NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Lithium-Ion Battery Testing
E-flite EFLB1501S

October 2011

Testing was completed by NREL's Center for Transportation Technologies and Systems

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Outline

- **E-flite Battery Specifications**
- **Battery Tests Performed**
- **Battery Test Results**
- **Lessons Learned - Summary**

E-flite Battery Specifications

- **Supplier: Horizon Hobby, Inc.**
- **Model Number: EFLB1501S**
- **Lithium Polymer**
- **Nominal Voltage: 3.7 Volts**
- **Energy Content: 0.5 Wh**
- **Capacity: 150 mAh**
- **Maximum Rated Discharge Rate: 12C or 12*(0.150) = 1.8 Amps**
- **Dimensions: 1.625” x 0.440” x 0.220”**

Battery Tests

- **Exposing to extreme heat:**
  - Place in a fire
  - Heat on a stove
  - Heat in an oven
  - Put in an operating microwave
  - Overheat the terminal with glue or a solder gun

- **Instigating physical damage:**
  - Cut in half with a pair of scissors
  - Crush by a hammer or other heavy object
  - Puncture with a staple
  - Puncture battery with a nail

- **Creating electrical damage:**
  - Over charge with a smart phone battery charger
  - Over charge with a 9V battery
  - Plug into a AC outlet
  - Connect +ve to –ve terminals through the battery connector
  - Drop in salty water
  - Put a drop of salty water on the terminal (simulating a tong touching the terminals)
  - Connect battery to the motor alone

