

1.0 Purpose and Applicability

- 1.1 It is the policy of the University of Pennsylvania in coordination with the Office of Environmental Health and Radiation Safety to provide the University community with a safe and healthful environment. This program provides the Penn community with guidelines for the safe use, storage, and disposal of lithium-based batteries.
- 1.2 This program applies to Penn Schools and Centers that use lithium-based batteries for education and research activities.

2.0 Roles and Responsibilities

- 2.1 ***Penn's Office of Environmental Health and Radiation Safety (EHRS)*** is responsible for:
 - 2.1.1 Maintaining the University's Lithium Battery Safety Program.
 - 2.1.2 Completing lithium battery incident investigations.
 - 2.1.3 Providing or coordinating safety education and communication of lithium battery safety information to the Penn community.
 - 2.1.4 Waste management including proper recycling or disposal of batteries.
 - 2.1.5 Emergency response. Contact 215-898-4453 at any time on any day.
- 2.2 ***Penn's Division of Public Safety – Fire and Emergency Services (FES)*** is responsible for:
 - 2.2.1 Collaboration with EHRS on lithium battery incident investigations.
 - 2.2.2 Assisting end users with the selection and proper placement and use of appropriate fire extinguishing equipment.
- 2.3 ***Principal Investigators, Faculty in Charge or Supervisors within Penn's Schools and Centers*** are responsible for:
 - 2.3.1 Implementation of applicable provisions of this program.
 - 2.3.2 Obtaining, reviewing, and maintaining the battery manufacturer's technical specifications and safety information for each battery.
 - 2.3.3 Educating all users of secondary lithium batteries on proper usage and the potential hazards associated with them.
 - 2.3.4 Development of standard operating procedures for safe work practices related to specific lithium battery tasks or use applications.

3.0 BACKGROUND INFORMATION

Lithium-based batteries, especially lithium-ion and lithium-polymer rechargeable batteries, have become highly popular due to their favorable power to weight ratio and the fact that lithium-polymer batteries can be configured in various shapes and sizes. Lithium batteries are quite safe, however if damaged or used without proper care, can overheat, ignite, and burn aggressively. Lithium battery users must be acquainted with their unique vulnerabilities.

The most important safety consideration for lithium-ion and lithium-polymer batteries is to treat the battery as if it will ignite at any time. Even though the odds are remote, if each battery is segregated from combustible materials during storage, charging, and in use, in the rare possibility that a fire does occur, the odds are better that it will be limited to the battery itself.

3.1 Battery Categories - Batteries are classified into two categories: Primary and Secondary.

3.1.1 Primary batteries are not rechargeable. Examples of lithium-based primary batteries are button cells and camera/smoke detector batteries. Primary batteries contain metallic lithium which reacts violently with moisture. The lithium is hermetically sealed within the rigid battery container. Fires involving primary lithium metal batteries are extinguished by smothering with a material such as sand or a class D fire extinguisher that is rated for metal fires. Water is not an effective extinguishing material for primary lithium battery fires.

3.1.2 Secondary batteries are rechargeable. Unlike primary lithium batteries, secondary lithium batteries do not contain metallic lithium, they contain an intercalated lithium compound where lithium ions move back and forth between the battery anode and cathode during discharging and charging. Fires involving secondary lithium-ion or lithium-polymer secondary batteries can be extinguished with a traditional ABC - type fire extinguisher or smothered with a material such as sand.

3.2 Lithium-Ion (Li-Ion) vs. Lithium-Polymer Batteries (LiPo) - The difference between lithium-ion and lithium-polymer batteries is the type of electrolyte used. Lithium-polymer batteries contain a micro porous gel electrolyte instead of a porous separator as found in lithium-ion. Standard lithium-ion batteries require a rigid case to press the electrodes together, whereas lithium-polymer batteries use laminated sheets that do not need compression.

3.3 Rechargeable Lithium Battery Voltage - Each individual battery cell has a working voltage range from 3.0 volts minimum recommended discharge, to 4.2 volts full charge. The battery manufacturers use 3.7 volts as the nominal voltage and this value is used to rate the battery. To increase the voltage, additional cells are added together in series, therefore a single cell rechargeable lithium battery will be listed as 3.7 volts and a two cell battery will be listed as 7.4 volts, etc.

