Rowan University

ENVIRONMENTAL HEALTH & SAFETY

Lithium-Ion Battery Guidelines

April 8, 2025

1.0 PURPOSE

This guideline aims to provide users of lithium-ion (Li-ion) and lithium polymer (LiPo) cells and battery packs with enough information to safely handle them under normal and emergency conditions.

Caution must be taken in Li-ion battery storage, use, management, and disposal due to the potential for fire and injury if these batteries are misused or damaged. Several incidents at Rowan University and other universities have involved Li-ion and LiPo batteries. At Rowan University, these incidents were related to batteries left on chargers for extended times, unattended charging, incompatible chargers, cheap knock-off batteries, and shorts from improperly wired or isolated connections.

2.0 BACKGROUND

Batteries are classified as primary or secondary. Primary batteries irreversibly transform chemical energy into electrical energy. When the initial supply of reactants is exhausted, electrical energy cannot be readily restored to the battery. Alkaline and lithium-metal batteries are examples of primary batteries. Primary lithium batteries are briefly discussed in this guidance, but since these batteries contain lithium metal, a water-reactive material, the handling recommendations for these batteries in an emergency differ from Li-ion/LiPo batteries.

Secondary batteries can be recharged; their chemical reactions can be reversed by supplying electrical energy to (charging) the cell. However, secondary batteries age during each cycle and are not indefinitely rechargeable. Before the widespread introduction of Li-ion/LiPo batteries, lead acid, nickel-cadmium, and nickel-metal-hydride were the most common types of secondary batteries.

Li-ion/LiPo batteries have emerged in recent years as the most popular secondary batteries due to advantages that include being lightweight, having a higher energy density, having a low memory effect, and having a longer life span. They provide a compact and powerful energy source for Rowan University research projects and Remote-Controlled (RC) vehicles requiring electrical energy. With this technology, Li-ion/LiPo batteries are stored in the anode (negative electrode) and transported during the discharge to the cathode (positive electrode) in a flammable organic electrolyte. The materials used are graphite for the anode and metal oxide for the cathode.

Li-ion batteries are used in battery packs for portable laptops, power tools, and other devices requiring electrical power. LiPo batteries are commonly seen in applications like RC vehicles, where their relatively light weight and high current draw are an advantage. Since both battery types have similar chemistries, they require similar care in charging and handling to avoid unsafe situations.

3.0 RESPONSIBILITIES

3.1 Researchers/Students

- Implementation of all applicable provisions of this Procedure.
- Obtain and review the battery manufacturer's Safety Data Sheet (SDS), Technical Specification sheet(s), and other available documents.
- Perform hazard analysis to understand the various failure modes and hazards associated with the proposed configuration, type(s), and number of batteries used.
- Ensure that written standard operating procedures (SOPs) for lithium and lithium-ion-powered research devices are developed and include methods to safely mitigate possible battery failures that

can occur during assembly, deployment, data acquisition, transportation, storage, and disassembly/disposal.
- Ensure that the battery assemblies are disposed of properly or left in a safe condition for storage after testing.

3.2 Environmental, Health & Safety (EH&S) Office
- Maintain this Guidance.
- Assist in training and communicating safety requirements to Rowan University personnel.
- Waste management (removal of hazardous waste).
- Assist in the investigation of incidents involving Li-ion/LiPo batteries.
- Incident Response.

3.3 Rowan University EHS and Shipping
- EHS will assist with meeting regulatory requirements for the shipment of Li-ion/LiPo batteries, including proper packaging and documentation.

4.0 HANDLING AND USE

If the cells and batteries are correctly handled, the risk of a fire developing from a Li-ion/LiPo battery from a reputable manufacturer is very low. Most incidents involving Li-ion/LiPo batteries find a root cause in the mishandling or unintended abuse of such batteries. Possible causes of Li-ion/LiPo battery fires include overcharging or discharging, unbalanced cells, excessive current discharge, short circuits, physical damage, excessively hot storage, and poor electrical connections for multiple cells in a pack.

