# PowerRESPONDER® Safety Parameters

## Executive Summary

Safety has become a priority for users of energy storage technology. This is in part a result of increased incidents of lithium ion battery explosion and self-ignition, grabbing international attention with reports from NBC, CNN, BBC, and more. Several safety tests were performed on the PowerRESPONDER®, a hybrid supercapacitor, to establish the behavior under abnormal and extreme conditions. Results indicate this product is much safer than a Lithium-ion battery.

## Methods

The PowerRESPONDER® is a UL (810A) certified supercapacitor product line having passed all required tests for supercapacitors. The PowerRESPONDER® is often used as a replacement for lithium-ion batteries, so these studies were modeled on standard safety qualification experiments applicable to lithium ion batteries. These qualifications include UN/DOT 38.3, IEC 62133, UL 810A, and primarily UL 2054, a rigorous set of comprehensive tests designed to qualify the safety of lithium-ion batteries/cells[1].

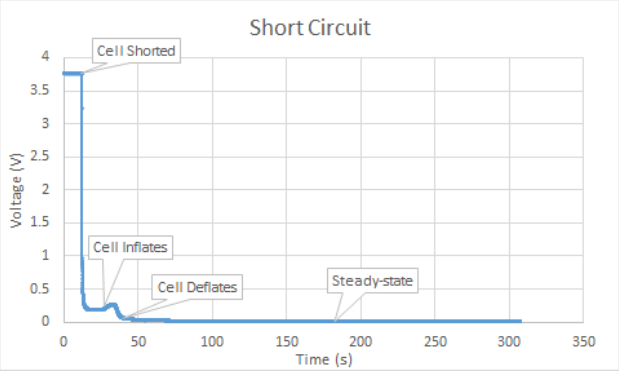
The safety demonstration tests carried out on the PowerRESPONDER® hybrid supercapacitor products were of two types: electrical safety and physical safety. The electrical tests were as follows: short circuit, overcharge, and forced discharge. The four physical tests performed were: crush, penetration, drop, and thermal shock. All tests were performed on two typical form factors of the PowerRESPONDER®, the PR140 (140 farad, 4V nominal voltage, 1A nominal current; *similar to PR160F cell*) and the PR340 (340 farad, 4V nominal voltage, 3A nominal current). Throughout each experiment, temperature, voltage, and current were monitored by a high precision DAQ. The methods for each test are described briefly in Table 1, along with the critical results (a result of 'no effect' indicates no cells vented (sealed edge opened to allow gas to exhaust), exploded, or self-ignited). Further description and discussion of each test's results follow, including voltage trends and other important observations

*Table 1: Brief description of each test methods and population.*

| | Test | Description | Population | Results |
|---|---|---|---|---|
| **Electrical** | **Short Circuit** | Short fully charged cell (4V) for 30 minutes | 5 PR340<br>5 PR140 | No effect |
| | **Overcharge** | Charge cell at 200% nominal current to 150% nominal voltage | 5 PR340<br>5 PR140 | Cell vent |
| | **Forced Discharge** | Discharge cells at nominal current for 30 minutes | 5 PR340<br>5 PR140 | No effect |
| **Physical** | **Drop** | Drop cell from 10' height | 3 PR340<br>3 PR140 | No effect |
| | **Penetration** | Fully penetrate cell with electrically conductive nail | 3 PR340<br>3 PR140 | Minor leak |
| | **Crush** | Crush cell under 2 ton press | 3 PR340<br>3 PR140 | Minor leak |
| | **Thermal Shock** | Cycle cells between -30C and 70C for 100 iterations | 5 PR340<br>5 PR140 | No effect |