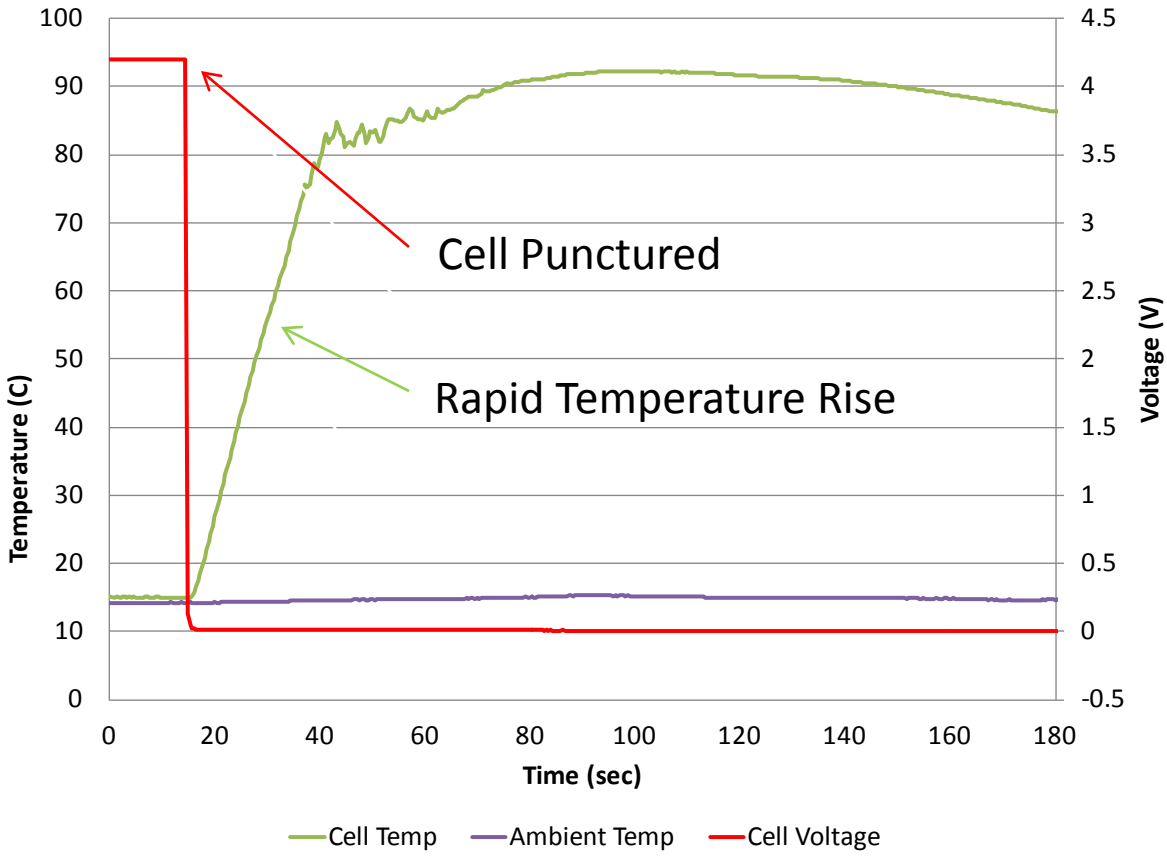
*Battery Tests Performed in Red

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Battery Test Results

Puncture with Staple

Battery Testing

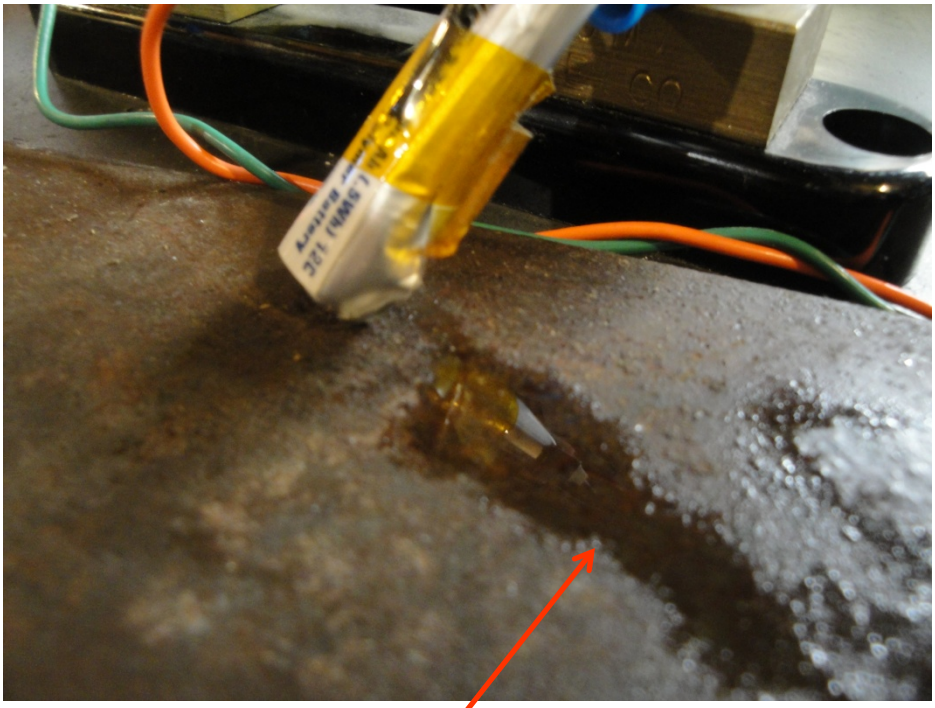


- After the cell was punctured with a staple, the temperature of the cell rose approximately 70°C (126°F).
- The maximum temperature achieved by the cell was 92°C (198°F).
- The excessive temperatures within the cell caused the electrolyte to internally vaporize; this, in turn, pressurized the aluminum packaging material of the battery.
- After pressurization, the aluminum packaging vented out of the bottom of the cell and liquid electrolyte was seen on the test surface.
- Smoke also exited the vent hole but a fire did not result.