3.4 Decoding a Lithium – Polymer (LiPo) Battery Pack:

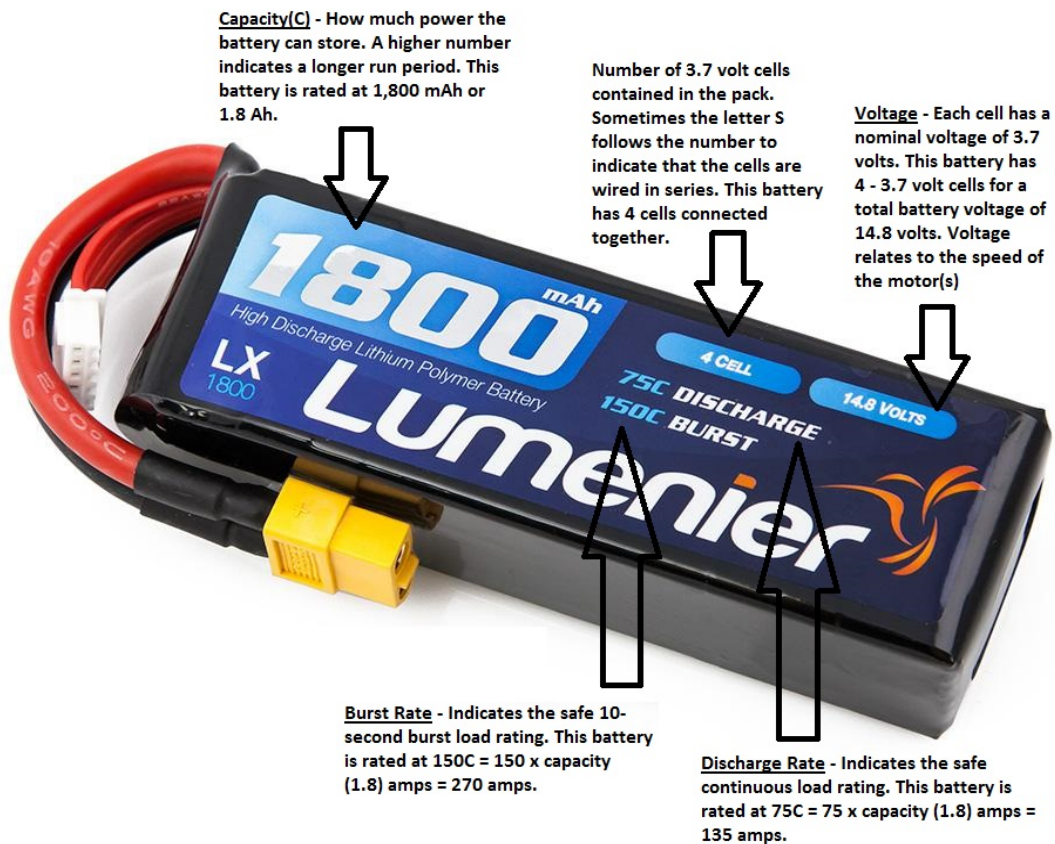


Image Source - GetFPV.com

3.5 Advantages of rechargeable lithium batteries over other types:

- 3.5.1 Small size.
- 3.5.2 Lightweight (No metal casing required for LiPo).
- 3.5.3 Can be made in almost any size and shape.
- 3.5.4 Extended shelf life - slow to discharge while in storage.
- 3.5.5 High current discharge rate.
- 3.5.6 Rapid recharge time.
- 3.5.7 Minimal to no memory - No need to discharge prior to charging.

3.6 Disadvantages of rechargeable lithium batteries:

- 3.6.1 Can have a shorter lifespan than other types of batteries.
- 3.6.2 Require special care for charging, discharging and storage.
- 3.6.3 Short circuiting can lead to aggressive release of gasses and aggressive fire.
- 3.6.4 Soft casing for LiPo batteries can make them vulnerable to damage.
- 3.6.5 Degrades at high temperatures or when stored at full charge.

4.0 Procedures

4.1 Battery Storage

- 4.1.1 Keep the minimum quantity of batteries on hand as possible. It can be difficult to properly monitor and maintain storage voltage on numerous batteries. Also, in the event of a battery fault resulting in rapid battery overheating, heat from a single battery cell can cause additional battery cells and battery packs to overheat and possibly ignite.
- 4.1.2 Promptly coordinate disposal of batteries that are no longer functioning properly, damaged, or not needed.
- 4.1.3 **All lithium batteries must be stored in a dedicated area clear of combustible materials.** When more than a few lithium batteries must be kept within a given area, they should be stored in a vented metal flammable liquids or metal acid storage cabinet that is strictly dedicated to the storage of lithium batteries. No other hazardous or combustible materials shall be stored in or on the cabinet. The cabinet should help to contain a battery fire within the cabinet and prevent spread to the building or contents. Maintain at least 2-inches clearance around the cabinet. The cabinet vents must be kept open to allow fire-generated gasses to escape. Additional clearance from combustible materials must be provided around the vents. Label the outside of the cabinet to indicate that it contains lithium batteries.
- 4.1.4 When only a few lithium polymer batteries are needed within a given location, storage within lithium battery safety bags/containers is recommended. They are usually labeled as LiPo Guard or LiPo Safe, etc. The storage bags/containers shall be stored in areas clear

of combustible materials. Larger batteries should be kept in a dedicated bag/container. Placing multiple large batteries in a single bag/container can result in an aggressive fire that can burn through it. Use caution when purchasing the battery safety bags/containers. Only purchase through known reputable vendors to help insure that they are of adequate quality to help contain a battery fire. End users report positive experiences with Thunder Power RC products.