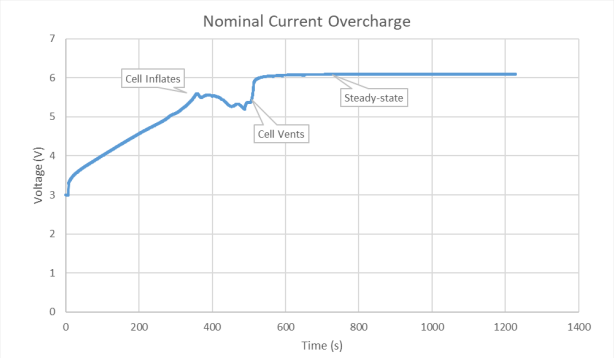
[1] More information regarding UL 2054 at https://standardscatalog.ul.com/standards/en/standard_2054_2

## Short Circuit



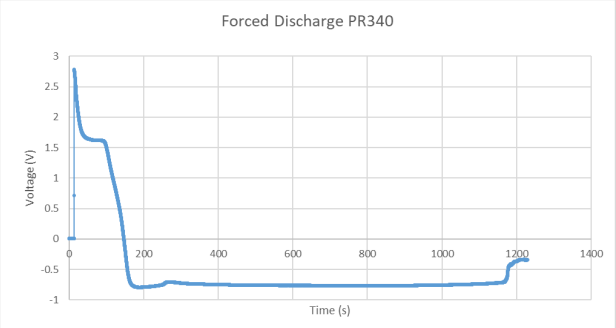

Shorted cells quickly lost voltage, and near 0V experienced some slight puffing, but no cells vented.

## Overcharge




An overcharged cell begins to inflate around 5.8V, losing some voltage until it vents between the tabs.

## Forced Discharge

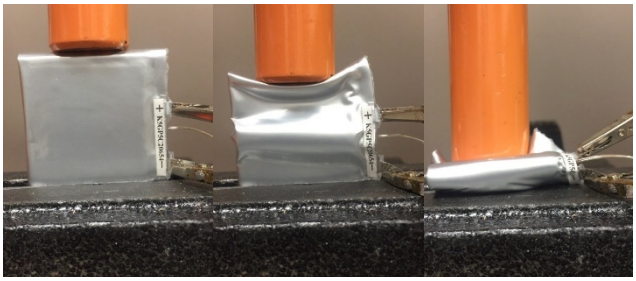



This test's results closely mimicked those of the short circuit. Some cells showed slight inflation, but no cells vented.

## Drop

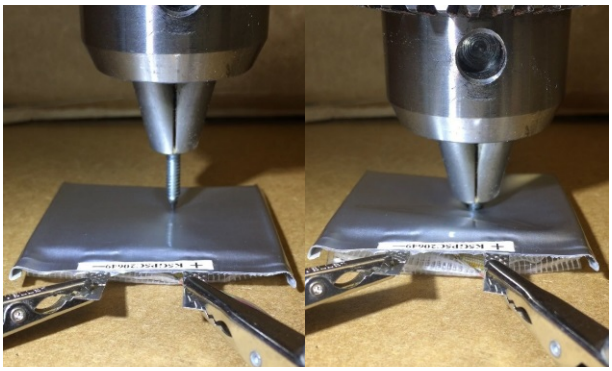
No cell experienced any damage from the 10' drop, and in fact, all cells maintained all normal electrical properties (capacity, ESR, discharge energy).

## Crush



Crushed cells worked normally until crushed fully (right of image) to the point of slicing open the cell enclosure on the vice grips, releasing less than a tenth of a milliliter of electrolyte.

## Penetration



Results here also closely resembled short circuit results (since the nail internally shorts the cell). Cells leaked less than a tenth of a milliliter of electrolyte.

## Thermal Shock

Cells exposed to thermal shock cycling showed no loss of electrical properties and had no visible changes.

# Conclusions

The objective of this experiment was to determine if the PowerRESPONDER product can be considered safe. The two typical form factors were chosen for testing (PR340 and PR140) to represent the product line best. Tests were designed from internationally recognized standards, particularly the UL2054. The PR340 and PR140 products are deemed as safe when exposed to extreme electrical and physical conditions since no cells exploded or ignited. The results of these tests lead one to acknowledge the PowerRESPONDER is a safe product under normal usage and under these extreme conditions.