Puncture with Staple

Battery Testing

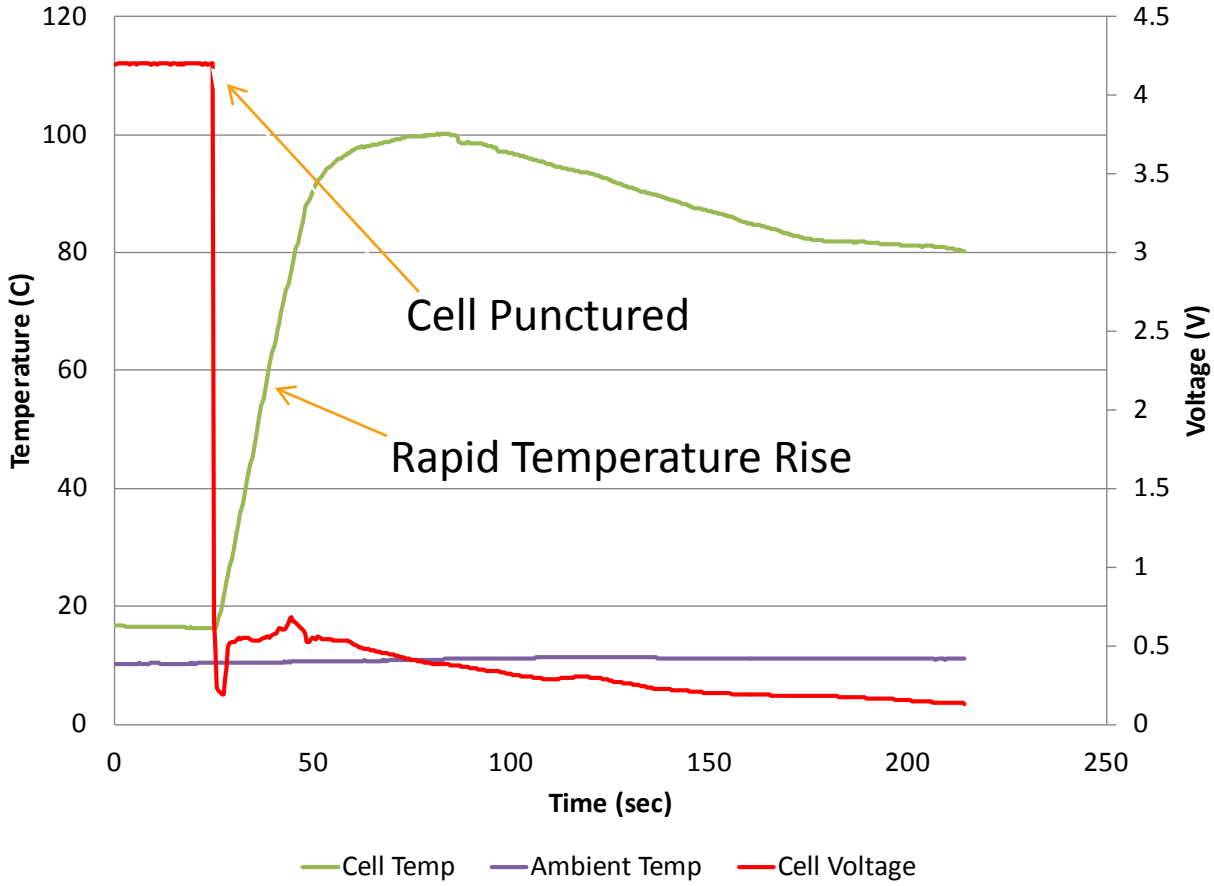
Staple



Electrolyte from cell venting.

Puncture with Nail

Battery Testing



- After the cell was punctured with a nail, the temperature of the cell rose to approximately 100°C (212°F).
- The excessive temperatures within the cell caused the electrolyte to internally vaporize; this, in turn, pressurized the aluminum packaging material of the battery.
- After pressurization, the aluminum packaging vented out of the bottom of the cell and liquid electrolyte was seen on the test surface.
- Smoke also exited the vent hole but a fire did not result.