- 4.1.5 Rechargeable lithium batteries should not be stored at full charge. If the batteries are not going to be used within a short timeframe (well within one week) it is best to discharge them to approximately 3.8 volts per cell. Most chargers have a storage setting that will charge or discharge the battery to this voltage. Battery voltage should never drop below 3.0 volts or the battery may be irreversibly damaged. Best practice is to not let voltage drop below 3.5 volts.
- 4.1.6 If there is a need to store lithium batteries while away from the laboratory, set up an area free of combustible materials and keep the batteries within the lithium battery safety bags/containers or a metal container such as an ammunition can with the lid seal removed and some sand in the bottom to insulate from the surface it is sitting upon. Label the outside of the can to indicate the type of batteries in the container.
- 4.1.7 Inspect all batteries at least weekly. Any batteries with damaged or swollen casings must be segregated from other batteries and combustible materials and placed in a safe location. Details related to the handling of damaged batteries are contained in section 4.5 of this program. Contact EHRS for disposal.

4.2 Charging

- 4.2.1 **Never charge batteries unattended.**
- 4.2.2 Never charge batteries inside vehicles.
- 4.2.3 Charge batteries individually. Do not charge in parallel. Battery packs designed to be connected together in series should be charged in the use configuration.
- 4.2.4 Place LiPo batteries in a lithium battery safety bag/container while charging.
- 4.2.5 Designate a charging area. The area must be free of combustible materials and preferably located under a sprinkler head. This also applies where charging takes place while traveling or otherwise away from the laboratory.
- 4.2.6 Maintain as much space as possible between charging batteries to avoid fire propagation between batteries.
- 4.2.7 Use a quality charger. Consider the following features:
 - 4.2.7.1 Ability to charge various types of batteries including NiMH, Ni-Cd, and Lead Acid as well as lithium if needed.
 - 4.2.7.2 Ability to charge multiple batteries simultaneously.
 - 4.2.7.3 Provision for balancing the voltage between each battery cell during charging.

- 4.2.7.4 Various charging voltage options - Full (4.2v), Storage (3.8) and Discharge (0) for safe disposal.
- 4.2.8 Let batteries cool down to ambient temperature before charging.
- 4.2.9 Insure LiPo cell voltage balancing cable is connected. This keeps the cell voltage constant across each cell in the battery pack. If the cells are not balanced, one cell's voltage can drop below the 3.0 volt minimum, which can damage the battery.
- 4.2.10 Follow the battery manufacturer's charging instructions. Pay particular attention to the maximum charging rate for the battery. If it is not listed, the maximum charge rate should be 1C or 1 x capacity of the battery in amps. For example, a 1500 mAh battery, the maximum charge rate would be 1.5 amps.
- 4.2.11 Monitor the battery during charging. If any swelling of the casing is detected, stop charging, place the battery in a safe location away from other batteries and combustible materials and monitor for at least one hour. Use an infra-red thermometer to monitor the battery temperature during this period. Contact EHRS for battery disposal.
- 4.2.12 A fully charged lithium battery cell is 4.2 volts. Storage charge is approximately 3.8 volts. Battery voltage should never drop below 3.0 volts.

4.3 Handling and Use

- 4.3.1 General - Li-Ion and LiPo batteries cannot tolerate short circuiting. Ensure the areas where batteries are handled are free of conductive surfaces and tools/objects as well as sharp edges that can penetrate the soft LiPo battery cell covering. Do not wear metal jewelry such as watches, bracelets, rings and pendants that can cause a short circuit.
- 4.3.2 Handling - Do not expose batteries to excessive physical shock or vibration. Use care when inserting/removing LiPo batteries into equipment to avoid damaging the soft battery casing.
- 4.3.3 Personal Protective Equipment - Wear safety glasses while handling batteries.
- 4.3.4 Physical Damage - Any battery cells or battery packs observed to be dented or otherwise damaged upon receipt or through use, shall not be used since there is increased likelihood of an internal short occurring. Place the damaged battery in a safe location away from other batteries and combustible materials. Details related to the handling of damaged batteries are contained in section 4.5 of this program. Contact EHRS for disposal.
- 4.3.5 LiPo Battery Fabrication - In-house fabrication of LiPo battery packs from individual cells is not recommended. If there is a need to fabricate LiPo battery packs, contact EHRS to perform a hazard assessment to define safe work practices and procedures.
- 4.3.6 Connectors - Installation and removal.
 - 4.3.6.1 Preferred Method - The preferred method is to prewire the connector with wire leads so that the live battery leads do not need to be soldered in the cramped confines of the connector body. Only the lead wires need to be connected which is much easier to accomplish without creating a short circuit.

