Mitigating Risks of Battery Testing in Environmental Chambers

Mark Chrusciel & Wayne Diener, Cincinnati Sub-Zero

Abstract

We will briefly review the various types of batteries along with the qualifications tests that are performed. 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. The vast array of different battery types, sizes, chemistries and failure modes, means that there is no one standard environmental chamber that can be used or recommended.

The different cell types, test procedures, summary of safety concerns when performing battery testing will be covered along with important criteria to consider on how to select the most appropriate test chamber for the battery test application. In vehicles, it is important to understand how the product interacts with other components. We will explain what safety features and precautions must be used and why. Li-ion thermal runaway is an extremely fast, intense and self supporting reaction. Controlling the reaction is less important than properly managing the by-products (pressure and gases).

Introduction

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, which is specific to the product being tested.

There are many UL and IEC specifications for testing batteries to ensure that they can survive their everyday environment. Many of these involve the use of environmental chambers to subject the batteries to low and high temperatures (often while charging and discharging).

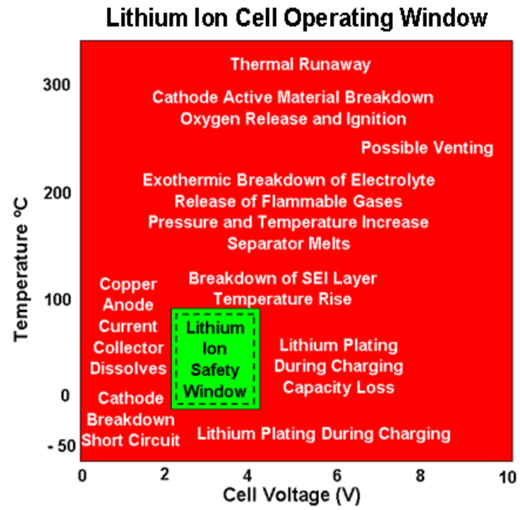


Figure 1

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 DOD should be controlled at an agreed reference level in order to have repeatable results which can be compared with a standard. Some other tests also introduce humidity or vibration. 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.

Safety Features

The selection of the proper environmental test chamber is an important decision for test engineers regardless of the application. However, when the product being tested is a Li-Ion battery, there is a great deal of information to consider. Significant considerations should be based around the level of safety required for the end user's application along with the utilities that are required and available.

Each Li-Ion battery manufacturer has a proprietary chemistry and packaging, which in turn carries its own risk during testing.

The most common concern involved during environmental testing is the release of flammable gases into the test environment should a thermal runaway occur. In most instances this release happens at high pressures for very short durations of time (usually 5 to 10 seconds per cell).

Unique properties of the gases involved should be reviewed when manufacturers design applicable safeties for the test chamber. Materials that are involved with Li-Ion batteries provide all of the elements required for a fire (i.e. heat by the chemical reaction, fuel in the form of the flammable gas, and oxygen produced by the battery itself). Due to the "production" of oxygen by the battery, the fire itself is difficult to extinguish. Gaseous nitrogen purging is effective in preventing the spread of the flame to other components in the chamber. Many test facilities have chosen to prevent a failure during temperature testing versus reacting to the failure after it has occurred.

Hazard Severity	*Description*	*Classification Criteria & Effect*
0	*No Effect*	*No Effect, no loss of functionality*
1	*Passive Protection Activated*	*No damage or hazard; reversible loss of function. Replacement or re-setting of protection device is sufficient to restore normal functionality.*
2	*Defect/ Damage*	*No hazard but damage to RESS; Irreversible loss of function. Replacement or repair needed.*
3	*Minor Leakage/ Venting*	*Evidence of cell leakage or venting with RESS weight loss < 50% of electrolyte weight.*
4	*Major Leakage/ Venting*	*Evidence of cell leakage or venting with RESS weight loss > 50% of electrolyte weight.*
5	*Rupture*	*Loss of mechanical integrity of the RESS container, resulting in release of contents. The kinetic energy of released material is not sufficient to cause physical damage external to the RESS.*
6	*Fire or Flame*	*Ignition and sustained combustion of flammable gas or liquid (approximately more than one second). Sparks are not flames.*
7	*Explosion*	*Very fast release of energy sufficient to cause pressure waves and/or projectiles that may cause considerable structural and/or bodily damage, depending on the size of the RESS. The kinetic energy of flying debris from the RESS may be sufficient to cause damage as well.*