4.1 Best Practices for Li-ion/LiPo Cell/Battery Use
- Always purchase batteries from a reputable manufacturer or supplier. Cheap or counterfeit batteries may not undergo the same quality control processes and are more likely to fail.
- Be sure to read all documentation supplied with your battery.
- Never burn, overheat, disassemble, short-circuit, solder, puncture, crush, or mutilate battery packs or cells.
- Do not put batteries in contact with conductive materials, water, seawater, strong oxidizers, and strong acids.
- Avoid excessively hot and humid conditions, especially when batteries are fully charged. Do not place batteries in direct sunlight, on hot surfaces, or in hot locations.
- Always inspect batteries for any signs of damage before use. Never use and promptly dispose of damaged or puffy batteries.
- Li-ion/LiPo batteries assembled to offer higher voltages (over 60 V) may present electrical shock and arc hazards. Therefore, adherence to applicable electrical protection standards (terminal protection, shielding, PPE, etc.) is required to avoid exposure to electrical hazards.
- Do not reverse the polarity.
- Do not mix different types of batteries or mix new and old ones (e.g., in a power pack).
- Do not open the battery system or modules without training and permission.
- Do not use the unit without its electronic management system.
- Do not submit to static electricity risks to avoid damage to the Protecting Circuit Board.
- Immediately disconnect the batteries if they emit an unusual smell, develop heat, change shape/geometry, or behave abnormally during operation or charging.
- Exercise caution with new products like Hoverboards (banned on campus), where all safety considerations may not be recognized or that may encourage cheap knockoffs built without adhering to safety standards.

4.2 Transporting batteries

Take precautions to avoid dropping batteries during transport. Protect the battery terminals and uninsulated connections from contact with other objects by using the original packaging or a suitable plastic container when transporting a battery.

4.3 Charging/Discharging

If from a reputable manufacturer, the Li-ion/LiPo battery packs found in portable laptops and similar devices usually require no user input for charging other than connecting them to the charging cable. They contain a Battery Management System (BMS) that controls the charging process. Be sure to use the manufacturer's AC adapter. Those charging these batteries still need to follow all manufacturer recommendations and be alert for anomalies like unusually hot batteries.

Batteries used in RC drones and other research projects require a much more conscious effort by users to charge safely and avoid battery damage. Li-ion/LiPo battery users for these applications should incorporate the following recommendations into their charging practices:

- Batteries must only be charged with a charger or method designed to charge cells or battery packs at the specified parameters safely. Be sure that the charger settings—both voltage and current settings—are correct for the battery pack being charged.
- Never leave a battery pack unobserved during charging. Always stay in or around the charging location to periodically check for any signs of battery or charger distress. Occasionally check on output levels and balancing effectiveness.
- For series packs (2S and above), always balance the charge with a charger capable of monitoring the condition of individual cells to prevent individual cells from being overcharged. This charger and the battery should be placed on a heat-resistant, nonflammable, and nonconductive surface. Fire-safe containers designed for Li-ion/LiPo batteries are available. Never place them on a car seat, carpet, or similar surface.
- Keep all flammable materials away from the operating area.
- Do not overcharge (greater than 4.2V for most batteries) or over-discharge (below 3V) batteries.
- Ensure batteries do not exceed manufacturers recommended operating temperatures during charging or discharging. Use caution when charging or using a battery that is still warm from charging.
- Never parallel charge since chargers cannot monitor the current of individual cells.
- Best practice is to charge and store batteries in a fire-retardant container like a high-quality Lipo Sack.
- Do not leave batteries connected to chargers after charging is complete (see storage section).

4.4 Working Area

- Make sure the working surface is made of nonconductive, noncombustible material. Cover the surface with an insulating material if you are working on a conductive material.
- The area should be clear of any flammable or combustible materials such as wood tables, carpet, gasoline, or other solvents.
- Keep the area free from sharp objects that may puncture the insulating sleeve on cells.
- Ambient temperature should not exceed 60°C. The best working temperatures are between 15°C and 35°C.

5.0 STORAGE

Proper Li-ion/LiPo battery storage is critical for maintaining optimum battery performance and reducing the fire and explosion risk. Many recent accidents regarding Li-ion/LiPo battery fires have been connected to inadequate storage areas or conditions. While Li-ion/LiPo spontaneous fires are rare, they need just an internal short circuit to start a series of reactions that may lead to a fire. Other factors that pose a higher risk of fire in a storage area are the type of cell design, chemistry, temperature, state of charge, and length of storage period.