- 4.3.6.1.1 When preparing battery leads for connector installation, only cut or work with one lead at a time to avoid short circuiting the battery. Never cut through both leads at the same time.
- 4.3.6.1.2 Cut approximately one-half the length off the battery lead wires, one at a time. After each wire is cut, tape the end connected to the battery so it cannot short circuit.
- 4.3.6.1.3 Solder the removed wire sections to the connector and install heat shrink tubing over the connections.
- 4.3.6.1.4 Add additional heat shrink tubing to one of the wires and solder the battery lead wire to the connector lead wire.
- 4.3.6.1.5 Slide the heat shrink tubing over the soldered wire connection and heat with a hair dryer or heat gun.
- 4.3.6.1.6 Repeat process with the other lead.
- 4.3.6.2 Alternate Connector Installation Method - If the active battery leads must be soldered directly to the connector without wire splicing, the following steps should be followed:
 - 4.3.6.2.1 When preparing battery leads for connector installation, only cut or work with one lead at a time to avoid short circuiting the battery. Tape the end of the battery lead that is not being worked with.
 - 4.3.6.2.2 Strip one-quarter inch of insulation from the red lead.
 - 4.3.6.2.3 Tin the exposed lead wire and the connector terminals.
 - 4.3.6.2.4 Slip heat shrink tubing over the red lead.
 - 4.3.6.2.5 Solder the red lead to the connector.
 - 4.3.6.2.6 Once cool, position heat shrink into place over the connection and use a hair dryer or heat gun to secure heat shrink tubing over the soldered connection. Be careful to focus heat on the heat shrink only, not the battery itself.
 - 4.3.6.2.7 Repeat process with the black lead.
- 4.3.7 Salvage Pre-Wired Battery Connectors - Pre-wired battery connectors can be salvaged from depleted batteries to simplify adding connectors to new batteries.
 - 4.3.7.1 On batteries that are to be disposed of, cut one of the leads with a length of wire of sufficient length to connect to a new battery lead and tape the cut end connected to the battery to prevent short circuiting.
 - 4.3.7.2 Repeat process with the other lead.
- 4.3.8 Short Circuit Testing - Prior to installing batteries in equipment, especially equipment manufactured in-house, where possible, perform continuity testing of the equipment prior to installing the battery for the first time to identify short circuits.
- 4.3.9 Monitor Battery Voltage - Once the battery is installed in the equipment, it is important to ensure that the device does not discharge the battery below 3.0 volts. One method to accomplish this is through the use of a low voltage cutoff (LVC) switch. The switch cuts off power to the motor once the battery reaches a minimum cutoff around 3.2 volts. If a

LVC is not installed, such is typical in aircraft, the best practice is to use an inline battery voltage meter on the equipment and monitor the battery voltage during use. Cease operations when the meter indicates 3.2 volts. After a few monitoring periods, the amount of time required to discharge the battery from full charge to 3.2 volts can be determined and a timer can be used to define the appropriate run time.

4.4 Transportation and Shipping

4.4.1 Transportation by Vehicle - When there is a need to transport lithium batteries in a vehicle, the following is required:

4.4.1.1 Transport the minimum number of batteries possible.

4.4.1.2 Ensure battery leads and connectors are insulated to prevent short circuits.

4.4.1.3 Place each battery in a battery safety bag or carrier or use a metal ammunition can with the lid seal removed. A couple inches of sand should be placed in the bottom of the can to provide some insulation between the bottom of the can and the surface it is sitting on. Label the can indicating the type of batteries it contains.

4.4.1.4 Do not leave batteries in a vehicle. Remove the batteries from the vehicle upon arrival at the destination.

4.4.2 Transportation by Air - Refer to Appendix A - [FAA Battery Guidelines](#)

4.4.3 Shipping Batteries - Only authorized personnel may ship batteries.

4.4.3.1 Individuals who need to ship batteries must contact [EHRS](#) to determine what training requirements must be met.

4.4.3.2 There are numerous restrictions related to battery shipment. The best practice is to consult directly with the desired shipper, since requirements will be dictated by the specifics of the batteries to be shipped.

4.5 Emergency Procedures

4.5.1 Emergency Isolation Container - Each area where lithium batteries are used must have an emergency isolation container on hand to safely hold depleted or damaged batteries that pose a potential fire risk until they are picked up for disposal. Keep a pail of sand in the area to use as a smothering agent. The container must be placed in an area with as much clearance from combustible materials as possible. The purpose of the container is to contain a battery fire and prevent spread to the building or contents.