Table 3. Hazard Severity Levels and Descriptions (from Ref.[i], adapted from EUCAR [viii] and SAND2005-3123 [ix])

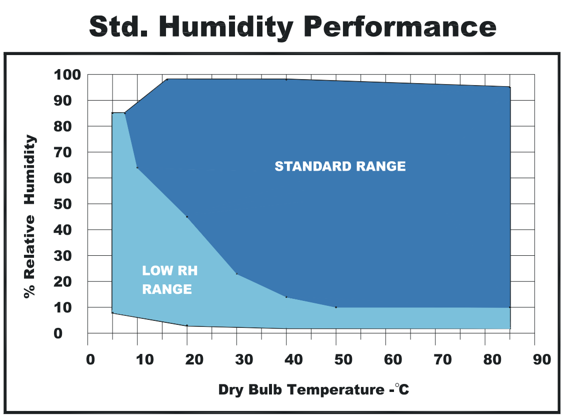
Cincinnati Sub-Zero Products, Inc.
12011 Mosteller Road
Cincinnati, OH 45241
513.772.8810 www.cszindustrial.com

As the previous chart indicates 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 limited sheath heaters. Many heaters used on environmental test chambers are Nicrome (Ni-Cr) wire heaters which can have surface temperatures of over +1,000˚F. The goal of sheathed heaters is to control the surface temperature of the heater to a value that will allow the chamber to meet the desired air temperature and stay below the auto-ignition point of any flammable gases that may have been released, but not ignited into flame. In addition to temperature limited sheath heaters, measures should be taken to mitigate the risk of spark sources in the chamber if it is determined that flammable vapors may be present. These preventative measures include but are not limited to non-sparking fan blades and/or blower wheels, intrinsically safe barriers on all sensors (both temperature and humidity) to prevent the potential of high voltage pulses into the chamber through wires, and the removal of any internal chamber lights.

Another issue to consider is pressure compensation. 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 (e.i. pouch, can, prismatic cylindrical). 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. In many instances these “standard” pressure relief ports may not be adequate to compensate for the pressure and volume released in the event of a failure. In lieu of the rupture disks that are often used to compensate for the rapid release of pressure, some chamber manufacturers have developed a pressure relief system that can be custom tailored for the required gas flow. The advantage to this system is that there is no maintenance required to “reset’ this port to the “at rest” position. Further, a rupture disk rupture disk would also require the attention of maintenance personnel to address the physical replacement of the disk to get back to a non-venting condition in the chamber. Regardless of the compensation method, the end user should verify they have accounted for management of the exhausted gases once it has been released from the environmental chamber. These gases are often toxic, noxious or at the very least have an offensive smell and should be vented to your exhaust system.

These are just some of the common safety features most commonly utilized. Depending on the expected hazard level there is an extensive list of accessories that may be used. Certain applications may include fire detection/suppression systems, gas monitors (H_2, O_2 or CO), door safety interlock switches (to prevent opening during a test or after and event), a flushing system of N_2 or CO_2 to help minimize a fire and help remove byproducts from the chamber, a reinforced chamber floor to withstand intense heat, and an internal cooling system to help control cell and pack temperatures. In certain extreme “test to failure’ applications, a protective enclosure/structure may need to be built to isolate the event.

In addition to mitigating the safety risks, there are many other factors that must be considered in selecting the right environmental chamber. What type of control system will you need and will it integrate with other equipment (like your cyclers)? What type of refrigeration system will be required? One compressor systems that control down to -54C may be preferred over cascade systems due to the energy savings. Also make sure that your system is sized properly to handle your heat load. If you require humidity it is much easier and cheaper to make sure it is included up front. Also be sure that the temperature and humidity points are obtainable (see chart).



Conclusion: It is very important that each battery or component manufacturer evaluate their individual risks and failure modes. If the risk is unknown, it may be beneficial to design for the "worse case" scenario. With this information you can then work with a chamber manufacturer to determine the proper safeties necessary your application. There is no standard safety equipment or battery chamber, as risk may vary considerably by product design, build and battery chemistry.

References :

Figure 1 – Electropedia, http://www.mpoweruk.com

Figure 2 – FreedomCAR : Electrical Energy Storage System Abuse Test Manual For Electric and Hybrid Vehicle Applications SAND 2005-2123

Cincinnati Sub-Zero

Cincinnati Sub-Zero Products, Inc.
12011 Mosteller Road
Cincinnati, OH 45241
513.772.8810 www.cszindustrial.com