The following are some guidelines that, if correctly followed, will reduce the risk of fire and explosion of stored batteries.

5.1 Cells - Batteries - Packs

- Every time a battery is not used actively (e.g., for more than 3 days), it should be placed in the storage area to avoid being damaged and unsafe.
- When not using your LiPo/Li-ion battery pack, store it at 60-70% of its rated capacity. Li-ion/LiPo cells should never be stored fully charged; they should be stored with a voltage of around 3.8V. Most chargers have a "storage mode" to charge or discharge the cell to the proper storage voltage. Experts recommend putting the cells in storage mode after every run; this will help the battery lengthen its usable life span.
- Remove the Li-ion/LiPo battery from a device before storing it.
- When storing batteries, using a Li-ion/LiPo battery fireproof safety bag or other fireproof container is a good practice. Always follow manufacturer recommendations on fireproof bags for details on using them correctly. Do not buy cheap fireproof bags; they might not be effective.
- Cell terminals must be protected by electrical insulating material.

5.2 Area

- Store batteries in a dry and well-ventilated place at room temperature or lower. While batteries can be used safely between -20 and 60 °C (-4 to 140 °F), it is strongly suggested that they be avoided at a temperature close to the upper or lower range.
- Storing batteries in a refrigerator may create internal condensation when the battery is brought to room temperature, and they may become dangerous when operated.
- It is best to reserve an area ONLY for Li-ion/LiPo battery storage. It must be cool and dry, away from heat sources.
- The area should be free from any materials that can catch fire, such as wood tables, carpets, or gasoline containers. Concrete, metal, ceramic, or any non-flammable material is the ideal surface for storing Li-ion/LiPo batteries.
- Batteries can be stored in a metal cabinet, such as a chemical storage cabinet; ensure that they do not touch each other and that no chemicals are stored there.
- A fire detector in the storage area is recommended.
- Never leave batteries unattended where someone can damage them.
- Have a class ABC or CO_2 fire extinguisher near the storage area.

6.0 SHIPMENT

Only trained and authorized personnel are allowed to prepare, package, and ship Li-ion/LiPo batteries. If you plan to ship Li-ion/LiPo batteries, with or without equipment, you must contact the EHS Office to establish if your product falls under the Dangerous Goods Regulations.

WARNING: Failure to comply with regulations for shipping hazardous materials can result in significant civil penalties for the shipper of up to $100,000.00 per violation.

The EHS Office will assist you in proper packing, labeling, and completing appropriate paperwork for the shipment.

For more information, visit the Hazardous Material Page on the Rowan University website.

7.0 EMERGENCY PROCEDURES

While all batteries must be handled cautiously, Li-ion/LiPo batteries pose additional safety risks due to their high energy density and flammable electrolyte. When these batteries are poorly manufactured, overcharged or over-discharged, incorrectly handled and connected, or exposed to excessive mechanical and physical stress, conditions may arise and lead to a thermal runaway that, in turn, may lead to the venting, leaking, explosion, and fire of the battery cell or pack. All Li-ion/LiPo cell users must be aware of and equipped to handle the emergencies mentioned above.

7.1 Damaged Batteries

Battery damage may not always be visible. Events that may damage a Li-ion/LiPo battery include a fall of 12 inches or greater, a crash with a speed of 20mph, a puncture by a sharp object, and expansion due to overheating. Use of a damaged battery may lead to thermal runaway and subsequent fire.

Procedure

- After the impact/accident, disconnect the battery if it is not hot, leaking, or smoking.
- Remove the battery from the equipment by wearing gloves, goggles/safety glasses, and a lab coat.
- To discharge the battery, move it to a well-ventilated area and place it in a metal or hard plastic bucket.
- Fill the bucket with a 3% saltwater solution.
- After 2 days in the saltwater bath, call the EHS office to have the battery disposed of.
- Check the voltage across the terminals to ensure it has reached 0 V.
- Alternatively, to discharge the battery, use a resistor with resistance greater than 10 times the battery's internal resistance rating.
- **Remember that there may be no visible damage; a delayed fire can occur hours or days after the impact/accident.** It is safest to discharge the battery immediately.