4.5.1.1 An empty ammunition can makes a very good emergency isolation container and is also a good option for transporting batteries between charging and storage areas to locations where the batteries are to be used. It is imperative to ensure that if a container with a lid is used, that gaskets and seals must be removed to allow



venting of gases that can occur during rapid overheating or a fire. Label the container with the type of batteries it contains.

- 4.5.1.2 Other simple but effective emergency isolation containers are ceramic pots or a cinderblock placed with the cavities facing up. Some sand can be placed in the bottom of the pot or each block cavity to protect the surface the pot or block is sitting upon from the battery. Damaged batteries can be placed in the pot or block cavity. If the battery is actively overheating, sand can be added to the pot or block cavity in order to help smother a fire. Large battery fires are difficult to smother, therefore it is imperative to ensure that the area around the emergency isolation container is free of combustible materials so the battery can burn itself out without spreading to the building or contents.
- 4.5.2 Battery Temperature Monitoring - An infrared thermometer should be kept on hand and used to monitor battery temperatures. The ability to monitor the battery temperature from a safe distance is useful for batteries that are suspected to be overheating.
- 4.5.3 Potentially Damaged Batteries - For a battery where a short circuit is known or suspected to have occurred, or that may have been subject to physical impact damage through a crash or other means, immediately place the battery in the emergency isolation container and monitor for at least one hour. An infrared thermometer is a good way to monitor the battery for continued temperature rise which is indicative of a dangerous battery. If there is no denting or swelling of the casing or indication of continued temperature rise, place the battery in a lithium battery safety bag/container and connect to the charger and set for storage voltage of 3.8 volts. Monitor the battery closely during charging or discharging and immediately disconnect from the charger if the casing begins to swell or temperature rise is observed to be greater than normal. Place the battery in the emergency isolation container and continue to monitor. Contact EHRS for immediate disposal.
- 4.5.4 Swollen or Puffed Battery Casing - A swollen or puffed battery casing is indicative of increased battery heating. Over time, internal corrosion forms on the battery anode and cathode which causes the battery to run warmer. The warmer temperatures liberate oxygen which is trapped within the battery casing. Slight swelling of the battery casing that slowly occurs over a period of time during normal use is normal and indicates that it is time to retire the battery. A sudden swelling or puffing of the battery casing can be indicative of an acute failure of the battery. Monitoring the battery with an infrared thermometer can help determine if the battery is actively overheating on its own. The battery should be immediately placed in the emergency isolation container and closely monitored. Contact EHRS for immediate disposal.
- 4.5.5 Battery Failure While Charging - If a battery gives indication of overheating while on charge, immediately disconnect the charger from the power source. If it is safe to do so, while handling only the leads and not the battery itself, disconnect the battery leads from the charger. Use insulated tongs to carefully grasp the battery leads while maintaining as



- much clearance as possible from the battery itself and carefully place the battery in the emergency isolation container. Monitor the battery for at least one hour using an infrared thermometer. Contact EHRS for immediate disposal.
- 4.5.6 Thermal Runaway/Fire - Thermal runaway results in rapid heating and release of gasses and typically results in an aggressive battery fire.
- 4.5.6.1 If inside a building, activate the building fire alarm and evacuate the building.
- 4.5.6.2 On the main campus, call 215-573-3333 from a cell phone or 511 from a campus phone.
- 4.5.6.3 If the rechargeable battery is small and has already been placed in the emergency isolation container, and it is safe to do so, smother with sand. An ABC-type fire extinguisher can be used to help contain the fire, although it will likely not extinguish the battery itself. Do not submerge actively overheating lithium batteries in water, since hazardous gases/vapors can be created.
- 4.5.6.4 If the gas release and fire is aggressive, do not attempt to put the fire out. Avoid inhaling smoke.
- 4.5.6.5 Report all thermal runaway events and fires, including those that are small and self extinguish or are successfully extinguished on-site to Penn's Division of Public Safety (215) 573-3333. Fire & Emergency Services will investigate and apply lessons learned to help prevent reoccurrence.
- 4.5.7 Medical Emergencies - If electrolyte gets onto the skin, wash the area thoroughly with soap and water. If it gets into the eyes, rinse at an emergency eyewash station for 15-minutes and seek medical attention.
- 4.5.7.1 Employees on the *main campus* must be seen at Occupational Medicine located at HUP Ravdin 2nd floor, 34th & Spruce Streets between the hours of 8:00 am – 3:30 pm or the HUP Emergency Department at all other times.
- 4.5.7.2 *Students* must be seen at Student Health Services at 3535 Market Street or at the HUP Emergency Department after hours or on Sundays.
- 4.5.7.3 *New Bolton Center* employees must be seen at the Occupational Health Center located at 830 West Cypress Street, Kennett Square or at the Chester County Hospital or Jennersville Hospital Emergency Department.
- 4.5.7.4 *Morris Arboretum* employees must be seen at Chestnut Hill Hospital Emergency Department.
- Provide the medical practitioner with the Safety Data Sheet (SDS) for the particular battery involved in the exposure so that the proper treatment can be quickly administered. SDS are easily found by online search.