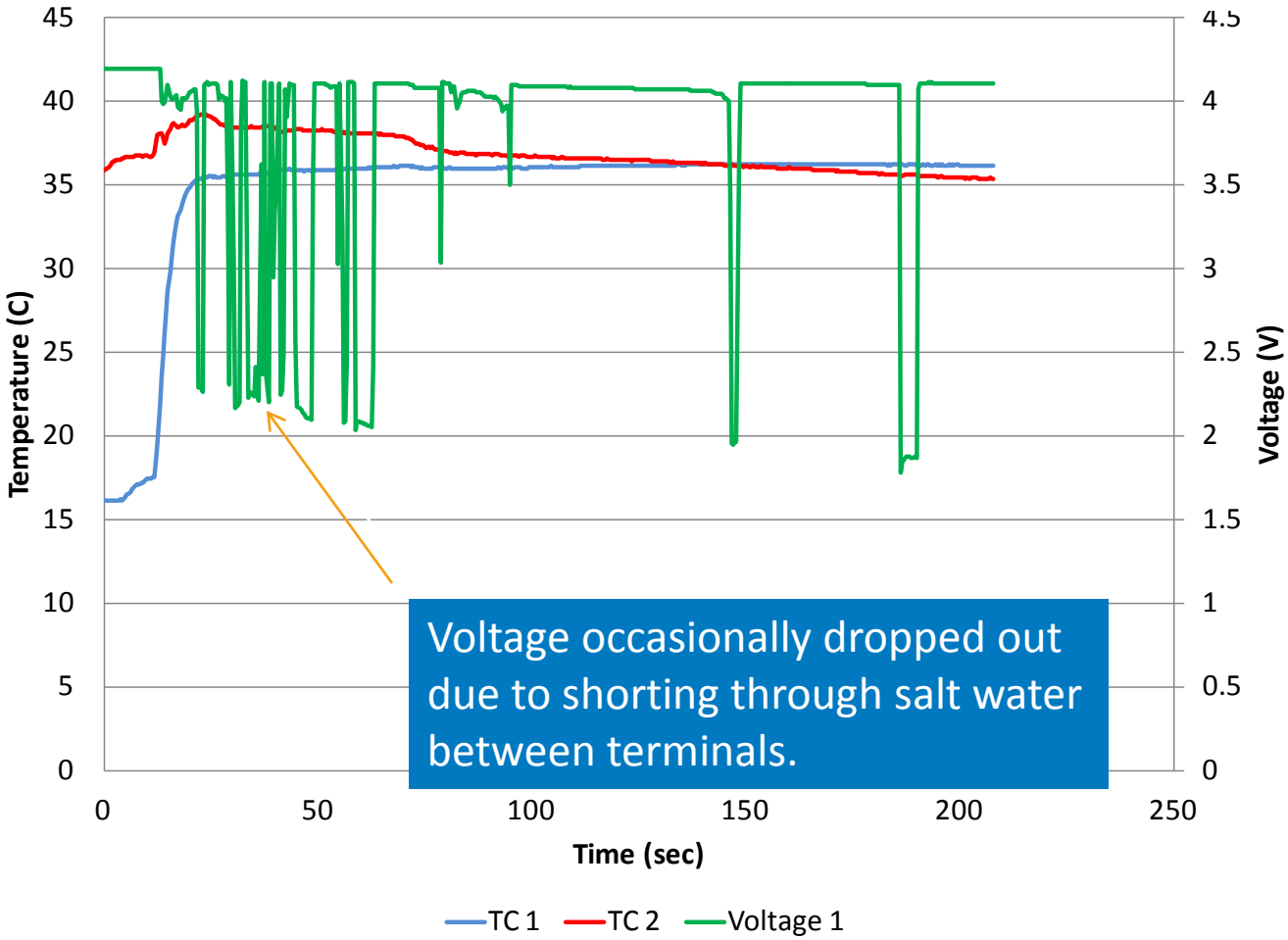
Puncture with Nail

Battery Testing

Nail

Immerse in Salt Water

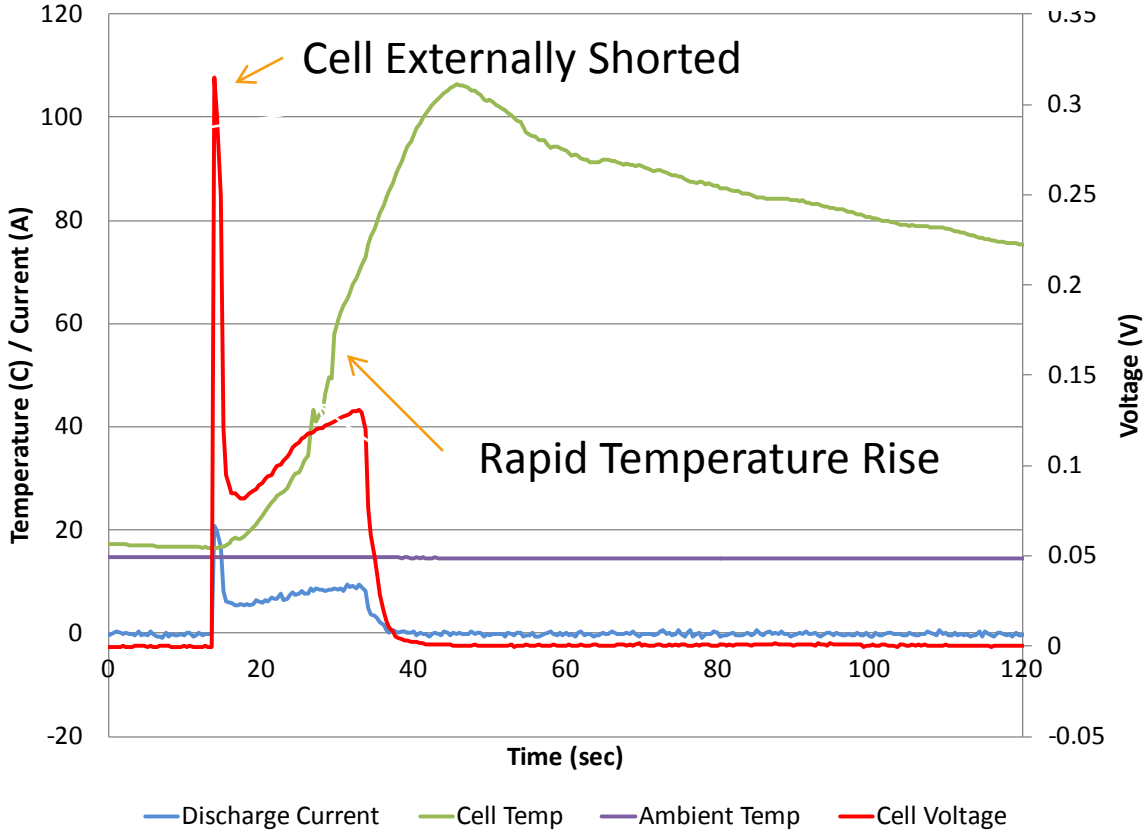
Battery Testing



- After the cell was immersed in salt water, the temperature of the cell remained virtually unchanged – the water thermal mass regulated the temperature of the cell.
- Electrolysis occurred between the terminals of the cell forming hydrogen and oxygen – hydrogen is a flammable gas.
- The cell did not pressurize and did not vent.
- During the test, the voltage occasionally dropped due to a short that developed through the salt water and between the terminals of the cell.

Externally Short Circuit Cell

Battery Testing



- After the cell was externally shorted (akin to dropping a wrench across the positive and negative terminals), the temperature of the cell rose to approximately 106°C (223°F).
- The excessive temperatures within the cell caused the electrolyte to internally vaporize; this, in turn, pressurized the aluminum packaging material of the battery.
- After pressurization, the aluminum packaging vented out of the bottom of the cell and liquid electrolyte was seen on the test surface.
- Smoke also exited the vent hole but a fire did not result.
- The current draw from the battery exceeded the 12C rating of the cell by a factor of 10.

Place Cell in Fire

- The cell was placed over three votive candles in order to vent the cell and ignite the electrolyte vented by the cell.
- After placing the cells over the candles, the excessive temperatures within the cell caused the electrolyte to internally vaporize; this, in turn, pressurized the aluminum packaging material of the battery.
- After pressurization, the aluminum packaging vented out of the bottom of the cell and liquid electrolyte was atomized into the air.
- The resultant liquid droplets caught fire due to the adjacent candles.
- Smoke exited the vent hole before, during, and after the fire.

Benign Test Protocols

- Two of the tests performed were very benign.