7.2 Overheating, Venting and Leaking Cells

Cell overheating will occur when a cell’s internal temperature and pressure rise faster than the rate at which they can be dissipated. This may be caused by electrical shorting, rapid discharge, overcharging, manufacturer defects, poor design, or mechanical damage, among many other causes. In series or parallel connected strings of batteries, high connection resistance from a poor electrical connection can lead to overheating. Overheating a given cell may produce enough heat to cause adjacent cells to overheat. The cell may vent, catch fire, or explode if it does not return to room temperature. Listen for sounds like “clicks” and “puffs,” which may indicate a preliminary vent release. Depending on the cell type and manufacturer, the critical temperature ranges around 120-300 °C (250-570 °F) (see manufacturer manual for details on the battery you use). Follow this emergency procedure if you have overheating, venting, or leaking cells.

Procedure

- If you notice hot cells, disconnect the charger and remove any external short circuit if present.
- If a cell is venting or smoking, evacuate all personnel from the area. The area should be secured to ensure that no unnecessary persons enter.
- If leaking material is present, do not touch it.
- Immediately dial 9-1-1 or 856-256-4911 to initiate emergency assistance.

- Do not approach the cell until it reaches room temperature. The cell temperature can be checked using a remote device (i.e., an infrared thermometer).
- If a remote device is unavailable, do not handle the cell for at least 24 hours.
- As soon as the cell reaches room temperature, contact EHS to have the damaged battery removed from the working area as hazardous waste (see section 9.0 waste management).

7.4 Exploded Cell
Like a vented cell, an exploded cell results from an overheated or mechanically damaged cell. After the explosion of a Li-ion/LiPo battery, the room quickly fills with dense white smoke that can cause severe irritation to the respiratory tract, eyes, and skin. All precautions must be taken to limit exposure to these fumes.

Procedure

- If a cell has exploded, evacuate all personnel from the area. The area should be secured to prevent unnecessary personnel from entering.
- Immediately dial 9-1-1 or 856-256-4911 to initiate emergency assistance.
- If a ventilation system is in place and it is safe to turn it on, initiate ventilation and continue until the cell is removed from the area and the pungent odor is no longer detectable.
- Contact EHS for assistance in removing the damaged battery cell as hazardous waste.

7.5 Li-ion/LiPo Battery Fires
Li-ion/LiPo fires may occur due to thermal runaway, shorting, and other conditions that increase temperatures. Once the battery begins to vent flammable vapors, it may easily catch fire. Rowan University personnel are not required to fight fires. Trained fire extinguisher users should attempt to extinguish early-stage (incipient) fires only if it is possible to do so safely. Portable fire extinguishers that can be used include ABC (dry powder), carbon dioxide (CO_2), and foam (noncombustible). Smothering the fire with sand or sodium bicarbonate may also be effective. After extinguishing the fire, water should be used to prevent the affected battery from reigniting and adjacent batteries from overheating.

Procedure for a small-scale fire

A typical example is a small wastebasket fire.

- All personnel from the area should be evacuated.
- Activate the nearest fire alarm pull station.
- If you are trained in fire extinguishers and know the type of battery in use, take the closest CO_2 or ABC extinguisher.
- Make sure you are positioned between the fire and the nearest exit before attempting to extinguish the fire.
- If using a portable fire extinguisher has little effect on extinguishing the fire, exit immediately. Do not initiate a second attempt.
- If you can put out the flames, pour water over the battery to cool it down if this will not create an electrical hazard. Depending on the size of the battery in use, you might need 1 to 5 or more liters of water.
- By-products of combustion may be toxic when inhaled. In the event of heavy smoke, exit the area immediately. Ensure others have left the area and close doors behind you as you leave.
- EHS will need to assess the cleanup and waste management situation after the situation is under control.

Large scale fire

In the event of a "larger" fire that has been active for a time, and those involving furnishings, interior finishes, and structural building components, evacuate the area.