4.6 Battery Disposal

- 4.6.1 Primary Lithium Batteries (Non-rechargeable) - Insulate terminals. Batteries may be placed in recycling containers provided by EHRS. Contact EHRS for recycling/disposal.
- 4.6.2 Lithium Ion Batteries - Insulate terminals. Batteries may be placed in recycling containers provided by EHRS. Contact EHRS for recycling/disposal.
- 4.6.3 Lithium Polymer Batteries:
 - 4.6.3.1 Routine - For batteries that are no longer needed, or cannot be fully charged, if possible, use discharge setting on charger to fully discharge the battery. Label the battery voltage on each battery if known. Batteries should be kept in the designated battery storage cabinet/area. Contact EHRS for recycling/disposal.
 - 4.6.3.2 Non-Routine - For batteries with swollen/puffed cases or known to be otherwise damaged, store the battery in the emergency isolation container and contact EHRS immediately for disposal. Do not attempt to discharge the battery. Keep the emergency isolation container in an area away from other batteries and combustible materials. Treat damaged batteries as if they will ignite at any moment. Due to the risk of an aggressive fire occurring unexpectedly at any moment, it is not recommended to attempt to relocate the battery outdoors.
- 4.6.4 EHRS Battery Disposal Procedures
 - 4.6.4.1 Primary Lithium Batteries and Secondary Lithium Ion Batteries
 - 4.6.4.1.1 EHRS shall insure battery terminals are properly insulated prior to transporting from campus locations to the EHRS waste facility.
 - 4.6.4.1.2 Primary lithium batteries and lithium ion batteries may be transported and stored in plastic battery recycling containers.
 - 4.6.4.2 Lithium Polymer Batteries
 - 4.6.4.2.1 EHRS shall insure battery terminals are properly insulated prior to transporting from campus locations to the EHRS waste facility.
 - 4.6.4.2.2 Actively overheating batteries shall not be transported.
 - 4.6.4.2.3 A metal ammunition-type can with the lid seal removed or lithium battery safety bag/container shall be used to transport batteries from campus lithium battery storage locations to the EHRS waste facility.
 - 4.6.4.2.4 LiPo batteries shall be carefully placed into the transportation containers.
 - 4.6.4.2.5 Battery transportation containers shall be placed in an area away from combustible materials within the EHRS waste transportation vehicle.
 - 4.6.4.2.6 LiPo batteries shall be stored in a designated area of the EHRS waste facility clear of combustible materials.

- 4.6.4.2.7 EHRS shall contact the battery recycling vendor for periodic routine pickup of LiPo batteries in order to maintain the minimum quantity possible on hand. Vendor shall be contacted for prompt pick up of damaged batteries.

5.0 References and Resources

- 5.1 *Battery University* – Technical information for various battery types.
www.batteryuniversity.com
- 5.2 *Federal Aviation Administration* – Information related to transportation on aircraft.
www.faa.gov/Go/PackSafe/
- 5.3 *FedEx* – Specific information for battery shipment by USPS [http://www.fedex.com/us/service-guide/ship-dg-hazmat/dangerous-goods/how-to-ship.html?fx-faq=Lithium Batteries Section IA IB](http://www.fedex.com/us/service-guide/ship-dg-hazmat/dangerous-goods/how-to-ship.html?fx-faq=Lithium+Batteries+Section+IA+IB)
- 5.4 *International Air Transport Association* – Lithium Battery Air Cargo Information-
<http://www.iata.org/whatwedo/cargo/dgr/Pages/lithium-batteries.aspx>
- 5.5 *Roger's Hobby Center* – A Guide to Understanding LiPo Batteries.
<https://rogershobbycenter.com/lipoguide>
- 5.6 *United Parcel Service* – Specific information for battery shipments by UPS
www.ups.com/batteries
- 5.7 *United States Postal Service* – Specific information for battery shipment by USPS
https://about.usps.com/postal-bulletin/2012/pb22336/html/updt_004.htm

Appendix A FEDERAL AVIATION ADMINISTRATION BATTERY INFORMATION

**Batteries Carried by Airline Passengers
Frequently Asked Questions**

Q1. What kinds of batteries does the FAA allow in carry-on baggage (in the aircraft cabin)?