  - Connecting the battery directly to the electric motor.
  - Placing a drop of salt water on the terminal.
- Neither test resulted in a significant rise in temperature (< 3°C) and no pressurization or venting of the cell occurred.

Lessons Learned (1/2)

- The following tests will most likely cause the cell to overheat and vent.
  - Putting in a fire
  - Heating on a stove
  - Heating in an oven
  - Placing in an operating microwave
  - Over heating the terminal with glue or a solder gun
  - Cutting in half with a pair of scissors
  - Crushing by a hammer or other heavy object
  - Puncturing the battery with a staple
  - Puncturing the battery with a nail
  - Over charging with a 9V battery
  - Over charging with a smart phone battery charger
  - Plugging into a AC outlet
  - Connecting +ve to –ve terminals through the battery connector
- The above list is not meant to be all inclusive.

Lessons Learned (2/2)

Summary

- The aforementioned tests will likely result in the following:
  - Rapid temperature rise of the cell – potential for first, second, and third degree burns.
  - Vaporization of the electrolyte within the cell.
  - Venting of the electrolyte within the cell through the seals of the aluminum pouch material (typically on the bottom of the cell.)
- The electrolyte is very flammable and if an ignition source exists, then fire and even an explosion could result.
- Furthermore, when the electrolyte is combined with water, there is the potential for hydrofluoric acid to form – an extremely toxic and corrosive substance. To learn more about hydrofluoric acid, visit the following link to the Center's for Disease Control website - http://www.bt.cdc.gov/agent/hydrofluoricacid/basics/facts.asp
- Lithium cells are like any other technology – if they are abused and used beyond their intended purpose, then catastrophic results may occur: first, second, and third degree burns, respiratory problems, fires, explosions, and even death. Please handle the lithium cells with care and respect.