unit

If the Touchscreen Unit does not work properly, its power and control connections with Raspberry Pi should be properly inspected. If everything seems fine, the program controlling the interface should be checked for any possible errors. If the keys become unresponsive, then it is advised to restart the system. If the problem persists, it suggests problem with the Touchscreen Unit, in which case, it may need to be replaced.

4. Fault in Data Acquisition Unit

Data Acquisition from the experiments being conducted in the cell test bed is done by the respective software that are coupled with the experiments itself. So, if there is a problem in acquiring data during experiments, the error log of the software should be checked for possible faults in the program. Thereafter, proper troubleshooting steps can be performed depending on the type of problem encountered.

In case of inaccuracies in the data being collected, the calibration of the temperature and humidity sensors should be inspected. Also, sensor cables should be inspected for loss of insulation which can cause leakage current to escape, thereby reducing the potential obtained from those sensors.

5. Short circuit fault during Experiment

Chances of short circuit is high especially during cycle testing experiment at high C-rates. Therefore, it is essential to look out for such faults which can damage the cell being tested, along with the cables and other components in the vicinity of the fault. In order to identify this, we can monitor the current being drawn from the cell and the terminal potential values at all times. It current exceeds a preset value, or potential falls below a certain value, an alarm is programmed to get activated so that the user can halt the experiment then and there.