A1. For carry-on baggage checked at the gate or planeside, see Q2, below. Passengers can carry most consumer-type batteries and portable battery-powered electronic devices for their own personal use in carry-on baggage. Spare batteries must be protected from damage and short circuit. Battery-powered devices must be protected from accidental activation and heat generation. Damaged or recalled batteries, including when in a device, must not be carried. **Batteries allowed in carry-on baggage include:**

- **Dry cell alkaline batteries:** typical AA, AAA, C, D, 9-volt, button-sized cells, etc.
- **Dry cell rechargeable batteries** such as Nickel Metal Hydride (NiMH) and Nickel Cadmium (NiCad). For rechargeable lithium ion batteries; see next paragraph.
- **Lithium ion batteries** (a.k.a.: rechargeable lithium, lithium polymer, LIPO, secondary lithium). Passengers may carry all consumer-sized lithium ion batteries (up to 100 watt hours per battery). This size covers AA, AAA, cell phone, PDA, camera, camcorder, handheld game, tablet, portable drill, and standard laptop computer batteries. The watt hours (Wh) rating is marked on newer lithium ion batteries and is explained in #3 below. External chargers are also considered to be a battery. With airline approval, devices can contain **larger lithium ion batteries** (101-160 watt hours per battery), but spares of this size are limited to two batteries in carry-on baggage only. This size covers the largest aftermarket extended-life laptop batteries and most lithium ion batteries for professional-grade audio/visual equipment.
- **Lithium metal batteries** (a.k.a.: non-rechargeable lithium, primary lithium). These batteries are often used with cameras and other small personal electronics. Consumer-sized batteries (up to 2 grams of lithium per battery) may be carried. This includes all the typical non-rechargeable lithium batteries used in cameras (AA, AAA, 123, CR123A, CR1, CR2, CRV3, CR22, 2CR5, etc.) as well as the flat round lithium button cells.
- **Nonspillable wet batteries (absorbed electrolyte)**, limited to 12 volts and 100 watt hours per battery. These batteries must be the absorbed electrolyte type (gel cells, AGM, etc.) that meet the requirements of 49 CFR 173.159a(d); i.e., no electrolyte will flow from a cracked battery case. Batteries must be in strong outer packaging or installed in equipment. Passengers are also limited to two (2) spare (uninstalled) batteries. Spare batteries' terminals must be protected (non-conductive caps, tape, etc.) within the outer packaging. Batteries and outer packaging must be marked "nonspillable" or "nonspillable battery." *Note: This exception is for portable electronic devices, not for vehicle batteries. There are separate exceptions for powered wheelchairs.*

Q2. What kinds of batteries does the FAA allow in checked baggage (including gate-checked bags)?

A2. Except for spare (uninstalled) lithium metal and lithium-ion batteries, all the batteries allowed in carry-on baggage are also allowed in checked baggage. The batteries must be protected from damage and short circuit or installed in a device. Battery-powered devices—particularly those with moving parts or those that could heat up—must be protected from accidental activation. **Spare lithium metal and lithium ion/polymer batteries are prohibited in checked baggage—this includes external battery packs. Electronic cigarettes and vaporizers are also prohibited in checked baggage.** "Checked baggage" includes bags checked at the gate or planeside.

Q3. How do I determine the watt hours (Wh) rating of a battery?

A3. To determine watt hours (Wh), multiply the volts (V) by the ampere hours (Ah). Example: A 12-volt battery rated to 8 Amp hours is rated at 96 watt hours (12 x 8 = 96). For milliamp hours (mAh), divide by 1000 (to get to Ah) and then multiply by the volts.

Q4. Is there a limit to the number of batteries or devices I can carry?

A4. The main limit is that the batteries and devices must be for personal use (includes professional use). Batteries and battery-powered devices carried for resale or for distribution by a vendor do not qualify for these exceptions. There is a two-spare limit on the large lithium-ion (101-160 Wh) and nonspillable batteries (see the chart on the next page).

Q5. What does "protected from short circuit" mean?







A5. When metal objects such as keys, coins, tools or other batteries come in contact with both terminals of a battery it can create a "circuit" or path for electricity to flow through. Electrical current flowing through this unprotected short circuit can cause extreme heat and sparks and even start a fire. To prevent short circuits, keep spare batteries in their original packaging, a battery case, or a separate pouch or pocket. Make sure loose batteries can't move around. Placing tape over the terminals of unpackaged batteries also helps to insulate them from short circuit.

For a quick reference guide, see illustrated table on next page...

Batteries Allowed in Airline Passenger Baggage in the US

Sep 9, 2016

Based on US DOT regulations (49 CFR, Sec. 175.10). TSA security, individual airline, and international rules may, at times, be more restrictive.