- Activate the nearest fire alarm pull station. Do not attempt to extinguish the fire by using a portable fire extinguisher.
- Call Campus Police (Dial 9-1-1) from a safe location.
- Plan to be available for the Glassboro Fire Department to provide information. This may include the fire's size, location, and nature, as well as the identification of any hazardous materials, especially in the event of a laboratory fire.
- Guide 147 (Lithium-ion and Sodium Ion Batteries) of the US DOT Emergency Response Guide provides detailed information on fighting a Li-ion/LiPo battery fire.
- EHS will need to assess the cleanup and waste management situation after the Glassboro Fire Department clears the scene.

<u>First Aid Procedures in Case of Contact with Electrolyte</u>

- While the electrolyte composition will vary depending on the type of battery cell, the general first aid procedures are the same for exposure to the electrolyte.
- EYES -- Immediately flush eyes with a direct stream of water for at least 15 minutes while forcibly holding eyelids apart to ensure complete irrigation of all eye and lid tissue.
- Remove contaminated garments.
- SKIN -- Flush with cool water or get under a shower. Remove contaminated garments. Continue to flush for at least 15 minutes. Get medical attention, if necessary.
- INHALATION -- Move to fresh air. Monitor airway breathing; if breathing is difficult, have a trained person administer oxygen. If respiration stops, provide first aid and CPR procedures - only if CPR-trained. GET MEDICAL ATTENTION IMMEDIATELY.
- If there has been significant exposure to the electrolyte, seek immediate medical attention. The applicable SDS should be sent to the hospital with the patient.

8.0 WASTE MANAGEMENT

The New Jersey Department of Environmental Protection (NJDEP) regulates the disposal of intact and damaged batteries. Intact Li-ion/LiPo batteries are considered to be Universal Waste (i.e., a subset of the hazardous waste regulations intended to ease the burden of disposal and promote proper collection, storage, and recycling of certain materials). Damaged Li-ion/LiPo batteries are considered hazardous waste and must be collected by the EHS Office. The following paragraphs describe the steps needed to comply with the above requirement. It applies to all Rowan University personnel and researchers who work with batteries.

8.1 Disposal

Intact batteries can be collected and recycled in any container. Spent battery terminals must be taped and gently placed into a container, then properly labeled for recycling through the Universal Waste Program. Labels should indicate: "Universal waste – Li-ion/LiPo batteries." Do not mix lithium-ion batteries with other batteries, such as alkaline, cadmium, or other rechargeable spent batteries. These units can be brought to a designated area within the building. Contact Rowan University EHS for further information on proper disposal. For damaged batteries and all spills from broken batteries and emergencies, contact the EHS Office for guidance.

9.0 DEFINITIONS

Anode: the negative electrode typically made with a graphite active material coated onto a metal (usually copper) foil current collector.

Cathode: the positive electrode typically made with a metal oxide ($LiMO_2$, where M= Ni, Mn, or Al) or a phosphor-olivine (i.e., $LiFePO_4$) coated onto a metal (usually aluminum) foil current collector.

Electrolyte: lithium salt (i.e., typically $LiPF_6$) in a mixture of flammable organic carbonate solvents.

Cell: A single battery (Understanding Battery Specifications).

Battery Pack: An assembly of cells connected in series or parallel (xPyS). Each battery pack contains only one type of cell. Connecting cells in parallel increases the pack capacity (ampere hour, Ah), and in series, the pack voltage, i.e., y times 3.6V (where x and y are the number of connected cells - see Appendix B for examples).

Primary (non-rechargeable) lithium metal cells: These cells have lithium metal anodes paired with a variety of cathode materials (e.g., MnO_2, CF_x, FeS_2, and $SOCl_2$) and corresponding nominal voltages (1.5V to 3.5V). Depending on the chemistry and application, cells may be available in button and cylindrical form factors. These cells are not rechargeable.

Secondary (rechargeable) lithium (Li-ion/LiPo) cells: These cells are rechargeable. Depending on the quality, design, and operating window, these cells typically can be cycled hundreds to thousands of times. The long cycle life is made possible because the lithium is not present in metallic form. Lithium is intercalated into the electrode active materials (i.e., graphite – $Li_{1x}C_6$ and lithium metal oxide – $Li_{1-x}MO_2$) and moves from the anode to the cathode during discharge and from the cathode to the anode when charging in ionic form. Li-ion/LiPo cells are generally available in cylindrical, prismatic, and pouch form factors.