Type of Battery <small>There is no limit to the number of batteries or devices carried for personal use unless specified below.</small>	Allowed in <u>carry-on</u> baggage?		Allowed in <u>checked</u> ¹ baggage?	
	In equipment ²	Spares	In equipment	Spares
Dry alkaline batteries 	YES	YES <small>When protected from damage and short circuit</small>	YES	YES <small>When protected from damage and short circuit</small>
Dry rechargeable – Nickel Metal Hydride (NiMH), Nickel Cadmium (NiCad), etc.  <small>For lithium ion, see below.</small>	YES	YES <small>When protected from damage and short circuit</small>	YES	YES <small>When protected from damage and short circuit</small>
Lithium ion (rechargeable lithium, lithium polymer, LIPO) as used in small consumer electronics, such as cell phones, tablets, tods, cameras, PDAs, and laptops. Limited to 100 watt hours ³ or less per battery. 	YES	YES <small>When protected from damage and short circuit</small>	YES <small>E-cigarettes and vaporizers are prohibited in checked baggage.</small>	NO
Larger lithium ion , 101-160 watt hours ³ per battery— <u>with airline approval</u> . Limits: Two spare batteries per passenger— <u>with airline approval</u> . 	YES <small>Airline approval required</small>	YES <small>When protected from damage and short circuit, and... Airline approval required</small>	YES <small>Airline approval required</small>	NO
Lithium metal (non-rechargeable) as used in small consumer electronics such as cameras, LED flashlights, watches, etc. (2 grams or less lithium per battery). 	YES	YES <small>When protected from damage and short circuit</small>	YES <small>E-cigarettes and vaporizers are prohibited in checked baggage.</small>	NO
Nonspillable wet batteries (absorbed electrolyte) for portable electronic devices, 12 volts and 100 watt hours ³ per battery.  Limits: Two spare batteries per passenger.	YES	YES <small>When protected from damage and short circuit and in strong packaging. Battery and outer packaging must be marked "nonspillable."</small>	YES	YES <small>When protected from damage and short circuit and in strong packaging. Battery and outer packaging must be marked "nonspillable."</small>

¹Note: "Checked baggage" includes carry-on-bags checked at the gate or planeside. ²Note: TSA security rules prohibit some power tools in carry-on baggage.

³Note: Watt hours (Wh) = Volts (V) x Amp hour (Ah) or for milliamp hours Wh = V x (mAh ÷ 1000)

Lithium Polymer Battery Use Checklist

Category	Description	Completion Date
Storage	Maintain the minimum quantity of batteries possible.	
<i>Numerous Batteries:</i>	Store lithium batteries in a dedicated, vented fire-rated cabinet. Keep combustible materials clear of the cabinet. Label cabinet as containing lithium batteries.	
<i>Few Batteries:</i>	Dedicate a battery storage area free of combustible materials.	
	Inspect batteries weekly. Look for puffed LiPo battery casing. Monitor temperature.	
	Store LiPo batteries at correct voltage (around 3.8 volts).	
Charging	Set up dedicated charging area. Area must be free of combustible materials. Maintain space between charging batteries.	
	Obtain a quality charger.	
	Never charge batteries unattended.	
	Charge at correct rate and proper voltage for either use or storage.	
	Use lithium battery safety bags/containers during charging.	
	Let batteries cool down prior to charging.	
	Insure LiPo cell balancing cable is connected.	
Handling & Use	Avoid physical damage and short circuiting. No metal jewelry. Work on insulated surfaces. Avoid sharp edges and tools.	
	Wear safety glasses.	
	Use recommended methods to make battery terminal connections.	
	Contact EHRS if LiPo battery packs are to be fabricated in-house.	
	Test equipment for short circuits prior to installing batteries.	
	Use low voltage cutoff switch or monitor battery voltage while in use on equipment. Do not allow voltage to drop below 3.0 volts.	
Shipping Transportation	Only authorized personnel may ship lithium batteries. Contact EHRS if there is a need to ship batteries.	
	If taking lithium batteries on an aircraft, follow FAA and IATA rules.	
	Obtain container to safely transport LiPo batteries between the labs and use locations. Remove from vehicle once at the destination.	
Emergency Procedures	Set up emergency battery isolation container.	
	Obtain sand. Use in bottom of isolation containers and as a smothering agent in case of fire.	
	Obtain infrared thermometer for remote battery temperature monitoring.	
	Place batteries suspected of being damaged into the emergency battery isolation container and monitor temperature.	
	For thermal runaway/fire, activate fire alarm, evacuate, contact public safety.	
Disposal	Obtain recycling container from EHRS for all batteries except LiPo.	
	Insulate all battery terminals on batteries to be disposed of.	
	Store LiPo batteries to be disposed of in a dedicated area of the battery storage cabinet or a dedicated area of the lab away from combustible materials. Contact EHRS for disposal of all lithium batteries.	
	If safe to do so, fully discharge batteries that are to be disposed of.	