Lithium-Ion: A lithium-ion battery is rechargeable in which lithium ions move from the negative electrode to the positive electrode during discharge and back when charging. (See Appendix A)

Lithium-ion Polymer cells: The same chemistry as lithium-ion cells, but the electrolyte is made as a gel with a polymer host, reducing flammability and preventing liquid electrolyte leakage from a damaged cell.

Pouch cell: The battery case is a polymer-aluminum laminate, similar to the material used for potato chip bags, allowing for light and slender designs.

C-rating: A dimensionless way of expressing discharge and charge rates, allowing the rate capabilities of different cell designs and chemistries to be compared. For example, the discharge time of a 1Ah cell at different C-rates (0.1C = 10h, 0.5C = 2h, 1C = 1hr, 2C = 30min, 5C = 12min). The currents would be doubled for a 2Ah cell, but the discharge times would be the same. Cells designed for high energy may have continuous discharge rates of 1C to 2C with pulse rates up to 5C. In contrast, high-power cells may have continuous 5-10C and pulse rates in the 50-70C range. For a given cell capacity, i.e., 5Ah, the discharge current for a given C-rate would be the capacity value times the C-rate. (See Appendix C)

Battery capacity (Ah or Amp-hour): The cell's rated Coulombic capacity. The unit is Amp hour, multiplied by 1000 for milliamp-hour. The rated capacity is measured at a specified discharge rate, typically 0.2C or 0.3C. The capacity obtained will depend on temperature, discharge rate, and battery state of health (calendar and cycle life, discharge and charge duty cycle, and conditions).

Open-Circuit Voltage (OCV): The OCV of a cell is present when the current flow is zero, and the internal cell state is at equilibrium. For LiMO2 cathode-based cell chemistries, the OCV can be correlated with the cell state-of-charge, SOC (100 x Available Capacity/Total Capacity). The cathode chemistry is the primary factor influencing the shape of the curve, voltage range, and temperature dependence. Iron phosphate cathode materials have a "flat" OCV curve versus SOC, similar to nickel-cadmium and nickel metal hydride cell types. The nominal voltage for LiMO2 cathode cells is typically 3.6-3.7V. This voltage corresponds to a SOC of 50%. The nominal voltage times the cell capacity generally is a reasonable estimate of the cell energy. The OCV for these cells will typically range from 3V (0% SOC) to 4.2V (100% SOC). Cobalt oxide-based cells may have maximum voltages of up to 4.35V.

Depth-of-Discharge Window (DOD): DOD is defined as 1-SOC. A cell can be discharged 100%, but practically, the maximum SOC may be reduced to 95% to 90%, and the minimum SOC may be limited to 5% to 10% to increase the cycle life of battery packs (xPyS). The DOD window may be 80% to 90%.

Voltage (V): During discharge or charge, "resistances" within the cell lower or raise the OCV.

Vcell = OCV + I x DCR where DCR= DC resistance of the cell, I(+ or -)

During discharge or charge, the resistive losses and the cell's chemical energy (endothermic or exothermic) will determine the temperature rise or fall in the cell. On discharge, the minimum voltage may be set to 2.75V – 3V. If a cell is severely over-discharged, V < 2.5V, the copper substrate of the anode may be dissolved. Charging the copper in solution may plate out at the cathode, forming a bridge or short back to the anode. If the cell is severely over-discharged (duration or number of times), the resulting short can cause the cell to go into thermal runaway. The charge voltage should not exceed the maximum rated voltage, typically 4.2V; otherwise, overcharging the cell will damage the cell and possibly force the cell into thermal runaway.

Watt-hour (Wh): A measure of energy. The cell will have a rated energy. The actual energy obtained from the cell will depend on the discharge rate and the cell's temperature. The energy obtained will decrease as the rate increases and cell temperature is lowered.

Battery Management System (BMS): Battery management systems are critical to safely operating Li-ion/LiPo battery packs. The system protects against over-charge, over-discharge, and excessive currents and temperatures. The BMS protects the pack from exceeding upper and lower voltage and temperature limits. It will also limit current as a function of temperature. Charging rates are typically reduced below 0oC and not allowed below 20oC. The BMS also estimates pack SOC and available power and communicates this to the controller. The BMS may also be responsible for providing cell balancing. Suppose the device controller or human operator does not respond to the BMS request to lower power or stop operation. In that case, the BMS should disconnect the pack by opening the contact, relaying it to the pack, or blowing an in-line fuse. Depending on the application, BMS systems can have multiple configurations, i.e., a central control board with sense (V, T) leads to each cell or a central master board with distributed boards with electronics for monitoring multiple cells.

Appendix A

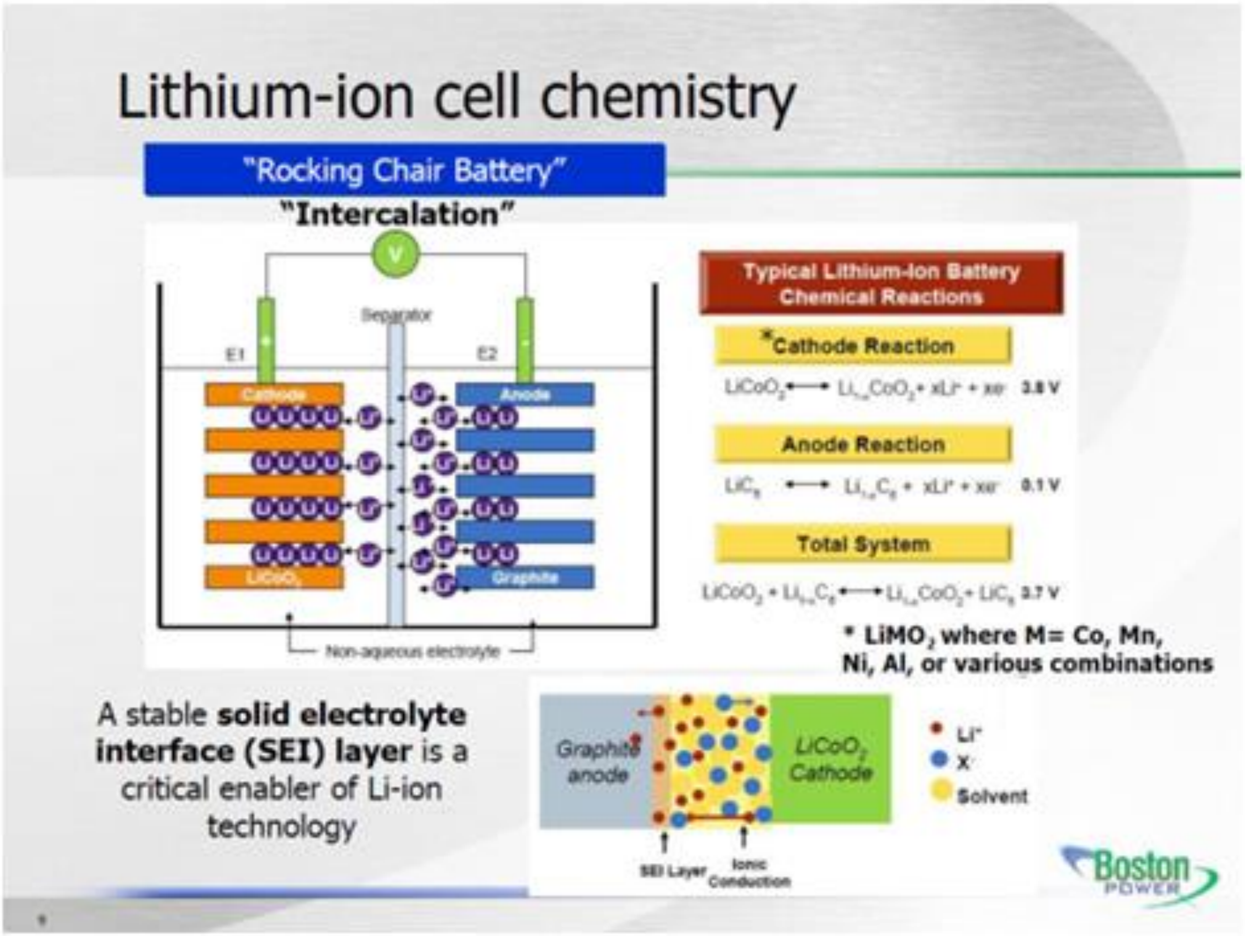
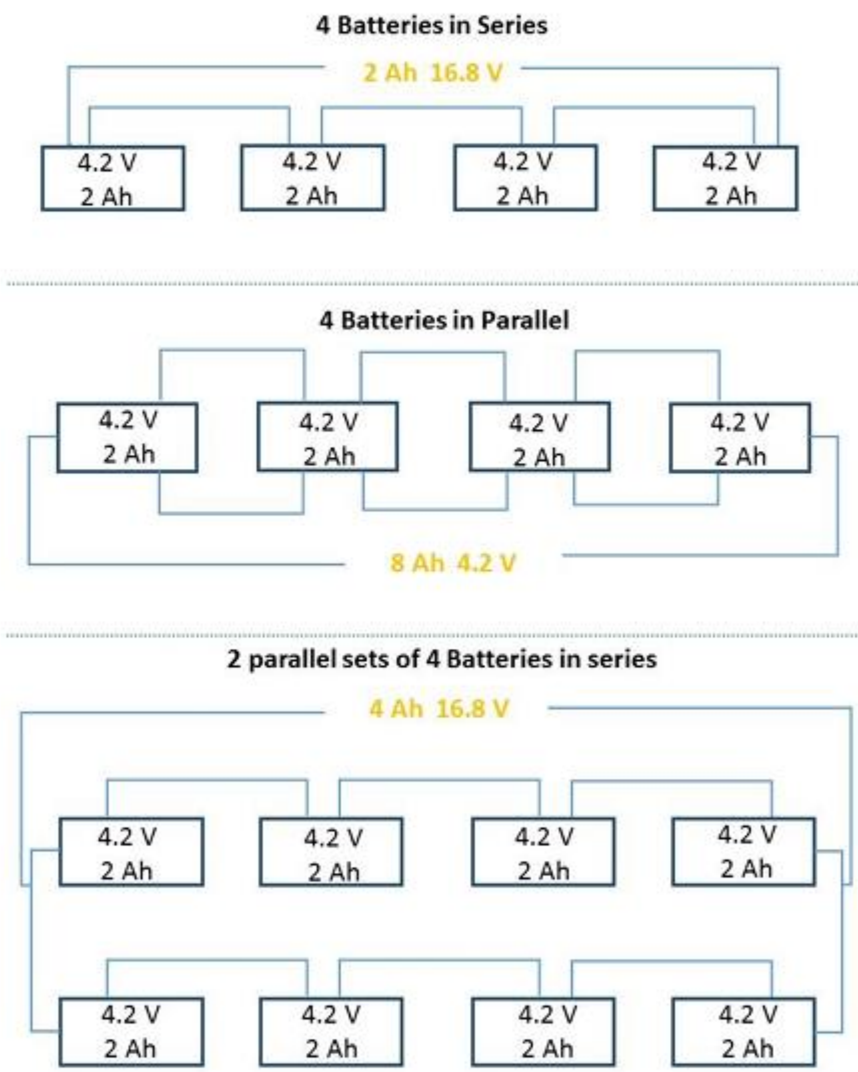


Image courtesy of Boston Power

Appendix B


4 Batteries in Series
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4 Batteries in Parallel
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Appendix C

LiPo/Li-ion Battery C-Rating Explained

C Rating is the tested value at which a battery can continuously charge or discharge without damage. The following formula calculates the maximum constant discharge current you can draw from the Li-ion/LiPo pack safely without harming the battery pack.

$$Max\ current\ draw\ (A) = Capacity\ (Ah)\ x\ C - rating$$

For example, if you have a 1000mAh (=1Ah), 20C LiPo pack (3S), your safe max current draw would be

$$1Ah \cdot 20C = 20A$$

For this particular example, drawing more current than the 20A is possible, but it is not recommended as it might damage the battery.

Cell Energy Example

The formula to calculate the cell energy is

$$Energy\ (Wh) = Capacity(Ah) \cdot Voltage(V)$$

Where Q is the capacity of the battery (Ah) and V is the nominal voltage of the battery (V).

The energy for the battery in the picture is

$$E = 5.2\ Ah \cdot 3.7V = 19.24\ Wh$$